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# Proceedings of the 2020 Connected Learning Summit

Edited by Jeremiah H. Kalir and Danielle Filipiak

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*EDITED BY JEREMIAH H. KALIR & DANIELLE FILIPIAK*

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# Contents

# From the Editors

For learners and their families, as well as for educators and their communities, 2020 has been a year defined by disruption, new forms of connection, and persistent creativity. Challenges associated with dual pandemics—the ongoing COVID-19 public health crisis, alongside uprisings for racial justice—have impacted both formal schooling and everyday learning. As members of the connected learning community, we know from our research and from our practice that diverse settings, literacies, practices, and relationships are of consequential value for those who have entrusted us to support their learning and flourishing. Despite much dissonance this year, so, too, have acts of resistance and solidarity demonstrated why connected learning is, perhaps now more so than ever, a critical framework for shaping more equitable learning futures.

Unlike the previous 2018 and 2019 Connected Learning Summits, which were hosted, respectively, at the Massachusetts Institute of Technology and the University of California, Irvine, our community was unable to gather as planned during the summer of 2020. Yet as editors, we have always taken seriously our responsibility to produce and share publicly a proceedings that demonstrates timely, insightful scholarship of the highest caliber. While the many challenges of 2020 have tested our collective resolve, our editorial team's commitment has not wavered and we are honored to present the *Proceedings of the 2020 Connected Learning Summit*.

This proceedings features 23 research papers that were accepted, after blind peer review, for presentation at the 2020 summit. Distance and disruption need not prevent us from recognizing the hard work and intellectual contribution showcased by these 67 authors. We are grateful that all of them worked with us over the past few months, despite the unusual circumstances, to produce this valuable record of connected learning scholarship. And as with prior proceedings, we could not have accomplished our work without guidance from the Connected Learning Lab's Jamieson Pond, additional assistance from Karen Bleske, as well as support from Brad King and his team at Carnegie Mellon University's ETC Press.

Finally, please know that our community will gather for some type of 2021 Connected Learning Summit, with details and dates to be announced during the coming months. Our community knows quite a bit about connection, and we look forward to reconnecting with you all soon.

On behalf of the proceedings team,

Remi Kalir and Danielle Filipiak

Co-Editors, *Proceedings of the 2020 Connected Learning Summit*

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# 1. Exploring the Relationship Between Creative Potential, Playing the Game Minecraft, and Engaging in Its Player Community

MICHAEL D. PROCTOR AND JOHN J. AEDO

**Abstract:** Technology and by extension innovation have become cornerstones of modern life and key drivers of prosperity. Creativity is considered one of the foundational skills to the evolution of technology and innovation. How one measures the contribution of various approaches to creativity enhancement still faces challenges. A study was conducted with middle and high school STEM students to explore the relationship of creative potential, their experience with the game *Minecraft*, and use of social media related to the game. The TCT-DP creativity test was selected because of its fitness to task and institutional experience. While the results did not support a link between either experience in *Minecraft* or engagement in its online communities, there are patterns that could inform both game design and creativity curricula.

## Purpose

The primary purpose of the research was to explore the relationship between creativity potential and individual time spent and/or expertise in *Minecraft*, the most popular builder game and one of the most popular video games ever (Gilbert, 2019). The secondary objective is to determine the effect (if any) of engaging in social media with regards to the game—posting comments, sharing works, contributing to player-generated content, and so forth.

## Introduction

Steinkuehler (2016) reflected on the state of educational-game development, lamenting the top-down approach that has failed to consistently produce games that marry pedagogically effective content, engaging design, and accurate content. She proposes to "create an indie scene that marries these three domains (and cultures) to produce not just games but educational media more broadly that do not simply reify what we already do" (p. 177). We can start by understanding the engagement dynamics of the games children actively seek out to play and the social structures around those games, such as the best-seller game *Minecraft*. Aedo and Proctor (2016) found support in the literature that both playing video games and participating in affirmational communities may support creativity. Day (2019) suggests that learning within communities happens in a networked structure of inquiry among members: "This is why we think that the question is not how a certain technology helps in the diffusion of information, skills, or knowledge, but rather how the network functions when problem finding and solving are involved" (p. 67).

Techniques to assess the level to which behaviors of inquiry, presenting the creative work to the group, and critiquing the work contribute to creativity are important to the way forward. Related questions include: What is the level of acceptance of creativity in a community or network? To what level is creativity facilitated by a game? To what level does a social media system support sharing and collaboration?

The above research questions represent end goals of the "big picture," requiring much more extensive data gathering than likely answered within the scope of this study. This research is limited to a quantitative case study aimed at exploring the nature of creativity among the player population of *Minecraft*.

## Method

The study was conducted through the University of Central Florida's summer STEM camps for aspiring engineers and scientists. Students ranged in age from 11 to 17. IRB approval was obtained on May 3, 2019, expiring May 3, 2020.

### Instruments

This study uses two instruments—a drawing-based Test for Creative Thinking-Drawing Production (TCT-DP) and a survey. The survey instrument is composed of two main sections. The first section is the game achievement inventory, which asks questions pertaining to activities and accomplishments inside the game *Minecraft*. The second is the social media engagement items, which ask questions about how often the participant posts in game forums or shares his or her in-game creations with others.

**The TCT-DP.** The TCT-DP is an easy-to-administer, drawing-based creativity test requiring no more than 15 minutes to complete, can be scored by trained laypeople (i.e., non-psychologists) with the guidance of the scoring manual, and can be administered to a wide age range (Urban, 2004). Thus, the TCT-DP enables transferability of creative behavior from games to a real-world setting by capturing creativity independent of setting, task, or other context-sensitive interactions with the subject.

**The game achievement inventory and social media engagement survey.** The survey instrument was designed, administered, and mostly scored within the Qualtrics web-based analytics software. In addition to the primary data of interest to the study, basic demographic data along with a unique identification number are prompted. The identification number is a randomly generated six-digit value, which is written at the top of the TCT-DP sheets. It is used to link the creativity test with the surveys.

Latham, Patston, and Tippett (2013) support the use of game-specific task completions and other measures of performance assigned by the game as valid constructs of video game expertise.

There are no established norms for what would differentiate a novice gamer from an expert gamer in *Minecraft*. The game achievement inventory collects three types of data: level of experience in combat, level of experience in resourcing, and experience in crafting and producing creative works in the game. Game achievement will be scored along two categories—Combat and Resourcing. The Combat score is a measure of the difficulty of enemies defeated in the game. Participants are presented a list of enemies in the game and asked to mark which ones they have defeated. The Resourcing score is a measure of how well they have mastered the environment. The various resources in the game (ores, wood, minerals, killed animals, and tamed animals) are presented in a similar checkbox list.

One gap in the *Minecraft* scoring system is its lack of a reward system for creative behavior or completing creative tasks. Most rewards regard combat and resourcing. In order to get a better picture of a player's creative achievement, supplementary questions inquire about structures crafted, the use of the redstone logic system, and the creation of custom player skins, maps, or game mods.

Combat scoring is based on a normalized point value system derived by a three-member panel of experts in *Minecraft*, with each member having a minimum of five years of experience in the game. While *Minecraft* features an experience-point award system for defeating enemies, this scoring system is too skewed to provide any meaningful analysis. According to the *Minecraft Wiki* (iMakerB, 2020), in the original scoring system, common enemies such as Zombies, which can be defeated by novices, provide 6–9 experience points. Defeating the final enemy at the End, meanwhile, earns 12,000 experience points. This scale effectively buries any other combat achievements a player may have earned along the way, since their point values are far lower (5–20 experience points for most enemies) than that of the End boss. The new scoring system, on the other hand, normalizes the awarded points based on the actual difficulty of the enemies encountered. The panel considered factors such as enemy mobility and offensive capability (e.g., single-target versus area-effect attacks) or unique abilities that pose a significant tactical challenge. The resulting scale gives a maximum possible combat score of 500 for defeating every enemy type in the game.

Resourcing scoring is derived similarly. The original experience-point tables provided by the game serve as the basis for the scores. However, Combat and Resourcing need to be balanced in their total respective scores as they are equally important factors in the *Minecraft* experience. The expert panel reviewed the experience-point table and derived new values based on the existing baseline and setting the scoring upper boundary to 500 points to match the top Combat score. Several factors were considered in scoring, such as the difficulty of obtaining the prerequisite tool for gathering the material. For example, obsidian requires the most difficult-to-obtain material, diamond. It also requires managing a hazardous environment, since obsidian is found near sources of lava. Other factors include the depth underground at which the material can be found. Deeper depths are more dangerous as the difficulty of the monsters encountered increases. These circumstances merit a score of 60, which is the same as defeating a wither enemy. Scoring for taming and killing wildlife also considered the relative disposition of the animal (peaceful or aggressive), its speed, abundance or rarity in the game world, and availability of any food or material required in its maintenance and breeding.

Three questions comprise creative output. The first is a free-response question: "What kinds of things have you made *in the game*?" Responses earned points in accordance to the five stages of skill acquisition (Dreyfus, 2004): *novice*, *advanced beginner*, *competent*, *proficient*, and *expert*. Each level is assigned a discrete value, 1 through 5, according to its proficiency level (see Table 1).

| Proficiency Level | Score | Qualities |
|---|---|---|
| Novice | 1 | Houses, static structures |
| Advanced Beginner | 2 | Structures with moving parts such as railroads, rollercoasters. Structures that span multiple levels/floors. |
| Competent | 3 | Structures that alter or define gameplay such as maps, arenas, mazes, obstacle courses |
| Proficient | 4 | Replicas of real-world places or objects (monuments, architecture) or complete maps |
| Expert | 5 | Dynamic creations that employ logic |

*Table 1. Scoring construction proficiency.*

The second question is a checklist of devices and contraptions crafted in the game. These items account for the dynamic elements that extend the game's creative palette beyond static structures to include things that react to players or the environment. Activity in any of these items indicates a level of proficiency beyond casual play, as these elements require an understanding of the game's logic systems and core engine. Moreover, *Minecraft* can be a development platform. Its game engine is available for programmers to extend in various ways at different levels. Players can choose to play with modifications to the game engine, which can significantly alter the play experience; mods could include adding utility to the user interface, adding new monsters, even creating entirely new and unique game rules/systems. Players can also choose to participate in modding by contributing their own game assets or code. Each activity is assigned a proficiency level (see Table 2).

| Activity | Score |
|---|---|
| Used redstone to create simple devices like automatic doors or light-triggered lamps | 1 |
| Used redstone to create simple digital circuits (flip-flops, clock circuits) | 3 |
| Used redstone to control mine carts with switching tracks and/or routing | 2 |
| Used redstone to create advanced digital circuits and devices such as calculators and CPUs | 5 |
| Used command blocks to spawn monsters | 1 |
| Used command block chaining | 3 |
| Used command blocks with redstone | 4 |
| Used mods like Tinkers Constructs, Extra Utilities, RF Tools, or similar | 2 |
| Created a mod pack | 3 |
| Contributed art or code assets to a mod | 5 |

*Table 2. Scoring advanced dynamic play.*

The third question relates to creative output outside of the game about the game—for example, drawing pictures of the game enemies, writing stories set in the game or about the game, or making videos about the game. As above, an activity checklist is presented, and the participants select those items that are true about them (see Table 3).

| Activity | Score |
|---|---|
| I have created custom maps for Minecraft. | 3 |
| I have draw pictures or paintings about Minecraft. | 1 |
| I have written poems or stories about Minecraft | 2 |
| I have made sculptures or models out of Legos/building blocks about Minecraft* | 3 |
| I have made videos about Minecraft | 3 |
| I have written songs or made music about Minecraft | 2 |
| I have written player guides, tutorials or other kinds of articles about Minecraft | 4 |
| I have created a custom player skin for Minecraft | 1 |
| I have made or helped make code or art for a Minecraft mod. | 5 |

*Table 3. Scoring out-of-game creativity.*

The social media engagement survey measures motivation for play, online play and discussions, collaborative creation, or sharing of creations. These questions are mostly free response; this is due to a goal of avoiding Likert-scale items as the survey targets children. Responses were interpreted on a five-point Likert frequency scale from 1 (nonresponse) to 5 ("More than two or three times per week").

Frequency of sharing game experiences online is composed of three Likert frequency questions: "How often do you record or stream your *Minecraft* games?", "How often do you post/write about the game online?", and "Mark all of the following activities that you've done." The same rubric used for "How often do you play with others?" is used for frequency of streaming or sharing.

### Sampling

Volunteer-based sampling is nonprobabilistic and therefore there is no formula for computing the required sample size (Ritter & Sue, 2007). Per Ritter and Sue (2007), the traditional N = 30 should suffice. For correlation analysis, Bujang and Baharum (2016) recommend N = 46 with an R0 = 0.0, R1 = 0.4 for inequality tests with a power of 80% and alpha of 0.05.

The population was sampled from participants in a series of summer camps hosted by the University of Central Florida to promote STEM enrollment among potential students from middle and high schools throughout the United States. The selection of the camps was based on schedule availability and consent of the instructors. Two camps were used: The Physical Sciences Summer Institute and the Computer Science Institute. The physical science camp hosted rising sixth through eighth graders and presented material across multiple disciplines, including earth and life sciences, engineering, computer science, and digital media. Although there were no skill or academic prerequisites, the students must have been recommended by a teacher to attend the camp. The computer science camp hosted older students, from rising ninth through 12th grade with a minimum age of 13 at the time of application.

### Administration Procedure

The camp facilitator introduced the principal investigator (PI) to the class and provided a brief explanation of the activity and its purpose, clearly identifying the investigator as a doctoral student in the Modeling and Simulation program at the university. The PI handed out the test sheets and pen while explaining the activity. In both camps, computers were available with Internet access through which to access the Qualtrics survey. Instructions for the creativity test were read directly from the TCT-DP manual. Students were given a maximum of 15 minutes to complete the test but were not informed of this to avoid adding unnecessary stress, which can affect creativity. Turn-in times were recorded on the test sheet as they were turned in.

## Data and Analysis

### Correlation Analysis

Simple correlation with the TCT-DP scores was calculated independently for time spent in game, game achievement, and social media engagement to directly answer the research questions. In all cases, correlation was statistically insignificant.

Every other measured attribute was also cross-correlated with all the others and with the TCT-DP scores. In Table 4, the negative correlations all correspond to the TCT-DP against each individual dimension of the survey. However, within this matrix, there are some correlations not related to the TCT-DP that merit further inspection. Combat and Resourcing are correlated at 0.79, suggesting confirmation that these two factors align with game achievement. The creative behavior dimensions show moderate correlation with Combat and Resourcing as well (between 0.54 and 0.63). This may be an indicator of the gamer profile represented by the students sampled in this study.

| | Combat | Resourcing | Cr - In Game | Cr - Out Game | Cr - Total | Social | Construction | TCT-DP |
|---|---|---|---|---|---|---|---|---|
| Combat | | 0.79 | 0.63 | 0.61 | 0.69 | 0.56 | 0.44 | -0.19 |
| Resourcing | 0.79 | | 0.54 | 0.58 | 0.62 | 0.49 | 0.44 | -0.14 |
| Cr - In Game | 0.63 | 0.54 | | 0.57 | 0.95 | 0.36 | 0.45 | -0.11 |
| Cr - Out Game | 0.61 | 0.58 | 0.57 | | 0.8 | 0.57 | 0.41 | -0.19 |
| Cr - Total | 0.69 | 0.62 | 0.95 | 0.8 | | 0.48 | 0.49 | -0.15 |
| Social | 0.56 | 0.49 | 0.36 | 0.57 | 0.48 | | 0.41 | -0.08 |
| Construction | 0.44 | 0.44 | 0.45 | 0.41 | 0.49 | 0.41 | | 0.07 |
| TCT-DP | -0.19 | -0.14 | -0.11 | -0.19 | -0.15 | -0.08 | 0.07 | |

*Table 4. Correlation matrix.*

## Combat and Resourcing Scores

Combat and Resourcing scores show an interesting pattern in their distribution and skew. Neither Combat nor Resourcing are normally distributed. Combat score is binormal in its distribution with a mean score of 253 (out of a maximum of 500) and a skewness of -0.03. However, half of the players scored more than 240 points, which is possible only by defeating some of the game's most difficult enemies, such as withers, elder guardians, and the Ender Dragon final boss. Resourcing shows a similar, but more pronounced, pattern. Resourcing is a more linear progression in the game. While it may be possible for a player to defeat more difficult enemies relatively early on, this is not the case with Resourcing. It is not possible to skip forward and gather the more difficult and rare resources. Resourcing is gated by the tool-progression system. This means that Resourcing is a good indicator of a player's true progress in the game. The distribution of Resourcing scores is skewed left with a skew parameter of -0.65. Much of the student population clustered at the far-right end, with many achieving close to the top score.

## Creative Behavior

Conversely, all three creative behavior measures clustered near the low end. In-game Creativity, an indication of the player's use and mastery of advanced dynamic game elements, skewed the most with a right skew of 1.02. Out-of-Game Creativity and Construction exhibited similar skews at 0.72 and 0.61, respectively.

## Analysis

The creative behavior scores are the first hint at what may be happening with our participants' scores within *Minecraft* and why there may not be any correlation with actual creative potential. These students were playing *Minecraft* to win at *Minecraft*. In any other game context, that would be a tautology. Most games are solely concerned with reaching the end state—defeating an opponent, beating the high score, or completing the story. *Minecraft* is not like that. *Minecraft* has very strong creative components, including a play mode, aptly titled "Creative Mode," in which all the combat elements and resource acquisition elements are effectively disabled. Enemies either do not appear in the game or are docile and all construction materials are available in infinite quantity from a menu. Even within “Survival Mode,” the creative component is still offered through the game’s building-block nature. Once the materials have been gathered, it is still possible to build freely with those materials. The Resourcing progression is the only limiter to creativity within Survival Mode. Many players craft their creations within Survival Mode because they enjoy the challenge of building under pressure. This study’s cohorts, however, clearly did not engage the creative facilities offered by the game.

The reason is simply because they did not need to. These players played to win. The Combat scores leaned to the right with most players (52%) engaging the game’s more difficult enemies. The Resourcing right skew likewise shows that these players advanced through the mining and gathering progression ladder. It is not possible to defeat the stronger enemies without strong weapons and for that, players must dig through the increasingly difficult materials to get to materials with which to fashion adequate weapons for the tougher enemies. Meanwhile, they opted not to use the advanced interactive dynamics. Defeating enemies does not require redstone gadgets or mastery of the game engine. Likewise, surviving in *Minecraft* does not require elaborate constructions. The only structure a player needs to build in the game is a strong walled structure big enough to house the crafting tools required to create and enhance his or her weapons and armor. Long-term security can be established by torching the perimeter of the structure far enough out to prevent monsters from spawning close enough to be a threat. Once the structure is built and the perimeter lit with torches, a player can be done with construction. If players opt to explore extensively, they can simply repeat that process at their new location.

Without their engaging in much creativity, then, there is not much reason to expect to see any differences in their creativity test scores.

## Conclusion

Personal experience and the literature suggested that creativity, especially among young adults, is on a decline (Kim, 2012). This research is motivated by a glimmer of hope that the author discovered on YouTube—a thriving microcosm of creativity all centered around *Minecraft*. Players are creating fantastic landscapes of every imaginable shape and size—personal castles intricately decorated with furniture and detailed appointments, sprawling roller coasters with dynamically triggered animations and special effects, complete scaled re-creations of real-world items and places. The magnitude of skill being demonstrated seems to suggest that perhaps there is something special about *Minecraft* that elicits such player engagement.

It seems that for many children, *Minecraft* may be just another monster-hunting adventure. While the game certainly affords the player a great deal of creative power, these cohorts apparently did not avail themselves of it. While the literature does seem to suggest that playing video games, in a generic sense, may offer cognitive benefits (Hutton & Sundar, 2010), we also know that many children play video games (ESA, 2019) and so therefore may already be enjoying their benefit.

Therefore, if a powerful platform such as *Minecraft* is to be exploited for any creative advantage, the learner must be guided and encouraged to use its features for self-expression. One possible way forward can be found in Microsoft’s sample Computer Science Curriculum for Minecraft (Mojang, 2020). This curriculum takes a traditional introductory computer science course and implements it entirely inside of *Minecraft*. The Education Edition of the game includes development tools that allow learners to manipulate entities in the game, either directly using the JavaScript language or through a visual interface such as Code.org, in which logic flow is graphically represented with interactive blocks. Assignments allow and encourage learners to engage the virtual world not only using their own avatars as they would with regular *Minecraft*, but through the programming interface. The final project is not only a test of their earned programming skills, but also an open canvas in which they can create whatever they want. The goal of that final assignment is simple: Use what you have learned to create something interesting and novel. That is the core of creativity, harnessed in a structured curriculum that happens to take place in *Minecraft.*

## References


Aedo, J., & Proctor, M. D. (2016). Assessing games, game features & meta-communities on their contribution to creativity & valued outcomes. *International Journal of Scientific Engineering and Applied Science*, 2(3), 278–286. Retrieved from http://ijseas.com/volume2/v2i3/ijseas20160330.pdf

Bujang, M. A., & Baharum, N. (2016). Sample size guideline for correlation analysis. *World Journal of Social Science Research*, 3(1), 37.

Day, M. (2019). *Networked inquiry and performative knowledge.* In J. H. Kalir (Ed.), *Proceedings of the 2018 Connected Learning Summit* (pp. 57–67). Pittsburgh, PA: ETC Press.

Dreyfus, S. E. (2004). The five-stage model of adult skill acquisition. *Bulletin of Science, Technology & Society*, 24(3), 177–181.

ESA. (2019). *Essential facts about the computer and video game industry*. Retrieved from the Entertainment Software Association website: https://www.theesa.com/wp-content/uploads/2019/05/ESA_Essential_facts_2019_final.pdf

Gilbert, B. (2019, 14 September). 'Minecraft' has been quietly dominating for over 10 years, and now has 112 million players every month. *Business Insider*. Retrieved from https://www.businessinsider.com/minecraft-monthly-player-number-microsoft-2019-9

Hutton, E., & Sundar, S. S. (2010). Can video games enhance creativity? Effects of emotion generated by Dance Dance Revolution. *Creativity Research Journal*, 22(3), 294–303.

iMakerB. (2020). Experience. *Minecraft Wiki*. Retrieved from https://minecraft.gamepedia.com/Experience

Kim, K. H. (2012). Yes, there *is* a creativity crisis! Retrieved from http://www.creativitypost.com/education/yes_there_is_a_creativity_crisis

Latham, A. J., Patston, L. L., & Tippett, L. J. (2013). Just how expert are "expert" video-game players? Assessing the experience and expertise of video-game players across "action" video-game genres. *Frontiers in Psychology*, 4, 941. doi:10.3389/fpsyg.2013.00941

Mojang, A. (2020). *Computing with Minecraft: Ages 8–10*. Retrieved from https://education.minecraft.net/class-resources/computer-science-subject-kit/

Mojang Studios. (2009). *Minecraft* [Video game]. Stockholm, Sweden: Xbox Game Studios.

Ritter, L. A., & Sue, V. M. (2007). *Using online surveys in evaluation*: San Francisco, CA: Jossey-Bass.

Steinkuehler, C. (2016). Videogames as a serious medium. *On the Horizon*, 24(2), 175–178.

Urban, K. K. (2004). Assessing creativity: The Test for Creative Thinking-Drawing Production (TCT-DP): The concept, application, evaluation, and international studies. *Psychology Science*, 46(3), 387–397.

# 2. Using Digital Clinical Simulations and Authoring Tools to Support Teachers in Eliciting Learners' Mathematics Knowledge

NANCY ANDERSON, RACHEL SLAMA, ROYA MOUSSAPOUR, GREG BENOIT, AND JUSTIN REICH

**Abstract:** Mathematics instruction that builds on student thinking has been linked to rich math learning environments and gains in student math achievement, yet it is challenging for teachers to find professional learning opportunities to develop these skills. Open-source digital clinical simulations with authoring features hold promise for supporting math teachers' professional learning at scale, particularly around skills that can be developed with low-stakes, repeated practice before classroom implementation. We engage a cohort of 19 middle-years math teachers in a midsized urban district in a program to regularly play and design simulations focused on eliciting learner math knowledge. Analysis of interview and simulation data revealed that teacher performance in the simulation related to their self-reported description of math discursive practice. At baseline, most participants did not report attending to the work of deepening students' reasoning as part of math instruction. Similarly, in the simulation, participants typically did not ask follow-up questions and instead engaged with their students in ways aligned with initiate-respond-evaluate conversation patterns. This simulation may be a promising diagnostic tool to help teachers implement classroom discussions to promote effective discursive practices. The paper concludes by discussing design implications for digital clinical simulations that support teachers' use of productive math talk.

## Introduction

Mathematics instruction that builds on student thinking has been broadly linked to rich math instructional environments (e.g., Clarke, 2008) and gains in student math achievement (e.g., Bobis et al., 2005; Jacobs, Franke, Carpenter, Levi, & Battey, 2007). To elicit student thinking, teachers ask questions or assign tasks in which students share their thinking about specific academic content, allowing the teacher to evaluate student understanding, guide instructional moves, and surface ideas that may benefit the whole class (Teaching Works, 2018). Teachers require ample practice to develop the requisite skills and professional judgment to support deep math learning (Ball & Forzani, 2009; United States Department of Education, 2016), but they often lack opportunities to practice critical competencies in low-stakes settings (Grossman et al., 2009; Levine, 2009).

We describe an open-source, chat-based digital clinical simulation called *Eliciting Learner Knowledge* (*ELK*) designed by our team of learning scientists and engineers to allow teachers to practice eliciting learner math knowledge in a low-stakes setting. The purpose of this chat-based simulation is to help teachers develop effective questioning strategies for understanding student conceptions and misconceptions that they can later integrate into the complex assemblage of their classroom practice. One player role-plays the teacher based on a predetermined teacher profile. The other player role-plays the student. The players engage in a seven-minute chat conversation about a specific student understanding. The objective of the game is for the teacher to identify what the student knows and does not know about a topic. A short true/false quiz at the end of the game where the "teacher" must respond as if she or he is the student tests the teacher's knowledge of the student's understanding. *ELK* also has an authoring tool component where users can quickly generate their own grade-level specific scenarios. We depict a composite chat transcript that results from the "student"-"teacher" interaction (see Figure 1).

**3:30:00: Teacher:** Hello Joel. Can you tell me how you solved 8 divided by ¼?
**3:30:20: Student:** Yes, I know that there are four fourths in one whole. So times 8 is 32.
**3:30:53: Teacher:** So I heard you say that if there are four fourths in one whole and since we have 8 wholes, that's 32. Is that what you said?
**3:30:58: Student:** Yes.
**3:31:21: Teacher:** Okay, tell me a bit more. Why did you think about the number of fourths in one whole?
**3:31:39: Student:** Because there are four fourths in one whole.
**3:31:57: Teacher:** Yes, you are right. But what is it about the expression 8 divided by ¼ that told you to count fourths?
**3:32:14: Student:** Well, it's division, so that means how many times ¼ goes into 8.
**3:33:29: Teacher:** I see. But let me check that I understand. You are thinking about division as how many times we can take out or repeatedly subtract groups. So to find the number of times we can take ¼ from 8, you first found how many times to take it out of one? Is that what you're thinking?
**3:33:34: Student:** Yes.

*Figure 1. Eliciting Learner Knowledge composite chat transcript.*

Through a yearlong fellowship program with 19 math teachers teaching Grades 3–9 in a midsized urban school district, we study the effects of playing and co-designing scenarios within the simulation on learners' perception of the role of math discussion in the classroom and change in teacher practice. We discuss implications for the design and scale of digital clinical simulations.

### Research Questions

In this paper, we explore the following research questions:

1. How do teachers describe their discursive math practices in interviews?
2. How does teacher performance in a simulation relate to the descriptions of their practice?
3. To what extent do teachers deploy new discursive math practices in simulations?

## Background and Context

### Eliciting Learner Knowledge and Student Math Learning

To effectively elicit a math learner's knowledge, a teacher must draw out a student's thinking through carefully chosen questions and tasks that consider and check alternative interpretations of the student's ideas and methods. Effective teachers build on students' preconceptions and misconceptions about a topic (e.g., Fuson, Kalchman, & Bransford, 2005) that can provide a bridge to new material and engage the individual learner, surfacing mathematical ideas that support mathematical thinking for the whole class (e.g., Van Zoest et al., 2017). However, to drive gains in student math achievement, teachers must move beyond eliciting learner knowledge and attending to students' strategies to interpreting their understandings and deciding how to respond (e.g., Jacobs, Lamb, & Philipp, 2010). Teaching skills related to attending to and interpreting student thinking are difficult to learn (Shaughnessy & Boerst, 2018) and have proved challenging to assess among teachers. These skills occur interactively in the classroom (Jacobs, Lamb, & Philipp, 2010); student responses to teachers' questions are difficult to predict (e.g., Shaughnessy & Boerst, 2018) and student responses may be context-dependent (Sleep & Boerst, 2012). Teaching is complex, and teachers need opportunities to engage in targeted, low-stakes, improvisational rehearsal of these practices (Grossman et al., 2009; Levine, 2009).

## Using Digital Simulations to Practice Eliciting Learner Math Knowledge

*ELK* leverages games, technology, and playfulness to help teachers grow their teaching practice in math. We leverage widely accessible, mobile, web-based technology to help teachers to practice everyday interactions between teachers and students that can shape K–12 students' academic trajectories (Reich, Kim, Robinson, Roy, & Thompson, 2018, 2019). Most opportunities for teachers to practice have focused on replicating the full complexity of teaching as closely as possible through mock teaching or digital simulations, whereas *ELK* tries to create more targeted, low-stakes opportunities to practice specific dimensions of teaching that can be systematically improved and reintegrated into the teacher's practice. Participants role-play as students with conceptual misunderstandings and teachers try to elicit student thinking. This activity aims to support the teacher to engage naturally with productive practice (Thompson et al., 2017).

## Measuring Teacher-Student Math Discourse

Classroom talk typically adheres to a triadic structure wherein the teacher initiates an exchange, the student responds, and the teacher responds to what the student said. In traditional instruction, the triadic structure is typically of the form "initiate-response-evaluate" (IRE) in which the teacher offers feedback such as an evaluation or correction in the "third slot." By contrast, in discourse-intensive instruction, the triadic structure is in the form "initiate-response-follow-up" (or IRF; Cazden, 2001; Nassaji & Wells, 2000; Wells, 1996) in which the teacher responds with follow-up questions that seek additional information about what the student said.

Chapin, O'Connor, and Anderson (2013) describe types of questions or "talk moves" that help teachers and other students examine the intended meaning, mathematical merit, or relevance of a student contribution. *Revoicing* consists of the teacher's repeating the student's prior turn while also offering the student the chance to verify or clarify the teacher's interpretation of his or her intended meaning (O'Connor & Michaels, 1993, 1996). *General press for reasoning* refers to any prompt that encourages the student to keep talking about his or her ideas. *Specific press for reasoning* questions aim to develop students' thinking by building awareness for the fundamental ideas at the heart of their explanation, connecting individual aspects of their explanation in more robust ways, and situating their explanation within the relevant mathematical concepts under inspection (Truxaw & DeFranco, 2008). Prior research suggests that it typically takes more than two specific and consecutive follow-up questions to increase the accuracy or robustness of a student's original explanation (Franke et al., 2009).

## Instructional Design and Simulation Co-Design Process

As part of a yearlong fellowship, we met with fellows one evening per month for a four-hour in-person block of time between October 2019 and January 2020. During each four-hour meeting, fellows participated in the following types of activities: (a) review of instructional strategies, (b) playing *ELK*, (c) debriefing and reflecting on their performance in the simulation, and (d) designing their own *ELK* scenarios based on a series of low-fidelity prototype templates. Fellows also received biweekly coaching sessions at their school sites focused on the instructional strategies presented at the meetings.

# Methods

We employed a design-based implementation research approach (DBIR; e.g., Collins, Joseph, & Bielaczyc, 2004), which allowed for rapid-cycle testing of our digital clinical simulations. Our mixed-methods approach included analysis of interview data and simulation chat transcripts.

## Research Site and Participants

We recruited a cohort of 19 math teachers to participate in our yearlong fellowship through a widely circulated open call for participation. All fellows teach in a midsize, urban school district in a middle-years math classroom (defined as Grades 3 through 9). They teach at 16 different schools and in mainstream, inclusion, and sub-separate classroom environments. Nearly all of the fellows' schools (94%) have a student population with a majority of students who are Black or Latino. Most fellows (81%) teach at schools where more than half of the student body (51%) experience poverty. Fellows have between 2 and 30 years of teaching experience. Of the 19 fellows, 47.4% self-report as White, 10.5% as Asian, 21.0% as Black or African American, 5.3% as Hispanic/Latino, 5.3% as Other, and 10.5% did not report their race.

## Data Collection and Analysis

We report on two data sources—interviews and simulation chat transcripts—to capture fellows' perception of their discursive math practice (Research Question 1), the link to their performance in the simulation (Research Question 2), and the degree to which they deploy new discursive practice in the simulation (Research Question 3). Below, we describe each of the data sources.

**Fellow interviews.** In September and October 2019, we conducted a set of semistructured interviews with fellows ($N = 16$) that asked participants a range of demographic and contextual information about professional learning at their school and how they facilitate discourse in the math classroom. Using an established framework defining four goals of the math teacher's role in facilitating classroom discourse (Chapin et al., 2013), we double coded a subset of questions according to these *etic* codes: (a) *share*: helping students share their reasoning; (b) *deepen*: helping students deepen their reasoning; (c) *attend*: helping students attend to the reasoning of others; and (d) *engage*: helping students engage with the reasoning of others. The percent agreement between the two raters was 60%. All disagreements were resolved by discussion between the raters.

**Simulation chat transcripts.** We collected and coded fellows' transcripts from the *ELK* platform in October, November, December, and January. Two researchers coded each of the transcripts for the type of exchange (*independent*, *dependent*, *other*, *not applicable*), as well as the teacher turn type (*revoicing*, *general press for reasoning*, *specific press for reasoning*, and *other*). Coders also marked the number and length of sequences—or chains—of extended student-teacher exchanges because of the prior link established between this form of classroom talk and student learning (Franke et al, 2009). We calculated interrater reliability using Cohen's kappa for each exchange type (independent and dependent). Interrater reliability for Rater 1 and 2 was moderate for independent—Kappa = 71% ($p < 0.001$), 95% confidence interval, or CI (0.63, 0.78)—and dependent exchanges—Kappa = 70% ($p < 0.001$), 95% CI (0.62, 0.79) (McHugh, 2012). All disagreements were resolved by discussion between the two raters.

## Results

In Research Question 1, we examined how teachers described their discursive practice before participating in the professional learning. We identified examples of attending to the goal of helping students *share* their reasoning in all participant interviews. Sixty-nine percent of participants reported helping students *attend* to the reasoning of others and 63% of participants reported helping students *engage* with the reasoning of others. Only 19% of participants reported helping students *deepen* their own reasoning. Examples of helping students share their reasoning included talk-based routines or activities; these included number talks, estimation puzzles, and "do now" tasks. When describing the student talk that occurs during these activities, participants focused on student explanation or justification. Strategies for helping students attend to the reasoning of others included supporting students in talking to each other in order to reach consensus on a solution to a problem, students examining and questioning each other about their problem-solution strategies or computational methods, and standing before the class and explaining a strategy before soliciting peer feedback. Engage-facilitation strategies focused on students' using each other's ideas to develop a full explanation as well as examining mistakes and correcting faulty solution strategies. Only three participants described using teacher questioning as a strategy for supporting students who struggle to explicate their thinking or to deepen student reasoning.

In Research Question 2, we sought to understand how teacher performance in a simulation relates to descriptions of their own practice. Based on the *ELK* chat transcripts, we summarized teachers' discursive practice by calculating the mean length and standard deviation for the total number of conversational chains per month. The average chain length varied from 1.25 to 1.45 exchanges across the four data-collection points (see Table 1). These data indicate that discursive chains were typically only one exchange in length. When playing the role of the teacher in the chat, participants most often initiated an exchange and followed the student response with a new question that was unrelated to the mathematics ideas within the student's prior response. These findings suggest that teachers' performance in a simulated environment are aligned with how they describe their classroom discussion practices. Only three participants mentioned teacher questioning strategies as an aspect of this work. These data suggest that participants provide students with opportunities to engage in discussion on a regular basis but do not attend to the teacher's role in asking follow-up questions that aim to deepen students' reasoning.

| Month | Length of chain | |
|---|---|---|
| | Mean | SD |
| October | 1.38 | 0.81 |
| November | 1.33 | 0.68 |
| December | 1.45 | 0.97 |
| January | 1.25 | 0.56 |

*Table 1. Mean conversational chain length.*

In Research Question 3, we sought to understand the extent to which teachers deploy new discursive practices in simulations. We coded chains by length to see if there was change through time in the frequency with which participants engaged in interactions with "students" in the simulation. The frequency of chains made up of one exchange remained consistent throughout the intervention (see Table 2). We also looked at the frequency of follow-up questions by type that participants asked during each month of the intervention. Our results revealed no clear change in frequency or prevalence of any of the three types of follow-up questions (revoicing, general press for reasoning, or specific press for reasoning).

| Chain Length | October | November | December | January | Total, October - January | Total, November - January |
|---|---|---|---|---|---|---|
| 1 | 77.4 | 73.1 | 75.5 | 79.1 | 76.3 | 75.9 |
| 2 | 13.2 | 22.4 | 11.3 | 17.9 | 16.7 | 17.7 |
| 3 | 3.8 | 3.0 | 9.4 | 1.5 | 4.2 | 4.3 |
| 4 | 5.7 | 1.5 | 1.9 | 1.5 | 2.5 | 1.6 |
| 5+ | 0.0 | 0.0 | 1.9 | 0.0 | 0.4 | 0.5 |

Table 2. Percent of chains of length 1, 2, 3, 4, or 5+.

## Discussion

Consistent with data on teachers' self-described practice, our simulation data suggest that participants' chats aligned with direct-instruction conversational formats. On average, chains remained shorter than two exchanges across each *ELK* administration. The teacher player in a chat typically asked the student player a question and awaited a response. After the student response, the teacher then asked another question that did not seek to follow up on the student's ideas in his or her prior contribution. Instead, the teacher asked a new question that was unrelated to the student's prior contribution and sought to redirect the student toward alternate solution-strategy pathways.

Future simulation design and research considerations include supporting teachers in unpacking the relevant mathematics, identifying common student misconceptions related to that content, and analyzing student work. In order for the teacher to "poke at" certain key ideas or identify the misconception, the teacher player must know the relevant mathematics deeply. Materials that help teachers practice and role-play in a variety of ways might also support effective discursive practice in the simulation. This may include modeling teacher-student scenarios, highlighting model *ELK* questioning practice, and analyzing how other teachers respond in *ELK*. This study also highlights the promise of *ELK* as a diagnostic tool. Participants' self-reported discursive practice was closely aligned with their performance in the simulation, in which students had very few opportunities to expand on their original explanation, illuminate their correct concepts and misconception, or connect new understanding to prior knowledge.

## Conclusion

Digital clinical simulations with authoring features hold promise for supporting math teachers' professional learning, particularly around skills that benefit from low-stakes, repeated practice before classroom implementation such as facilitating a discussion. *ELK* shows particular promise as a diagnostic tool that reflected teachers' understanding of their role in promoting math discourse. Future iterations of the simulation will explore the integration of supports directly into the tool as an intervention to promote effective discursive practice.

## References


Ball, D. L., & Forzani, F. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education*, 60(5), 497–511.

Bobis, J., Clarke, B., Clarke, D., Thomas, G., Wright, R., Young-Loveridge, J., & Gould, P. (2005). Supporting teachers in the development of young children's mathematical thinking: Three large-scale cases. *Mathematics Education Research Journal*, 16(3), 27–57.

Cazden, C. (2001). *Classroom discourse* (2nd ed). Portsmouth, NH: Heinemann.

Chapin, S., O'Connor, M., & Anderson, N. (2013). *Classroom discussions: Using math talk to help students learn* (3rd ed.). Sausalito, CA: Math Solutions.

Clarke, B. (2008). A framework of growth points as a powerful teacher development tool. In D. Tirosh & T. Wood (Eds.), *International handbook of mathematics teacher education: Vol. 2. Tools and processes in mathematics teacher education* (pp. 235–256). Rotterdam, The Netherlands: Sense.

Collins, C., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, 13(1), 15–42.

Franke, M. L., Webb, N., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, 60, 380–392.

Fuson, K. C., Kalchman, M., & Bransford, J. D. (2005). Mathematical understanding: An introduction. In M. S. Donovan & J. Bransford (Eds.), *How students learn mathematics in the classroom* (pp. 217–256). Washington, DC: National Research Council.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, *111*(9), 2055–2100.

Jacobs, V. R., Franke, M. L., Carpenter, T. P., Levi, L., & Battey, D. (2007). Professional development focused on children's algebraic reasoning in elementary school. *Journal for Research in Mathematics Education*, 38, 258–288.

Jacobs, V. R., Lamb, L. L. C., & Phillip, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education*, 41, 169–202.

Levine, A. (2009). *Educating school teachers*. Princeton, NJ: The Education Schools Project. Retrieved from http://edschools.org/pdf/Educating_Teachers_Report.pdf

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica*, *22*(3), 276–282.

Nassaji, H., & Wells, G. (2000). What's the use of 'triadic dialogue?' An investigation of teacher-student interaction. *Applied Linguistics*, *21*, 376–406.

O'Connor, M. C., & Michaels, S. (1996). Shifting participant frameworks: Orchestrating thinking practices in group discussion. In D. Hicks (Ed.), *Child discourse and social learning* (pp. 63–102). Cambridge, UK, and New York, NY: Cambridge University Press.

O'Connor, M. C., & Michaels, S. (1993). Aligning academic task and participation status through revoicing: Analysis of a classroom discourse strategy. *Anthropology & Education Quarterly*, 24(4), 318–335.

Shaughnessy, M., & Boerst, T. A. (2018). Uncovering the skills that preservice teachers bring to teacher education: The practice of eliciting a student's thinking. *Journal of Teacher Education*, 69(1), 40–55.

Reich, J., Kim, Y. J., Robinson, K., Roy, D., & Thompson, M. (2018). Teacher practice spaces: Examples and design considerations. In *Proceedings of the 2018 International Conference of Learning Sciences*, London, UK. doi:10.31235/osf.io/ewn2g

Reich, J., Kim, Y. J., Robinson, K., Roy, D., & Thompson, M. (2019). Exploring authenticity and playfulness in teacher practice spaces. In J. H. Kalir (Ed.), *Proceedings of the 2018 Connected Learning Summit* (pp. 214–223). Pittsburgh, PA: ETC Press.

Sleep, L., & Boerst, T. A. (2012). Preparing beginning teachers to elicit and interpret students' mathematical thinking. *Teaching and Teacher Education*, 28(7), 1038–1048.

TeachingWorks. (2018). *High-leverage practices*. Retrieved from http://www.teachingworks.org/work-of-teaching/high-leverage-practices

Thompson, M., Roy, D., Wong, T., Tan, P., Huttner-Loan, E., & Reich, J. (2017, March). *Online practice for preservice teachers to elicit students' preconceptions*. Presented at the 2017 Society for Information Technology and Teacher Education Conference, Austin, TX.

Truxaw, M. P., & DeFranco, T. C. (2008). Mapping mathematics classroom discourse and its implications for models of teaching. *Journal for Research in Mathematics Education*, 39, 489–525.

United States Department of Education, Office of Innovation and Improvement. (2016). *STEM 2026: A vision for innovation in STEM education*. Washington, DC: Author. Retrieved from https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

Van Zoest, L. R., Stockero, S. L, Leatham, K. R., Peterson, B. E., Atanga, N. A., & Ochieng, M. A. (2017). Attributes of instances of student mathematical thinking that are worth building on in whole-class discussion. *Mathematical Thinking and Learning*, 19(1), 33–54.

Wells, G. (1996). Using the tool-kit of discourse in the activity of learning and teaching. *Mind, Culture, and Activity*, 3, 74–101.

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# 3. How Spiderman Can Teach You Math: The Journey of Memes From Social Media to Mathematics Classrooms

GIULIA BINI

**Abstract:** Memes are humorous digital artifacts created by web users copying an image and overlaying a personal funny caption. They are virally shared in the web and represent an important part of the online discourse young learners are exposed to on a daily basis. The aim of this paper is to show how memes on mathematical subjects can inspire learning activities that harness the participatory and playful nature of these digital artifacts, connecting positive emotions, focal for learning achievement, to serious mathematical reasoning. The paper presents a collection of 3 examples taken from different learning scenarios: 1 from a spontaneous out-of-school learning environment and 2 from intentionally designed school experiences conducted with 6th- and 12th-grade students, all pivoting on the use of a popular meme based on a Spiderman cartoon. The analysis elicits the core properties of these experiences in order to show how they fit within the connected learning framework. I hope the outcome of this research can shed some light on how educators can leverage on students' popular culture embodied in memes to foster interest-powered learning outcomes in mathematics.

## Introduction

Students' emotions and interest are acknowledged as key internal factors for learning achievement in the mathematics classroom. They can affect cognitive processing in several different ways, from the bias on attention and memory to the activation of reactive behaviors, such as that of math anxiety, that can hinder mathematical thinking (Hannula, 2015; McLeod, 1992; Schukajlow, Rakoczy, & Pekrun, 2017; Zan, Brown, Evans, & Hannula, 2006). For these reasons, fostering positive emotions in math class can be a winning practice that extends its effects well beyond the time span of the actual lecture. According to the connected learning framework (Ito et al., 2013, 2018), an effective way to associate positive feelings to learning experiences is building connections between academic goals and other areas of expertise and interest of the learners.

The aim of this paper is to show how memes on mathematical subjects can support building these connections, providing the basis for creative learning activities that harness the participatory and playful nature of these digital artifacts and bond positive emotions to serious mathematical reasoning. The paper presents a collection of three examples taken from different learning scenarios: one from a spontaneous out-of-school learning environment and two from intentionally designed school experiences, all pivoting on the use of a popular meme based on a Spiderman cartoon chosen for its relevance, which will be outlined in the next paragraph. The analysis elicits the core properties of these experiences in order to show how they fit within the connected learning framework. The paper concludes by discussing how educators can leverage on students' popular culture embodied in memes to foster interest-powered learning outcomes in mathematics.

## Background: From Cartoons to Meme Icon

The image in Figure 1, known as *Spiderman pointing at Spiderman*, is a snapshot from a 1967 cartoon that in the last decade has been promoted to a new status. It became the template (i.e., base image) of an extremely popular meme, a humorous digital artifact created by web users overlaying an image with a personal funny caption, widely shared in networking websites such as Reddit or Instagram.


*Figure 1. The Spiderman pointing at Spiderman template [Source: Reddit].*

In the process of meme genesis, whose mechanisms lie far beyond the scope of this paper, the *Spiderman pointing at Spiderman* template acquired the metaphorical meaning of two similar things meeting (see KnowYourMeme, https://knowyourmeme.com/, the Internet meme database). In this sense it triggered a wide range of modifications and personalizations, all aimed at capturing the humorous side of the acknowledged metaphor, with the personalized caption either in a white strip above the image (see Figure 2, left) or superimposed on the two Spiderman figures (Figure 2, right).


*Figure 2. Spiderman pointing at Spiderman meme examples [Source: Know Your Meme].*

The popularity of this template is so widely recognized that the above-mentioned KnowYourMeme website recently (2019) listed it among "The Top 50 Memes of the Decade." Its fame propagates even outside memes' natural habitat (i.e., social media websites), inspiring a handful of re-creations, such as the real-life Halloween *Spiderman pointing at Spiderman* that kids posted on Reddit (see Figure 3, left) and the digital 3D Spidermen in the advertisement of a new superhero-inspired video game (Figure 3, right).


*Figure 3. Spiderman pointing at Spiderman meme-inspired re-creations [Sources: Reddit and Twitter].*

All these evidences attest how deeply this meme has been interiorized by web users, who easily recognize and decode it even when it is taken out of context. From the point of view of mathematical reasoning, the metaphorical meeting of two similar things described by this meme resonates with the idea of the commonality of meanings across different semiotic representations of mathematical objects, whose recognition and understanding are acknowledged as cornerstones of an effective mathematical activity aiming beyond the mere memorization of facts and procedures (Duval, 2006; Etkind, Kenett, & Shafrir, 2015). In fact, this template is widely exploited within online communities exchanging memes on mathematical subjects, where its *puzzle effect* (the template implies that the two things are connected, but it is up to the viewer to unravel why) challenges users, providing openings for spontaneous learning.

## Literature and Theoretical Framework

With 144 million occurrences of the hashtag #memes on Instagram in July 2020, memes are a viral phenomenon acknowledged as a significant part of the digital culture that shapes young people's media literacy (Danesi, 2019; Shifman, 2014; Wiggins & Bowers, 2015). Their relevance in the online discourse is so widely established that researchers at Carnegie Mellon University recently disclosed the results of research aimed at developing a new technology to make memes accessible for people with visual impairments (Gleason et al., 2019). Despite this massive diffusion and accredited potentialities, memes remain understudied in educational research (Knobel & Lankshear 2005, 2007, 2018; Romero & Bobkina, 2017) and even less in research focusing on mathematics education, where at the present, only a few exploratory studies have been conducted (Benoit, 2018; Bini & Robutti, 2019a; Bini & Robutti, 2019b). Since memes on mathematical topics dwell at the intersection of the spheres of learning involving personal interests, peer culture, and mathematical academic content, I believe that the connected learning framework (Ito et al., 2013, 2018) could be a suitable lens to observe the learning experiences involving these artifacts. According to the framework, spontaneous connected learning experiences share the core properties of being production-centered, organized around a common goal, and openly networked. These characteristics inform the design principles for the intentional creation of connected learning environments that pivot around participation, experiential learning, interest cultivation and challenge, and interconnection among learners and between learners and teachers. The common thread linking these experiences, whether spontaneous or intentional, is that they are emotionally satisfying, thus connecting the sought-after positive emotions to the learning process.

Zooming in from the learning setting to the artifacts, I will use the *triple-s construct* of the *partial meanings* of a meme (Bini & Robutti, 2019a) to guide the understanding of the memes and of teachers' and learners' interaction with them. According to this construct, the comprehension of the *full meaning* of a meme is achieved through the understanding and intersecting of three *partial meanings*:

- The *first partial meaning* is **structural**, and lies in having a consistent aesthetic: text font, color and position, and overall visual impact (see Figure 4, left, for the examples analyzed in this work);
- The *second partial meaning* is **social**, and it is conveyed by shared rules about the message carried by images and templates (see Figure 4, right, for the examples analyzed in this work and the KnowYourMeme website for other memes);
- The *third partial meaning* is **specialized** and is carried by elements referring to a specific topic, in our case mathematical (see Figures 5, 6, and 7 in the Data and Analysis section).

*Figure 4. Structural meaning (left) and social meaning (right) of the Spiderman meme.*

This study is therefore designed to address the following questions:

- How do mathematical memes provide opportunities for connected learning experiences?
- How can the connected learning framework and triple-s construct support educators in designing effective learning scenarios involving mathematical memes?

## Method

This paper draws on my doctoral research on memes on mathematical subjects, developed throughout the last two years under the supervision of Ornella Robutti, exploring online communities and conducting school-based experiments with students creating and discussing memes. Data collected are memes and related comments for the online research, memes and questionnaires for the school-based research, complemented when possible with the videotaping of the creation processes and of the following discussion. This study presents three examples, chosen for their representative use of the *Spiderman pointing at Spiderman* template. The first is an example of spontaneous interest-driven learning, taken from r/mathmemes, the largest mathematical memes public community in the Reddit website, commonly acknowledged as the birthplace of memes (845,000 members in July 2020). The second example was collected during the discussion that followed a meme-creation experiment on complex numbers conducted with a class group of 29 12th-grade students (17 years old). The third example comes from a meme-creation experiment on exponents and powers conducted with two class groups of 19 6th-grade students (11 years old) each. In both school examples, the meme-creation activity was proposed after completing the indicated topic, with the didactical aim of fostering the reorganization of cornerstone ideas, possibly eliciting doubts and misconceptions.

## Data and Analysis: From Meme Icon to Learning Object

### Example 1: The Internet Spiderman

The meme in this example (see Figure 5, left) was uploaded to the popular r/mathmemes Reddit public community with the title "unit circle baby," and in the two following days it was commented upon by three different commenters (none of whom was the author of the meme). To protect the identity of commenters in the quoted excerpt, publishing dates are not shared and nicknames are replaced with the initials C1, C2, and C3; all comments are unredacted and originally in English.

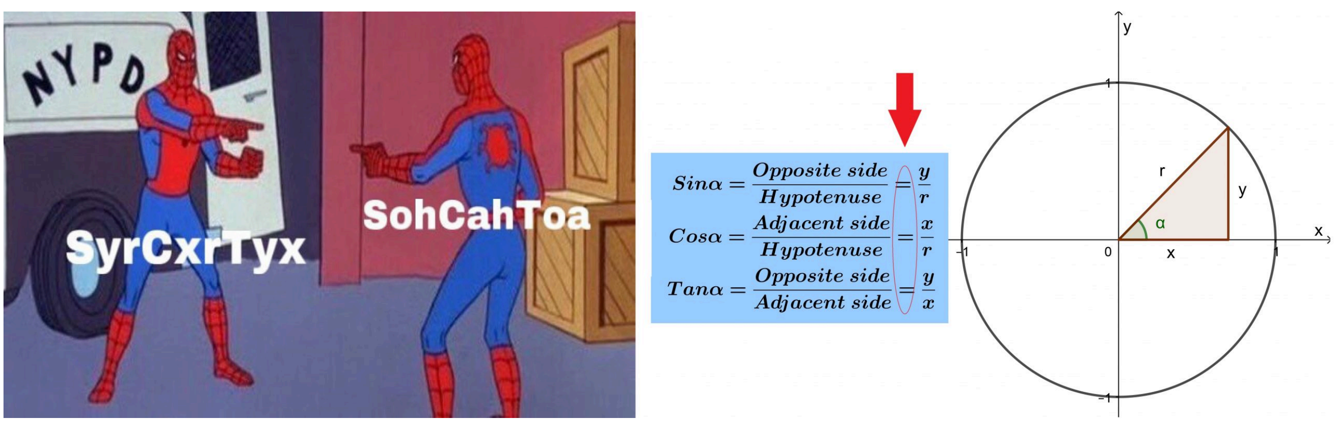


*Figure 5. The Internet Spiderman meme (left) and my representation of the explanation (right).*

> C1: [day 1, 9:40] Explain pls
> C2: [day 1, 13:44] SohCahToa is a mnemonic for trigonometry students to remember the right triangle definitions of the trig functions: soh is "sine is opposite over hypotenuse" coh is "cosine is adjacent over hypotenuse" and toa is "tangent is opposite over adjacent"
> SyrCxrTyx is using the circle definitions: sin is y/r, cos is x/r, tan is y/x
> C1: [day 1, 13:46] Oh thx didn't know that
> C3: [day 2, 00:29] It defeats the purpose of the mnemonic. If you can remember where the y,x and r are supposed to go you already know the formulas.
> C2: [day 2, 01:52] I absolutely agree. I was just explaining the joke to OP ["original poster" in Reddit jargon, i.e., C1]

This example shows how the sharing of a meme in an openly networked environment, where people communicate across national boundaries, provides a connected learning opportunity for commenter C1, who explicitly seeks help, going back to the website after a while to check for answers. Research in the Reddit website revealed that C1 is a nonnative English speaker, thus not acquainted with the SohCahToa mnemonic device for trigonometric functions, which is language sensitive and therefore diffused in English-speaking learning environments only. C2, a native English speaker, gives a thorough explanation of the SohCahToa acronym and its connection to SyrCxrTyx (as summarized in Figure 5, right, image elaborated by the author of the present study), confirming that mathematical meanings have to be framed within the "sphere of practice" where they are constructed (Kilpatrick, Hoyles, Skovsmose, & Valero, 2005, p. 10). C2 subsequently agrees with C3 in contesting the advantages of the second representation, whose clarification was nevertheless due in order to testify that he successfully cracked the meme. The challenge represented by the puzzle effect of the meme offered C2 an opening to show off his mathematical knowledge, attesting his position as a member of the community, and at the same time resulted in a connected learning opportunity for C1. As a final observation, we note how the *Spiderman pointing at Spiderman* popularity previously described led C2 to assume without hesitation that C1's explanation request was referring to the specialized partial meaning and not to the social one.

## Example 2: The School Spiderman (Teacher Version)

This example focuses on a meme I created that was proposed in the class after the students' meme-creation activity, in a peer-based exchange of memetic productions between students and educators. Students received printed worksheets with the meme in Figure 6 (among others) and were asked to explain the specialized partial meanings; teacher and author were present. All students turned in correct answers for this meme, with the exception of one student who wrote, "I have no idea." This student, while filling in the handout, had asked me for support in decoding the meme, and some effort was needed to persuade him that he could simply leave it blank or write that he did not know the answer. He was convinced only after being reassured that he would eventually receive the requested explanation during the discussion. This behavior is diametrically opposite to what commonly happens in a math class, where students, unfortunately, rarely care for explanations of unsolved questions: I believe that this can be interpreted as evidence of the connected learning features of interest cultivation and challenge associated with the meme.


*Figure 6. The teacher's Spiderman.*

In the discussion that followed, the equivalence implied by the meme between the multiplication by $i$ of a complex number and the rotation of the associated vector in the complex plane was further examined:

> Teacher: What does it mean?
> Students [in chorus]: that they are the same thing: on a graphic level multiplying by $i$ is equivalent to a pi/2 rotation
> Teacher: Ok
> Author: And did you already know this or did you gather it from the meme?
> Students answer indistinctly; some voices can be heard saying "from the meme" [...]
> Author: Who understood it thanks to the meme? [Five students raise their hands]
> Student [pointing to the meme and addressing his classmate] you rely on the meme … it means that they must be equal!

This excerpt shows another connected learning feature of memes, in this case how they succeed in linking peer culture and academic content. In fact, in this example and in other experiments involving this same meme, students' proficiency in recognizing the *Spiderman pointing at Spiderman* meme and identifying its social partial meaning, ascribable to the exposure to this type of artifact outlined in the background section, allowed mathematical specialized meanings to be easily carried. As a complement, the mentioned puzzle effect connected to the meme created a challenge that kept students hooked to the following review of the motivations supporting the equivalence, eventually leading to some shared learning.

## Example 3: The School Spiderman (Student Version)

This last example incorporates two different memes, created by students in a meme-creation activity in which the mathematical topic and templates were assigned. Because of their younger age, and consequent lower exposure to social media, students were not all acquainted with the *Spiderman pointing at Spiderman* template and its partial meanings, which were illustrated by the teachers at the beginning of the activity using the triple-s construct. Students' creations were then shared and discussed in the class groups. The experience was followed after several months by a test and a feedback questionnaire.

In this activity the use of memes, instead of traditional exercises, positively challenged learners, allowing each student to participate and contribute according to his or her personal mathematical expertise. This constructive climate fostered metacognitive processes that enabled assessing the basic knowledge about powers (see Figure 7, left), and in some cases elicited misconception (see Figure 7, right).


*Figure 7. The students' Spidermen.*

The sharing and discussion of the memes orchestrated by the two teachers provided immediate feedback from peers in a nonjudgmental way and supported the learning process initiated by the memes. In the feedback questionnaire, 80% of the students declared themselves pleased with the experience “because we invented the jokes,” and they described it as “a fast funny, different, easy way to learn math.” After the summer break, the entry test administered to all parallel classes in the school showed that students exposed to the meme activity scored significantly better results in questions about exponents and powers than other students in the school. Surely this cannot be considered as the result of a proper quantitative study with control groups; nevertheless it argues in favor of the educational effectiveness of the engagement and motivation component given by the meme.

## Results and Discussion

This work sampled the learning potential of a particular meme, but the overall investigation revealed that the affordances of the *Spiderman pointing at Spiderman* meme occur in many other templates: In fact, a moderator of one of the most popular mathematical memes groups in Facebook acknowledged in a public post in the group page that “without them [the mathematical memes] I wouldn’t have discovered all the fun I want to learn and know!”

This is consistent with the idea that mathematical memes can provide opportunities for learning experiences characterized by the creative, participatory, challenging, and interconnected features that typify the connected learning model. I think that the common thread bringing together all examples is that they provide evidences of learning practices “linking deep ‘vertical’ expertise with horizontal expertise and connection to other cultural domains and practices” (Ito et al., 2013, p. 56). In this case the deep vertical expertise is the mathematical academic knowledge (the specialized meaning of the meme) and the broad horizontal one is learners’ acquaintance with memes and popular culture (the structural and social meanings). Reversing the order of the factors, the connected learning framework can support educators in designing new learning experiences that incorporate mathematical memes. For instance, the interconnection feature, which was restricted to the class group in the reported examples, can be amplified by sharing students’ memes at school level or ever further within online communities, and the challenge feature can be enhanced, allowing students to team and compete in a different way, not only encoding mathematical meanings into their memetic creations, but also decoding the mathematical meanings of memes created by classmates. In agreement with the connected learning stance, in these activities teachers should fall in the background, giving space to peer-based learning experiences in which students and students’ creations are central. The triple-s construct can therefore be an effective tool for educators to survey and facilitate the process of didactic transposition (in the sense of Chevallard, 1988) that allows the transformation and adaptation of knowledge to the new means of communication.

I believe that the results of this work point to the potential of mathematical memes in associating positive feelings to learning experiences and in fostering interest-powered learning outcomes in mathematics, and show that the connected learning design principles together with the triple-s construct can support educators in creating activities that successfully link school culture and popular culture.

## References


Benoit, G. (2018). *Mathematics in popular culture: An analysis of mathematical Internet memes* (Doctoral dissertation). Teachers College, Columbia University, New York, NY.

Bini, G., & Robutti, O. (2019a). Meanings in mathematics: Using Internet memes and augmented reality to promote mathematical discourse. In U. T. Jankvist et al. (Eds.), *Proceedings of the 11th Congress of the European Society for Research in Mathematics Education*. Utrecht, The Netherlands: Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.

Bini, G., & Robutti, O. (2019b). Thinking inside the post: Investigating the didactic use of mathematical Internet memes. In A. Shvarts (Ed.), *Proceedings of the PME and Yandex Russian Conference: Technology and Psychology for Mathematics Education* (pp. 106–113). Moscow, Russia: HSE.

Chevallard, Y. (1988, August). *On didactic transposition theory: Some introductory notes*. Paper presented at the International Symposium on Research and Development in Mathematics, Bratislava, Czechoslavakia.

Danesi, M. (2019). *Memes and the future of pop culture*. Leiden, The Netherlands: Brill.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics*, *61*, 103–131.

Etkind, M., Kenett, R. S., & Shafrir, U. (2015). Learning in the digital age with meaning equivalence reusable learning objects (MERLO). In R. Railean, G. Walker, A. Elçi, & L. Jackson (Eds.), *Handbook of research on applied learning theory and design in modern education* (Vol. 1; pp. 310–333). Hershey, PA: IGI Global.

Gleason, C., Pavel, A., Liu, X., Carrington, P., Chilton, L. B., & Bigham, J. P. (2019). Making memes accessible. In ASSETS '19: *The 21st International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 367–376). ACM. https://doi.org/10.1145/3308561.3353792

Hannula, M. S. (2015). Emotions in problem solving. In S. J. Cho (Ed.), *Selected regular lectures from the 12th International Congress on Mathematical Education* (pp. 269–288). Switzerland: Springer International.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., … Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub. Retrieved from https://dmlhub.net/publications/connected-learning-agenda-for-research-and-design/

Ito, M., Martin, C., Cody Pfister, R., Rafalow, M. H., Salen K., & Wortman, A. (2018). *Affinity online: How connection and shared Interest fuel learning.* New York: NYU Press.

Kilpatrick, J., Hoyles, C., & Skovsmose, O., & Valero, P. (2005). Meanings of 'meaning of mathematics.' In J. Kilpatrick, C. Hoyles, O. Skovsmose, & P. Valero (Eds.), *Meaning in mathematics education* (pp. 9–16). New York, NY: Springer.

Knobel, M., & Lankshear, C. (2005, November). Memes and affinities: Cultural replication and literacy education. Paper presented at the National Reading Conference, Miami, FL.

Knobel, M., & Lankshear, C. (2007). Online memes, affinities, and cultural production. In M. Knobel & C. Lankshear (Eds.), *A new literacies sampler* (pp. 199–228). New York, NY: Peter Lang.

Knobel, M., & Lankshear, C. (2018). *Memes online, afinidades e produção cultural (2007–2018)* [Online memes, affinities and cultural production (2007–2018)]. https://doi.org/10.13140/rg.2.2.34717.77280

Know Your Meme. (2019, December 17). *The top 50 memes of the decade*. Retrieved from https://knowyourmeme.com/editorials/meme-review/the-top-50-memes-of-the-decade-40-31

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics, teaching and learning* (pp. 575–596). Reston, VA: National Council of Teachers of Mathematics.

Romero, E., & Bobkina J. (2017). Teaching visual literacy through memes in the language classroom. In K. Donaghy & D. Xerri (Eds.), *The image in English language teaching* (pp. 59–69). Floriana, Malta: ELT Council.

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2017). Emotions and motivation in mathematics education: Theoretical considerations and empirical contributions. *ZDM: Mathematics Education*, 49, 307–322.

Shifman, L. (2014). *Memes in digital culture*. Cambridge, MA: The MIT Press.

Wiggins, B. E., & Bowers, G. B. (2015). Memes as genre: A structurational analysis of the memescape. *New Media & Society*, 17(11), 1886–1906.

Zan, R., Brown, L., Evans, J., & Hannula, M. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics*, 63(2), 113-121.

# 4. Comparing Parent Report and Telemetry Measures of Child Media Use

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**Abstract:** Accurate measurement of children's media use is critical for understanding media effects on child outcomes. Researchers commonly rely on parent-reported media use despite well-known methodological drawbacks (e.g., Robinson et al., 2006). An alternative method that may be more accurate is tracking usage via data drawn from tracking software. However, telemetry-tracked data do not capture rich qualitative information on how users engage with media. This study compares these 2 approaches for measuring usage of a media-based intervention. Data were drawn from a study of an 8-week digital media intervention for 4- and 5-year-old children from low-income families in 5 U.S. states (N = 216). As part of the intervention, participants were given a tablet computer with educational game and video apps installed. Parents reported children's usage of the intervention materials via a weekly online survey. Researchers collected telemetry data from tracking software installed on tablets. Parent-reported and telemetry-tracked information on use of intervention materials were moderately correlated ($r = 0.35$). On average, parents reported that children used the intervention digital media materials more often than the telemetry data indicated. This pattern was consistent across each of the 7 weeks during which we collected these data. Findings suggest that parent report is not a reliable substitute for telemetry data when measuring time spent with media. However, telemetry data cannot describe child affective engagement with the media and the social context within which children use media. Researchers must therefore be mindful in selecting measures to accurately describe distinct dimensions of media usage.

## Introduction

The growing ubiquity of technology in young children's lives has raised concerns about the relationship between the amount of media a child uses and the extent of positive or negative effects on children's development. To answer such questions, researchers need accurate measures of child media usage. This study compares two approaches to measuring use of a child-focused media-based intervention: parent weekly surveys and usage data extracted from computer tracking software.

Studies of children's media use, including national surveys (e.g., Rideout, 2017), often use parent report because it is noninvasive and fairly simple to collect. Although parent media logs are straightforward to develop and administer relative to telemetry data, they can be resource intensive to collect, as incentives are often necessary to combat declining completion rates through time. As with other forms of self-report, parent-reported child media use is subject to flawed recall and understanding, as well as to social desirability bias, which could result in either over- or underreporting children's media use. Social desirability regarding screen-time limitations may motivate parents to underreport their child's media use, just as they overestimate their own role in mediating their child's media use, compared with child reports (Gentile, Nathanson, Rasmussen, Reimer, & Walsh, 2012). Parents may also underreport media use that they do not observe. For example, evidence indicates that parents of 4- to 7-year-olds underreport the child's media use when a television is present in the child's bedroom (Robinson, Winiewicz, Fuerch, Roemmich, & Epstein, 2006). Similarly, parents may underreport children's use of portable devices because children may use them out of view.

Several factors may lead parents to *over*report their child's media use. For example, studies using similar self-report measures have found that adults tend to overreport their own media use (Scharkow, 2016; Sewall, Rosen, & Bear, 2019). They may similarly overreport their children's media use. Participant characteristics, such as well-being, may influence rates of overreporting (Sewall et al., 2019). Further research is needed to determine whether parent characteristics affect reporting of child media use. Additionally, intervention study participants may feel social pressure to report that their child complied with the study by using the intervention media.

Some prior studies have tracked media use via telemetry data, captured by software embedded in the media intervention or mobile device (e.g., Roberts, Chung, & Parks, 2016). The primary reason to use telemetry data is its apparent objectivity—automatic usage tracking is not subject to recall or social desirability biases. Further, telemetry data may reduce participant burden because they are collected automatically rather than through written surveys. However, telemetry data may not provide an accurate representation of media use by an individual or family. Unless telemetry software is installed on every device in the home, it can capture only device-specific media use, thus potentially underreporting total media usage. In addition, telemetry data may attribute usage to the focal child when in fact others were using the device, resulting in overreporting of the child's usage. Telemetry methods may also overreport usage because they cannot distinguish instances of engaged usage from instances when a child opens a video or game and becomes distracted. Further, tracking software may not always be reliable. Some parental control software is incompatible with tracking software and can disrupt its data collection. Participants or their parents may also intentionally or unintentionally disable the tracking software.

The present study compares parent-reported and telemetry-tracked child media use to provide insight into the biases or possible error inherent in both approaches. Our research questions are:

1. How do parent reports and telemetry-tracked estimates of child media use correlate? How do they differ?
2. How does the relationship between parent-reported and telemetry-tracked data change through time?
3. How does the relationship between parent-reported and telemetry-tracked data differ by parent characteristics?

# Method

## Sample

The data examined in this study are from an eight-week randomized controlled trial conducted during the winter and spring of 2019. Participants were 454 families with four- and five-year-old children in five locations across the United States: Boston, Massachusetts; Minneapolis, Minnesota; New York, New York; Phoenix, Arizona; and San Francisco, California. Children were all English-speaking and from low-income households where parents spoke either English or Spanish (Grindal et al., 2019). This study examines data from the 216 families in the treatment group for whom at least one week of both telemetry and parent-reported usage data is available. The data set includes weekly measures of parent-reported and telemetry-tracked usage for each of the first seven weeks of the study. Parent-reported usage was not collected in the eighth week of the study.

## Telemetry Tracking

To track use of the intervention games and videos, researchers provided each treatment-group family with a tablet that included an intervention video player app to watch the intervention videos, as well as an intervention games app. Researchers developed the video player app in collaboration with a third-party developer. The video app logged which videos were watched, the date, and the number of minutes the video played. To track children's use of the intervention game app, intervention producers developed a research version of the intervention app, identical to the publicly available app except that it logged the games each treatment-assigned child played, his or her use time and date, and the actions he or she took within the games.

### Weekly Parent Surveys

Researchers texted parents during study weeks 1–7 with a link to complete a short (five-minute) online survey with several questions about the child's use of the intervention media in the prior week. Participants who did not complete the weekly media log within three days received an additional text message reminder to do so. Families received an incentive to complete the study, but incentives were not tied to weekly survey completion. The item used for this study asked parents how much time their child spent watching or playing the intervention videos and games over the last seven days. The question phrasing did not limit media usage to the study-provided tablet.

## Results

Media log response rates ranged from 74% to 88% across the seven weeks. Rates of nonmissing telemetry data ranged from 63% to 98% (see Table 1). Missing telemetry data include weeks in which the child did not use the tablet computer. The data do not allow us to separate zero-usage weeks from truly missing data. We are aware of one instance in which the telemetry tracking software did not send video tracking data. In five other cases, the telemetry tracking software malfunctioned so that it prevented children from using the tablet (once families reported the problem, researchers replaced them with tablets that did function). Analyses for this paper include only data points for which both parent-reported and telemetry-tracked data are available for the same participant in the same week; weekly rates of usable data range from 45% to 77%.

| Week | Number of Participant Media Logs Submitted | Number of Participants with Telemetry Data | Number of Participants with Media Log and Telemetry Data |
|---|---|---|---|
| 1 | 176 (77%) | 224 (98%) | 164 (72%) |
| 2 | 201 (88%) | 209 (91%) | 176 (77%) |
| 3 | 184 (80%) | 192 (84%) | 153 (67%) |
| 4 | 170 (74%) | 180 (79%) | 134 (59%) |
| 5 | 179 (78%) | 161 (70%) | 127 (55%) |
| 6 | 171 (75%) | 144 (63%) | 111 (48%) |
| 7 | 164 (72%) | 131 (57%) | 102 (45%) |

*Note.* Total *N* = 229 families in the treatment group. Subsequent analyses include only the 216 families in the treatment group for whom at least one week of both telemetry and parent-reported usage data is available.

*Table 1. Data availability rates by source.*

## How Do Parent Reports and Telemetry-Tracked Estimates of Child Media Use Correlate? How Do They Differ?

Parent-reported and telemetry-tracked usage data were moderately correlated at $r = .35$ ($p < .001$). For 41% of our data points, parent-reported usage was within one hour of telemetry-reported usage (see Figure 1). Parents tended to report their child's media usage as higher than telemetry data indicated.

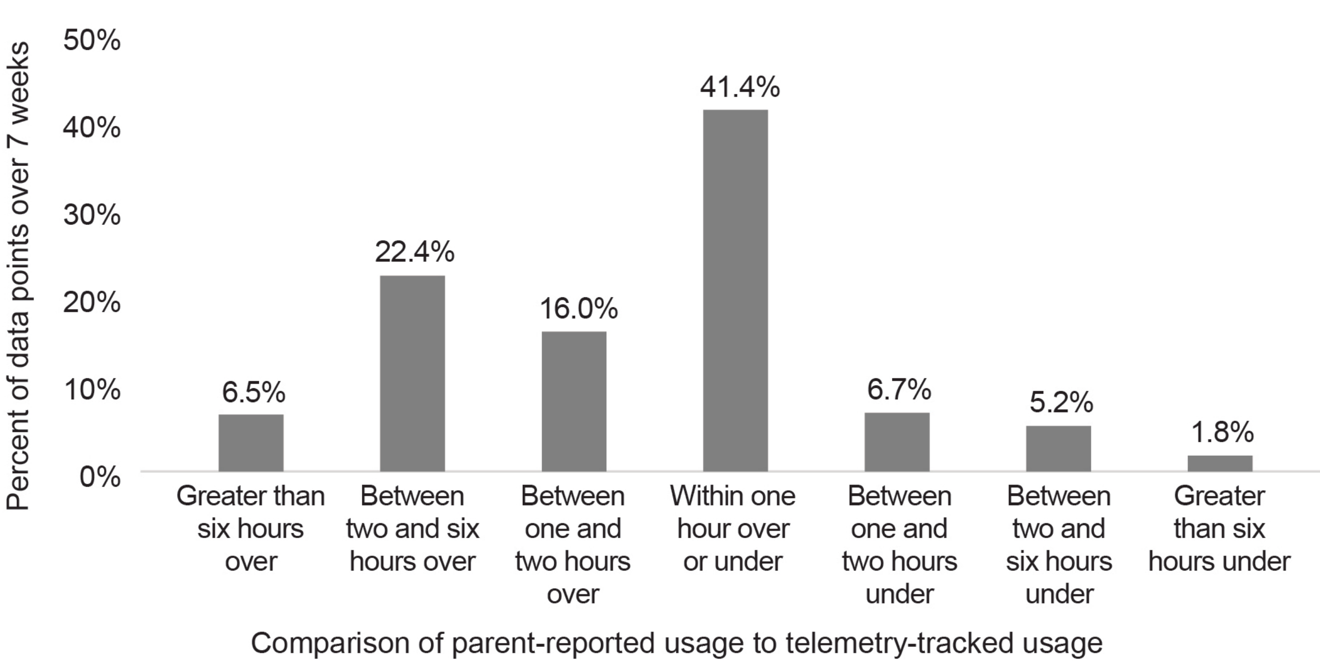


*Figure 1. Differences between parent-reported media usage and telemetry-tracked media usage.*

Median parent-reported usage was double the median telemetry-tracked usage (two hours compared to one hour in a week; see Table 2). Similarly, maximum parent-reported usage (60.5 hours in one week) was about double the maximum telemetry-tracked usage (27.7 hours in one week). Minimum telemetry-tracked usage was above zero because zero-usage weeks appear as missing data.

| Descriptive | Telemetry-Tracked Usage | Parent-Reported Usage |
|---|---|---|
| Number of weekly telemetry reports or parent media logs | 1,233 | 1,190 |
| Median minutes (*SD*) | 61 (197) | 120 (293) |
| Maximum minutes | 1667 | 3630 |
| Minimum minutes | 0.004 | 0 |

*Note.* Parent-reported usage is reported in integers because parents were only asked to report in whole numbers. For telemetry data, weeks with 0 minutes of usage are treated as missing.

*Table 2. Descriptive statistics for weekly telemetry-tracked and parent-reported usage.*

## How Does the Relationship Between Parent-Reported and Telemetry-Tracked Data Change Through Time?

Telemetry-tracked and parent-reported usage was, on average, nearly identical in the first week. However, as telemetry-tracked media usage declined in subsequent weeks, parents consistently reported more media usage than telemetry data suggest (see Figure 2).

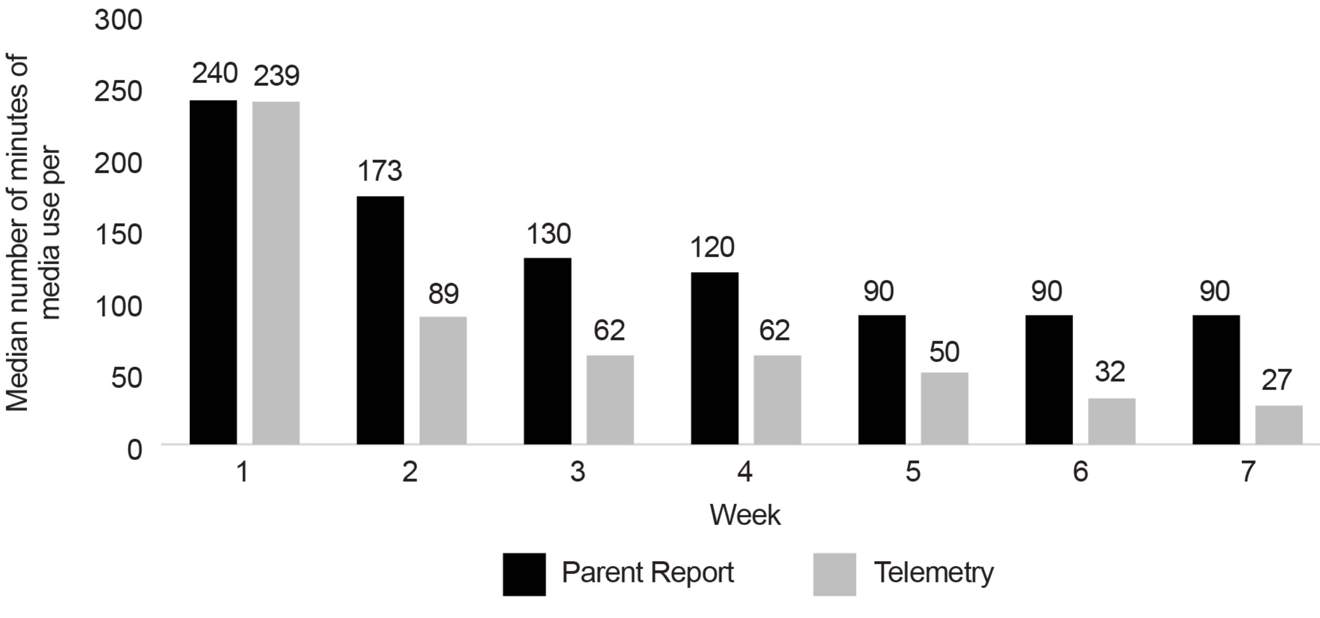


*Figure 2. Parent-reported versus telemetry-tracked media usage by week.*

## How Does the Relationship Between Parent-Reported and Telemetry-Tracked Data Differ by Parent Characteristics?

Table 3 presents parent-telemetry concordance by parent characteristics. To test the statistical significance of these differences we conducted a mixed model regression, clustered by child, with a fixed effect for week. We did not identify statistically significant ($p < .10$) differences in the concordance between parent-reported and telemetry-tracked usage by parental education, parent income, or whether the child's home language was English.

| Participant Characteristic | *N* Observations | Median Difference in Minutes (*SD*) |
|---|---|---|
| Parental education: High school or less (40 children) | 185 | 40.4 (353) |
| Parental education: Greater than high school (158 children) | 782 | 48.9 (279) |
| Parental annual income: Less than $50K (95 children) | 460 | 53.2 (342) |
| Parental annual income: Greater than $50K (98 children) | 484 | 40.4 (244) |
| Home language: Not English (47 children) | 228 | 65.9 (413) |
| Home language: English (151 children) | 739 | 40.2 (244) |

*Note.* Medians indicate the number of minutes, on average, by which parent report exceeds telemetry report. Positive medians indicate greater parent-reported use than telemetry-tracked use. Negative medians indicate greater telemetry-tracked use than parent-reported use. Medians reported in this table do not account for the clustering of data points within child – that is, the fact that most children contributed multiple data points. All differences are not statistically significant; statistical analyses did account for the clustering of observations within child.

*Table 3. Difference (in minutes) between parent-and tablet-reported child media usage by parent characteristics.*

## Discussion

This study examined concordance between parent-reported and telemetry-tracked tablet use among 4- and 5-year-old children. We found that these two media-use tracking methods are significantly positively correlated, and their estimates of child media use were within one hour of one another for 41% of the data points in this study. These findings are consistent with prior television-viewing studies (Anderson, Field, Collins, Lorch, & Nathan, 1985; Robinson et al., 2006), and extend their findings to tablet computer usage.

Yet these two sources of data do not concur perfectly. In study week 1 parent-reported media usage was nearly identical to telemetry-tracked media usage. In subsequent weeks telemetry-tracked usage declined more sharply than parent-reported usage. We interpret these findings to indicate that parents overreported their child's media use. As their child's media usage declined, parents may have felt pressure to report that their child was still using the intervention media for the recommended duration of one hour or longer. This finding may also be explained by self-selection bias. As parent media survey response rates declined over seven weeks, it is possible that those who continued to complete surveys were systematically different—for example, more conscientious—in a way that biased them toward overreporting.

Some potential explanations for these findings seem less plausible because they do not account for the contrast in parent-telemetry concordance between week 1 and all subsequent weeks. For example, this pattern is not consistent with a general trend toward overreporting observed media use (Robinson et al., 2006; Sewall et al., 2019). It is also possible that some parents may have misunderstood the survey question, which asked for hours and minutes of media usage. Perhaps they assumed that the minutes field required a conversion of weekly hours into minutes. This would explain higher parent-reported than telemetry-reported usage, but it would not explain the concordance gap between week 1 and subsequent weeks.

It is also possible that the telemetry data underreported children's media use. Telemetry recorded usage on only one device per participant, whereas parents had the opportunity to report on usage across devices. We think this explanation is unlikely for two reasons. First, we would expect such a trend to be consistent across weeks, whereas we found a sharp contrast between week 1 and weeks 2 through 7. Second, it is unlikely that children were using the intervention media on other devices because the intervention videos were not publicly available, although the intervention games were. In addition, parents were told that the study-provided tablet should be the primary way the child accessed the treatment media during the study.

For both data-collection methods, it is possible that media usage may have been affected by the parents' knowledge that it was being tracked, or that they were in a study that was asking them to use media, rather than in a naturalistic environment.

Researchers planning future studies using parent-reported child media usage measures might consider ways to improve parent-reporting methods to reduce memory and recall effects. For example, experience sampling may provide more accurate data (Csikszentmihalyi & Larson, 2014). Studies using telemetry usage data might devise ways to track who is using the tablet, such as with a log-in screen, and to track whether the user is engaged, such as requiring a periodic screen tap during video play.

These findings suggest that parent report is not a reliable substitute for telemetry data when measuring time spent using a media-based intervention. Parent report may diverge from telemetry data, subject to the most salient social pressures and the observability of the child's media use. Our findings suggest that when parent reports and telemetry data differ, parents may tend to overreport their child's media usage. Despite its limitations, parent-reported media usage may be preferable to telemetry data when measuring other aspects of media use, particularly how media are being used, such as questions of joint media engagement or attention while watching videos. Using both parent report and telemetry data together may provide the most comprehensive description of children's media use.

## References


Anderson, D. R., Field, D. E., Collins, P. A., Lorch, E. P., & Nathan, J. G. (1985). Estimates of young children's time with television: A methodological comparison of parent reports with time-lapse video home observation. *Child Development*, 56(5),1345–1357.

Csikszentmihalyi, M., & Larson, R. (2014). Validity and reliability of the experience-sampling method. In *Flow and the foundations of positive psychology: The collected works of Mihaly Csikszentmihalyi* (pp. 35–54). Dordrecht, The Netherlands: Springer.

Gentile, D. A., Nathanson, A. I., Rasmussen, E. E., Reimer, R. A., & Walsh, D. A. (2012). Do you see what I see? Parent and child reports of parental monitoring of media. *Family Relations*, *61*(3), 470–487.

Grindal, T., Silander, M., Gerard, S., Maxon, T., Garcia, E., Hupert, N., Vahey, P., & Pasnik, S. (2019). *Early science and engineering: The impact of The Cat in the Hat Knows a Lot About That! on learning*. New York, NY, & Menlo Park, CA: Education Development Center& SRI International. Retrieved from https://files.eric.ed.gov/fulltext/ED603162.pdf

Rideout, V. (2017). *The Common Sense census: Media use by kids age zero to eight.* San Francisco, CA: Common Sense Media.

Roberts, J. D., Chung, G. K. W. K., & Parks, C. B. (2016). Supporting children's progress through the PBS KIDS learning analytics platform. *Journal of Children and Media*, *10*(2), 257–266. https://doi.org/10.1080/17482798.2016.1140489

Robinson, J. L., Winiewicz, D. D., Fuerch, J. H., Roemmich, J. N., & Epstein, L. H. (2006). Relationship between parental estimate and an objective measure of child television watching. *International Journal of Behavioral Nutrition and Physical Activity*, 3(1), 43.

Scharkow, M. (2016). The accuracy of self-reported Internet use—A validation study using client log data. *Communication Methods and Measures*, 10(1), 13–27.

Sewall, C., Rosen, D., & Bear, T. M. (2019, April 12). *Examining the accuracy of estimated smartphone use: How well-being and usage level predict discrepancies between estimated and actual use.* https://doi.org/10.31234/osf.io/3sju4

# 5. Mentorship Network Structure: How Relationships Emerge Online and What They Mean for Amateur Creators

RUBY DAVIS, JENNA FRENS, NIHARIKA SHARMA, MEENA DEVII MURALIKUMAR, CECILIA ARAGON, AND SARAH EVANS

**Abstract:** Relationships form the core of connected learning. In this study, we apply and extend social network analysis methods to uncover the layered network structure of relationships among Fanfiction.net authors and reviewers. Fanfiction.net, one of the world's largest fanfiction communities, is a space where millions of young people engage with written media, connect over shared interests, and receive support and mentoring from a distributed audience. Does an affinity space such as Fanfiction.net have the same structure as social networks Facebook and Twitter? We applied k-means clustering on millions of relationships to determine that Fanfiction.net has 2 to 3 layers, in contrast with the 4-layer structure of Facebook and 5-layer structure of Twitter. In addition, we conducted a large-scale machine classification of Fanfiction.net reviews to reveal the types of mentoring exchanged in each layer. Our findings show that the relationships where reviews are exchanged most frequently are most likely to contain substantive reviews. We discuss implications of these findings for the theory of distributed mentoring as well as the design of online affinity networks.

## Introduction

Relationships in online affinity spaces provide emotional support, connection to employment, and learning opportunities to a generation of digitally connected young people (Ito et al., 2019). One such space, Fanfiction.net, hosts more than 10 million stories written by authors primarily aged 13 to 26. Between 2001 and 2018, 53 million relationships emerged among Fanfiction.net users. Quantitatively examining the network structure of Fanfiction.net can provide a view into how relationships emerge and their role in informal learning.

In this study, we extended Dunbar's social network analysis method (Dunbar, Arnaboldi, Conti, & Passarella, 2015) to reveal the two- to three-layer social structure of distributed mentoring on Fanfiction.net. We classified reviews according to category within a distributed mentoring framework and characterized relationships according to the type of support most often exchanged. Our analysis centers on the following two research questions:

1. How many layers are in a Fanfiction.net user's ego network structure?
2. What kinds of reviews are exchanged in each layer?

Prior work has shown that social networks Facebook and Twitter mirror the layered network structure of the offline world (Dunbar et al., 2015). Our work generalizes this theory to an affinity network and reveals differences between socially driven and interest-driven spaces. We also extend the theory of distributed mentoring (Campbell et al., 2016) by quantitatively examining the function of different relationships within social layers. This knowledge can aid in the construction of more effective mentorship communities whose affordances encourage and enhance distributed mentoring structures.

## Background

### Fanfiction and Affinity Networks

*Fanfiction*, or written works produced by fans who use characters or settings from preexisting media, plays a critical role in a vast digital participatory culture (Jenkins, 1992) that builds relationships around sharing, creating, and consuming content. One such community that centers around a given piece of media is a *fandom*. Fanfiction provides a vital outlet for marginalized people to express themselves, allowing those who are traditionally excluded from mainstream media production to tell their own stories (Aragon & Davis, 2019; Black, 2008). Today's fanfiction is primarily published and distributed online within fanfiction communities and archives, such as Fanfiction.net and Archive of Our Own. These sites are particularly popular among young people and represent part of a greater movement of youth participation in online digital media.

Fanfiction communities also serve as *affinity spaces*, or places where individuals of all skill levels may come together over shared interests (such as a TV show or book) to learn from one another (Gee, 2004; Ito et al., 2019). Affinity spaces such as online fanfiction communities exist within the greater context of shared culture, creation, skill building, and connection with peers known as an *affinity network* (Ito et al., 2019). As interest-driven online networks, affinity networks are distinct from many other popular social networks such as Facebook or Twitter, where the social network structure is already known. Our research unveils the previously unknown network structure of an affinity network and extends our understanding of affinity networks by examining where in the network different types of relationship behaviors may occur.

### Distributed Mentoring

Understanding the structure of relationships in fanfiction communities can extend the theory of distributed mentoring and provide further insight into how it may be fostered. *Distributed mentoring* describes a network-based collaborative mentoring process in affinity spaces (such as Fanfiction.net) built upon computer-mediated interactions (Aragon & Davis, 2019; Campbell et al., 2016; Evans et al., 2017). In distributed mentoring relationships, the roles of mentor and mentee are fluid; an author may mentor others in areas such as grammar while receiving feedback on world building. The feedback exchanged in distributed mentoring relationships within fanfiction communities can take a variety of forms, including *targeted constructive*, or reviews that offer constructive criticism; *targeted positive*, or reviews positively reflecting on specific aspects of the story; and *update encouragement*, or reviews that encourage further writing (Evans et al., 2017).

The theory of distributed mentoring has characterized these mentoring relationships and categorized the kinds of conversations that occur within them; however, little is known about the structure of the relationships in distributed mentoring networks. In addition, connections have yet to be drawn between the content of an exchange between individuals and where in an individual's network the exchange occurs. As relationships are the backbone of distributed mentoring, the context and history of a given distributed mentoring relationship may completely transform the meaning and impact of distributed mentoring artifacts, such as comments or reviews. Reviews from ongoing relationships, for example, may be received and interpreted very differently from a single one-off review. A model of distributed mentoring that incorporates this context will better account for the influence of informal learning in online spaces. To build this model, we need to quantify relationships and qualify the exchanges that occur within them.

## Dunbar's Circles

The number of relationships a person can maintain is finite. These relationships may be categorized into several distinct layers of closeness termed *Dunbar's circles* (Dunbar et al., 2015). The smallest circle consists of about five people (or alters) with whom the individual (or ego) has a very close relationship. Every subsequent circle increases in size and decreases in closeness until the cognitive limit is reached. The theory of Dunbar's circles holds for online relationships; on Twitter and Facebook, the structure of one's virtual relationships is similar to that observed in face-to-face relationships (Dunbar et al., 2015).

Our research explores whether such a hierarchy exists in distributed mentoring networks. We conduct Dunbar's analysis over a network of fanfiction authors and reviewers to uncover the number of mentees and frequency of mentoring in each distinct circle. We then we extend this method further by characterizing each layer.

# Method

We determine the number of layers in the social networks of Fanfiction.net's active authors and reviewers. Then we quantify each layer's review types as classified by a machine learning algorithm.

## The Fanfiction.net Data Set

We collected a data set from Fanfiction.net that contains the stories, author profiles, reviews, and associated metadata of activity on the site from January 2001 to January 2017. This massive data set contains approximately 28 million chapters of fanfiction and 177 million reviews written by an international group of 10 million young people. Previous literature further describes the collection and demographics of this data set (Bathija & Tekriwal, 2019; Frens, Davis, Lee, Zhang, & Aragon, 2018; Yin, Aragon, Evans, & Davis, 2017). Each review in the data set is associated with a time stamp from when it was posted to Fanfiction.net and IDs of the reviewer and author in the exchange. Using this data, we built a social graph of relationships on Fanfiction.net.

For the purpose of our analysis, we defined relationships as reviewer-author pairs with at least two reviews exchanged over a duration of at least one month. We define the contact frequency of a relationship as the number of times that social contact occurred over the duration of the relationship. To compute contact frequency, we divided the number of reviews by the amount of time, in months, between the first and last review. If the reviewer has written stories of his or her own, and the author reviews them, we represent this kind of relationship with bidirectional edges from reviewer to author and vice versa. In this graph, each user, or ego, is a node. Every reviewer-author pair is a directional edge, weighted by interaction frequency in reviews per month. Anonymous reviews were excluded from this analysis. The resulting graph contains 53,202,307 relationships between 2,580,411 reviewers and 1,373,910 authors.

## Dunbar's Approach

We used Dunbar et al.'s k-means clustering approach to determine the optimal number of layers in a social network (Dunbar et al., 2015). As in Dunbar's study, we analyzed the subset of users who are active in the community, either giving or receiving an average of 10 reviews per month or more. In addition to this restriction, we included only users with at least 25 connections. As our data set contains two different kinds of participants, reviewers and authors, we performed two versions of the analysis: one with reviewers as egos and one with authors as egos. Each involves a different data set of reviewers and authors based on the directional application of the inclusion criteria.

After we applied the inclusion criteria, the reviewer-as-ego data set contained 62,869 reviewers (egos) and 458,286 authors (alters), or 2.4% of the reviewer population in the Fanfiction.net data set. These reviewers reviewed 59.4 authors on average with a standard deviation of 65.6. The average interaction frequency of a relationship (edge) in this data set was 1.86 reviews per month (SD = 2.48), and there were 3,733,123 relationships in total. The reviewer-as-ego data set contained 31.4% of all reviews on Fanfiction.net.

The author-as-ego data set contained 66,798 authors (egos) and 747,502 reviewers (alters), or 4.86% of the author population in the Fanfiction.net data set. The authors in the data set received reviews from 70.87 reviewers on average with a standard deviation of 96.43. The average interaction frequency of a relationship (edge) was 1.85 reviews per month (SD = 2.52), and there were a total of 4,734,203 relationships. The author-as-ego data set contained 73.03% of all reviews exchanged on Fanfiction.net.

We extracted ego networks from the data set by aggregating edges per ego. We performed k-means clustering on each ego, varying k from 1 to 20. The k-means algorithm partitions an ego's edges, based on their weight, into k separate clusters with minimum sum of squared Euclidean distance between edges and cluster centers (MacQueen, 1967). As in Dunbar's analysis, we computed x, the optimal k for each ego in the data set. We then chose the overall optimal number of clusters k* using the elbow method, taking the value of k that most efficiently accounts for variance in Euclidean distance (Kodinariya & Makwana, 2013). We computed p(x), the proportion of ego networks where k* = x, that is, they are optimally clustered with x clusters. Figure 1 shows the probability distribution of p(x) for reviewer-as-ego and author-as-ego data sets. We calculated s(x), the silhouette score, to determine how closely the data are matched to data within their cluster (Rousseeuw, 1987). Values of s(x) close to 1 show that the data are optimally clustered.

## Categorizing Reviews Exchanged in Each Network Layer

We categorized the reviews in the Fanfiction.net data set by using a qualitatively coded subset of reviews as ground truth for a machine classifier. The grounded theory approach and qualitative coding process are described in prior work (Evans et al., 2017). A group of researchers coded 3,566 reviews by category within the distributed mentoring framework and combined this with the original qualitatively coded data set (Evans et al., 2017) for a total of 8,066 reviews. For the present analysis, we focused on three nonexclusive review categories: update encouragement, targeted positive reviews, and targeted constructive. We combined the latter two categories into a single "targeted" category to differentiate substantive reviews from update encouragement.

We then trained a machine classifier on the human-coded data set to classify all reviews in the Fanfiction.net data set. We improved and validated this method of qualitative to quantitative classification as described in detail by Scott et al. (2012), and the tools used in this process are outlined in detail by Michael Brooks (2015). Using the tool ALOE, we classified the reviews in the Fanfiction.net data set with 87% accuracy for update encouragement and 75% accuracy for targeted reviews. The review classification is further described in our blog (Bathija & Tekriwal, 2019). We then used this classification to examine the proportion of each type of review exchanged in each network layer.

## Findings

### The Two- to Three-Layer Network Structure of Fanfiction Reviewing

In the reviewer-as-ego data set, we determined the optimal number of clusters to be k* = 2, 3 using the elbow method, indicating that active Fanfiction.net reviewers have a two- to three-layer network. During the k-means analysis described above, we found the mean optimal number of clusters to be x = 2.39. Visualizing p(x) in Figure 1, we see a clear drop-off from 2 to 3 and from 3 to 4, and subsequent flattening of the graph. The mean silhouette score of ego networks clustered was s(x) = 0.6952, indicating that this is an appropriate and optimal clustering of the data set and the identified clusters are factual. In the author-as-ego data set we also confirmed that active Fanfiction.net authors have a two- to three-layer network. The mean optimal number of clusters was x = 2.36. Visualizing p(x) in Figure 1, we found a similar distribution to the reviewer-as-ego data set and determined k* = {2, 3}, with s(x) = 0.6857.

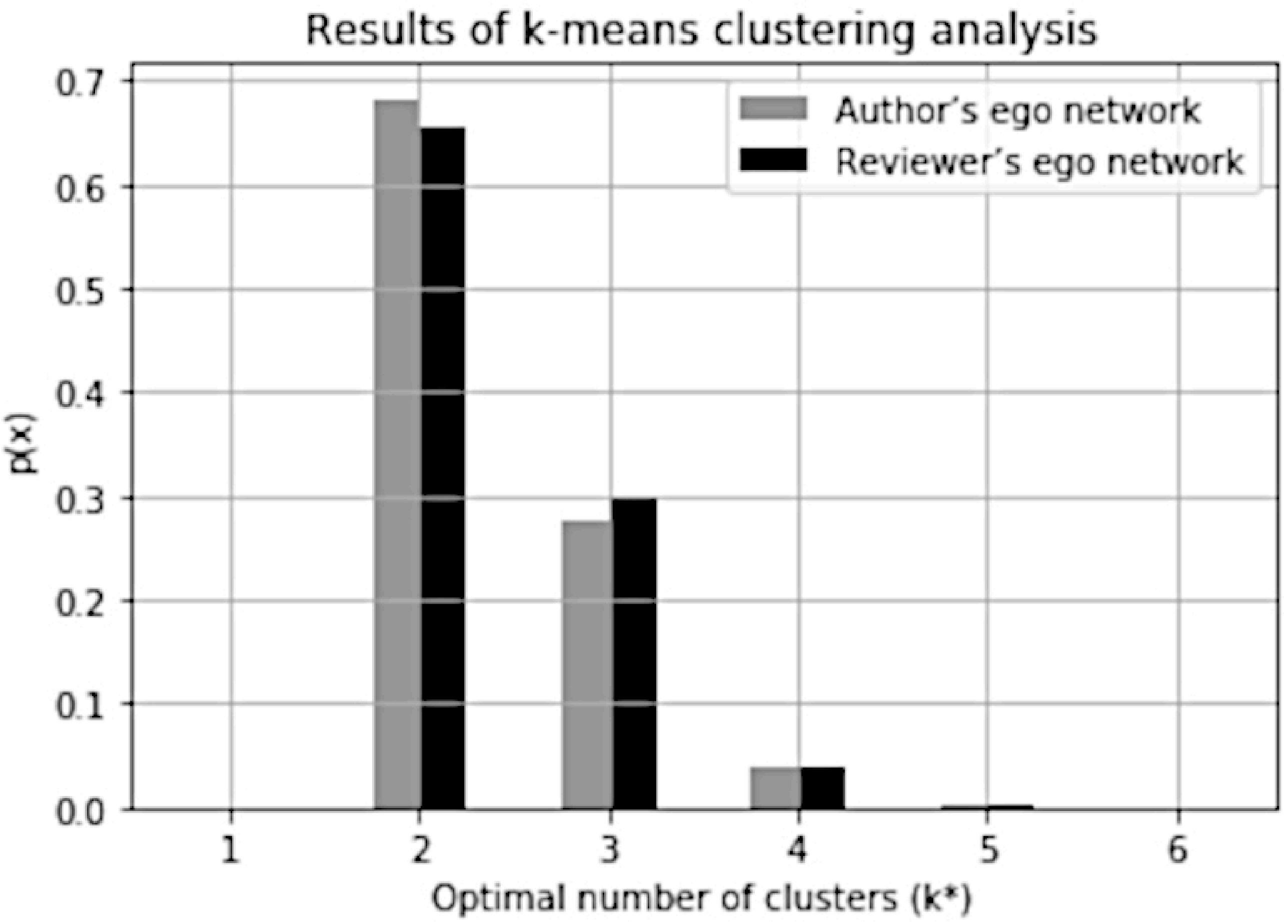


*Figure 1. The probability that an ego network is optimally clustered for (a) author's ego network, (b) reviewer's ego network, p(x), for x = k with k ranging from 1 to 6 network layers (we experimented with k ranging from 1 to 20 network layers, but layers after 6 have very low p(x) values).*

Figure 1 demonstrates a marked peak at k = 2 and k = 3 for both reviewer's ego and author's ego network data set, with an average optimal number of cluster size ranging between 2.36 to 2.38 for both data sets. To study the size and mean contact frequency of the ego network layer we used k = {2, 3}, which encapsulates both the median and mean of each data set. We summarize the size and mean monthly contact frequency of each layer in Table 1 and interpret these results in the next two sections.

| | Layer | 0 | 1 | 2 |
|---|---|---|---|---|
| Reviewer as ego (k=2) | Number of Alters | 9.08 ± 9.10 | 50.30 ± 59.34 | - |
| | Contact Frequency | 7.01 ± 7.50 | 1.26 ± 0.65 | - |
| Reviewer as ego (k=3) | Number of Alters | 3.89 ± 3.52 | 14.76 ± 13.98 | 40.73 ± 51.82 |
| | Contact Frequency | 8.66 ± 8.04 | 3.25 ± 2.92 | 0.97 ± 0.58 |
| Author as ego (k=2) | Number of Alters | 11.48 ± 12.39 | 59.40 ± 89.79 | - |
| | Contact Frequency | 6.77 ± 8.36 | 1.26 ± 0.72 | - |
| Author as ego (k=3) | Number of Alters | 4.72 ± 4.57 | 17.997 ± 19.45 | 48.16 ± 78.86 |
| | Contact Frequency | 8.38 ± 8.82 | 3.11 ± 3.32 | 1.02 ± 0.70 |

*Table 1. Mean (±SD) number of alters and contact frequency in each layer identified by k-means analysis.*

In the reviewer-as-ego data set, a reviewer's ego network is likely to have two or three layers. The innermost layer, layer 0, has a mean of 9.08 alters (for two-layer networks) or 3.89 alters (for three-layer networks). Reviewers review the authors in this layer around seven to eight times a month on average. This indicates that reviewers maintain a close reviewing relationship with a small group of authors, with individual variation causing contact to range from every day to a few times per month. The outermost layer has a mean of 50.30 alters (for two-layer networks) or 40.73 alters (for three-layer networks) and a mean frequency of about one review per month. This indicates that reviewers infrequently review a large group of authors that ranges widely in size. Three-layer networks also have a middle layer, which has a mean of 14.76 alters with a mean contact frequency of 3.25 reviews per month.

The author-as-ego data set revealed that authors are also likely to have ego networks with two or three layers. The author ego's closest circle, layer 0, has a mean of 11.48 alters (for two-layer networks) or 4.72 alters (for three-layer networks). Authors receive about seven or eight reviews per month from reviewers in this layer. This indicates that authors experience close but not necessarily daily contact from a small group of reviewers, with individual variation causing contact to range from daily to almost weekly. The outermost layer has a mean of 59.40 alters (for two-layer networks) or 48.16 alters (for three-layer networks). Authors get reviews about once a month from reviewers in this layer. This indicates authors are likely to receive infrequent contact from a large following that ranges widely in size. Three-layer networks also have a middle layer with a mean of 17.997 alters and a mean contact frequency of 3.11 reviews per month. We visualize an example author ego network in Figure 2.

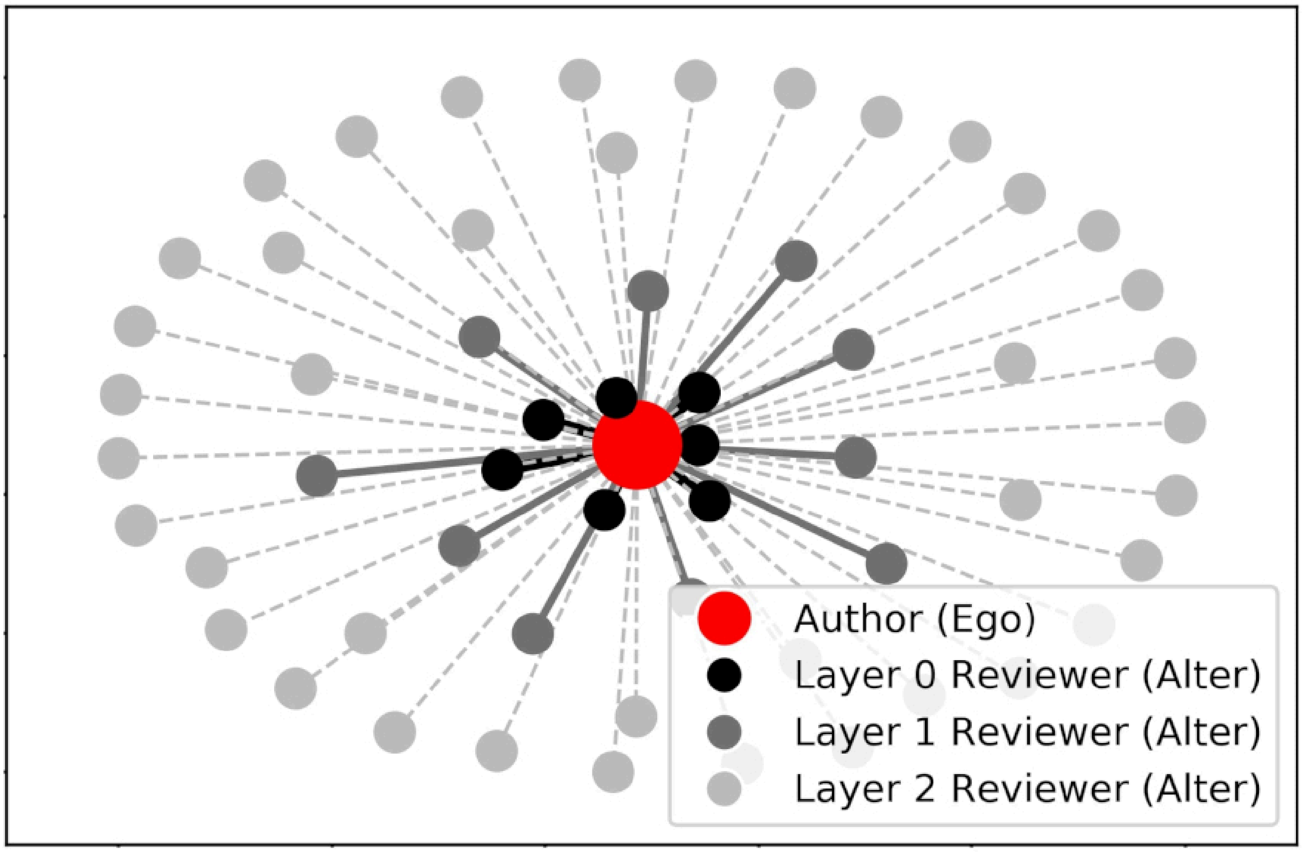


*Figure 2. Visualization of an author's relationships, colored by layer and weighted by contact frequency.*

Figure 2 depicts a Fanfiction.net author's ego network. For the particular author in Figure 2 (red node), we can see the connected reviewers (gray and black nodes) and the corresponding layers they fit in. The black nodes signify the closest layer, the dark gray nodes signify the middle layer, and the light gray nodes signify the final layer. This graph is weighted according to the frequency of contact for a given author-reviewer pair.

## Types of Reviews Exchanged by Layer

We computed a count of update encouragement and targeted reviews in each layer of the reviewer-as-ego data set. Update encouragement reviews contain statements to the author that he or she should continue publishing work. Targeted reviews contain substantive commentary about the writing. These categories are not exclusive. The counts for each layer are shown in Table 2.

| | Layer | 0 | 1 | 2 |
|---|---|---|---|---|
| Count (Percentage) of Reviews | Update Encouragement | 440,626 (17.6%) | 3,179,649 (24.3%) | 7,927,321 (27.9%) |
| | Targeted | 1,283,701 (55.3%) | 6,948,617 (53.1%) | 14,161,050 (49.8%) |

*Table 2. Count of each review type in each of the layers of a reviewer's network structure.*

As shown in Table 2, the proportion of update encouragement increases from layer 0 to layer 2, while the proportion of targeted reviews decreases. This indicates that reviewers spend more effort on substantive reviews in relationships with frequent contact. We discuss the implications of these findings below.

## Discussion

Our analysis revealed that active authors and reviewers tended to maintain a small number of close relationships (4 to 12) with both high frequency of contact (seven to nine times a month) and higher likelihood of exchanging effortful and substantive reviews (55.7%). Authors and reviewers also had a larger number of relationships (40 to 60) that were infrequent (one to three times a month) and more likely to contain less effortful reviews such as update encouragement (27.9%). These findings suggest that fanfiction participants tend to saturate their mentoring networks up to similar cognitive limits theorized by Dunbar et al. for more generalized social networks (Dunbar et al., 2015). We contextualize these findings within prior literature and discuss implications for the design of online affinity spaces.

### Comparison With Facebook and Twitter

Although the social network structures are similar, there are fewer layers in the ego networks of active Fanfiction.net users in comparison with Facebook and Twitter users (two and three versus four and five respectively [Dunbar et al., 2015]). The closest layer seen on Twitter, with alters contacting approximately at least once every one to two days, did not exist on Fanfiction.net. This may be explained by the affordances of reviewing fanfiction: Reviewer-author relationships are reliant on an author's story update schedule, and readers are unlikely to leave reviews without the catalyst of a new chapter's being published. Twitter users may simply be able to create content more frequently because tweets are typically shorter than fanfiction chapters, resulting in more frequent exchanges. Additionally, Fanfiction.net lacked the middle layer seen on Facebook and Twitter, showcasing the two types of reviewers on the platform: frequent or infrequent. The outermost layer of the Fanfiction.net data set and the Facebook and Twitter data set demonstrated similar behavior with some active reviewers typically maintaining low-contact relationships (the frequency of the outermost layer on Fanfiction.net was 1.26/month; on Facebook it was 1.37 and on Twitter 2.54).

### Comparison With Previous Findings

These results suggest a difference between interest-driven and socially driven online communities, or "hanging out" versus "geeking out" (Ito et al., 2019). Fans behave in a "nomadic" fashion, hopping from source material to source material as their interests change (Jenkins, 1992). Throughout the course of a reviewer-author relationship, a reviewer may lose interest in the story, unsubscribe from the author, or migrate to a new fandom. We also found high individual variation; the ranges in number of alters per layer were larger than Facebook and Twitter. This indicates a diversity of behavior among active reviewers on Fanfiction.net. Some of this variation may be a result of differences between fandoms—particularly small and large fandoms. Interest and participation in a smaller fandom may lead to fewer and closer connections than in a large fandom (Aragon & Davis, 2019).

The theory of distributed mentoring (Campbell et al., 2016) provides a framework for understanding the value and contribution of different feedback relationships. A large outer circle of reviewers helps to provide an abundance of feedback in the form of shallow positive reviews and update encouragement, which in turn are linked to continued participation (Bathija & Tekriwal, 2019) and language development (Frens et al., 2018). The inner circle provides specific, directive feedback, which authors value highly and reciprocate, leading to stronger relationships, shared context, and better feedback in a virtuous cycle. The closer the relationship, the more effort is invested in feedback exchange, oftentimes going beyond the reviewing platform to beta reading, in-progress feedback, and ideation feedback (Aragon & Davis, 2019).

### Design Implications

Our findings imply that fanfiction websites and other online affinity spaces could be designed to optimize distributed mentoring by considering Dunbar's theory in the implementation of affordances for connection, feedback, exposure, and recommendation. For instance, Fanfiction.net and Archive of Our Own both default to sorting works by their publication date—the most recently updated fanfiction works are most likely to be seen. The result is that authors who publish frequently are most likely to receive exposure. However, based on our findings, these authors are less likely to need additional exposure in comparison with new authors who are posting for the first time in that fandom. There is potential for designing a different default that grants new authors more exposure until their networks are close to saturation. Likewise, for users with saturated networks, designs could focus on deepening their current relationships over exposure to more connections. Furthermore, we find that readers who frequently review an author are more likely to give substantive feedback. Platforms could further encourage this behavior by reminding frequent readers to do so, while prompting less frequent readers to give low-effort reviews such as update encouragement.

### Future Research

Our research focused only on substantive reviews and update encouragement, but further research could examine the occurrence of additional review types in a reviewer-author network. Examining how the bidirectionality of communication may differ between layers could also bolster our understanding of what each layer represents. Furthermore, the reviews that are exchanged on Fanfiction.net represent a small portion of the many interactions that occur in fandoms across the net. Examining how fans engage with one another across many different platforms could provide a more holistic view of this affinity network and its structure. This research could also be extended to explore networks beyond fan communities by comparing Fanfiction.net's structure to that of other networks, such as in-person mentorship networks.

## Conclusion

Our large-scale analysis revealed the relationship structures within a distributed mentoring network. We characterized different layers of reviewer and author relationships and showcased the number, size, and distribution of relationship layers on Fanfiction.net. The findings show that targeted feedback is most likely to occur in the innermost layers, while less targeted feedback occurs more frequently in the outermost layers. To facilitate an ideal environment for distributed mentoring, sites must encourage the development of close relationships, where targeted feedback is exchanged, without oversaturating an individual's network beyond the limited number of relationships he or she can maintain. Future research can explore this design space to ensure the optimal balance of exposure and connection that allows individuals to build networks that facilitate mentoring. Designs that actively foster distributed mentoring networks can help millions of young people build their writing skills and share their voices.

## References

Aragon, C., & Davis, K. (2019). *Writers in the secret garden: Fanfiction, youth, and new forms of mentoring*. Cambridge, MA: The MIT Press.

Bathija, M., & Tekriwal, K. (2019). *Do substantive reviews improve authors' writing?* Retrieved from https://fanfictiondatascience.tumblr.com/post/185799483415/do-substantive-reviews-improve-authors-writing

Black, R. W. (2008). *Adolescents and online fan fiction*. New York, NY: Peter Lang.

Brooks, M. (2015). *Human centered tools for analyzing online social data* (Doctoral dissertation). University of Washington, Seattle, WA.

Campbell, J., Aragon, C., Davis, K., Evans, S., Evans, A., & Randall, D. (2016). Thousands of positive reviews: Distributed mentoring in online fan communities. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing* (pp. 691–704). New York, NY: ACM.

Dunbar, R. I., Arnaboldi, V., Conti, M., & Passarella, A. (2015). The structure of online social networks mirrors those in the offline world. *Social Networks*, 43, 39–47.

Evans, S., Davis, K., Evans, A., Campbell, J. A., Randall, D. P., Yin, K., & Aragon, C. (2017). More than peer production: Fanfiction communities as sites of distributed mentoring. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (pp. 259–272). New York, NY: ACM.

Frens, J., Davis, R., Lee, J., Zhang, D., & Aragon, C. (2018). Reviews matter: How distributed mentoring predicts lexical diversity on FanFiction.net. Retrieved from https://arxiv.org/abs/1809.10268

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling*. New York, NY: Routledge.

Ito, M., Martin, C., Pfister, R. C., Rafalow, M. H., Tekinbaş, K. S., & Wortman, A. (2019). *Affinity online: How connection and shared interest fuel learning.* New York: New York University Press.

Jenkins, H. (1992). *Textual poachers: Television fans and participatory culture*. New York, NY: Routledge.

Kodinariya, T. M., & Makwana, P. R. (2013). Review on determining number of cluster in k-means clustering. *International Journal*, 1(6), 90–95.

MacQueen, J. (1967). Some methods for classification and analysis of multivariate observations. In *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* (Vol. 1; pp. 281–297). Berkeley: University of California Press.

Rousseeuw, P. J. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, 53–65.

Scott, T. J., Kuksenok, K., Perry, D., Brooks, M., Anicello, O., & Aragon, C. (2012). Adapting grounded theory to construct a taxonomy of affect in collaborative online chat. In *Proceedings of the 30th ACM International Conference on Design of Communication* (pp. 197–204). New York, NY: ACM.

Yin, K., Aragon, C., Evans, S., & Davis, K. (2017). Where no one has gone before: A meta-dataset of the world's largest fanfiction repository. In *Proceedings of the ACM Conference on Human Factors in Computing Systems* (CHI '17; pp. 6106–6110). New York, NY: ACM.

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# 6. Developing Civic Empowerment for Black Youth Through Student-Driven Hip-Hop Music Production in the Classroom

**JABARI M. EVANS**

**Abstract:** In this study, I draw on ethnographic data (interviews and focus groups) to explore an in-school Hip-Hop Music Education pilot program within an urban school district to explore the link between civic development and hip-hop artistic practice. Results of this study indicate that the program participants thought the program provided them with culturally responsive pedagogy that also acted as an agent in developing civic imagination within the emerging media makers. Three primary themes that emerged within the data were: (a) supporting student enthusiasm for hip-hop, (b) promoting hip-hop song making as an agent for social change, and (c) legitimizing the hip-hop ethos as useful to a meaningful career pathway. These findings suggest that participants engaged in connected learning through hip-hop in ways that indicate an ability to leverage their music-oriented identity projects for their civic engagement into adulthood. These findings also suggest that adolescence is an important time frame in which children are developing hip-hop social identities, but in ways that are tied to realistic planning and skill development. To conclude, I suggest that urban schools should use Hip-Hop Music Education as a resource for helping students of color to connect lived experiences to their academic lives and future career aspirations.

## Introduction and Background

As increasing numbers of young people seek to master the use of media tools to express themselves, explore their identities, and connect with peers, urban school districts have sought to partner with community youth programs to encourage young media makers to exercise active citizenship through projects that allow youth to talk about issues that affect them personally (Clark & Marchi, 2017). Prior studies have suggested that these programs can bolster young people's enthusiasm for using digital media in the service of civic engagement (Barron, Gomez, Pinkard, & Martin, 2014; Larson et al., 2013). In doing so, this research has often depicted ways in which program mentors and facilitators help their students think about how they use different forms of media to communicate their public voices to audiences outside their community and to ensure their personal, professional, and academic achievement potential. (e.g., Rheingold, 2008). Though research on youth media programs has seen a surge in recent years, this research is only beginning to identify and define the distinct processes with which efforts within youth media programs can support an expanded and more contemporary view of the learning goals necessary for successful citizenship in the 21st century. Among these new goals are learning and innovation skills; information, media, and technology skills; life and career skills; and civic content around core subjects (Barron et al., 2014; Ito et al., 2013; Watkins & Cho, 2018).

Further complicating issues of learning equity is that racial and ethnic groups differentially access and experience schools, which can greatly affect their performance and life trajectories (Rowan, 1995). Questions regarding why learning equity gaps between racial and ethnic groups exist, particularly among African Americans, have largely dominated conversations about race in media literacy education (Rideout, Scott, & Clark, 2016; Watkins & Cho, 2018). In lessening this disparity, researchers have theorized that hip-hop music is a vital signal carrier for promoting innovative learning among young people of color (Evans, 2019; Peterson, 2013; Seidel, 2011; Watkins, 2019). Hip-hop artistic practices have been identified by researchers as an innovative way to teach technological skills and promote individual creativity

(Seidel, 2011). This rationale follows that hip-hop–based music education (HHBE) could not only involve learning to make hip-hop music itself, but also to the ways that young people learn to communicate with one another, express themselves, and establish their identities as well as generate knowledge through hip-hop culture (Peterson, 2013). Despite interest expressed in these earlier studies, there is a dearth of research about how HHBE programs can impact civic development.

This report is focused on civic empowerment as a barrier and a lever for expanding career opportunity, and thus narrows in on evaluating an HHBE program on its elements that influence civic development. Thus, the aim of this study is to explore how adversities for civic development among Black youth are confronted within HHBE experiences. Using Chicago's Foundations of Music Rap Songwriting and Production (SWP) program as a case study, the purpose of this paper is to examine an HHBE program as an exemplar to explore the ways in which enthusiasm for hip-hop can be used as an asset to shape civic development in African American youth (particularly those with skills related to digital media literacy and interest in professional media production). Additionally, the purpose of this study is to explore how those emerging identities might influence their attitudes and actionable efforts toward tangible academic and professional success.

Ultimately, in this paper I argue that the development of one's hip-hop "voice" (a unique style of personal expression that distinguishes one's communications from those of others) is called upon in the SWP program to help connect participants' energetic involvement in hip-hop's community of practice with cultivating civic empowerment that can carry them as adult citizens. I develop this argument in six parts. First, I analyze the existing literature discussing hip-hop's place in connected learning and formal music education. Next, I will use the connected learning framework (Ito et al., 2013) to talk about the importance of civic engagement to the academic achievement of low-income youth of color as well as pathways to 21st-century media careers. In the third part of the article, I will describe the SWP program, the context of Chicago, the profile of the participants, and my observation sites. In the fourth part of the article, I describe the corpus of my data, my methods, procedures, and process for data analysis. After that, I will discuss important themes that I have identified as outcomes of the SWP program. Sixth, in conclusion, I discuss the implications of these arguments for practice, public education, and social policy.

## Data, Methodology, and Analysis

Data for this study were gathered using three methods—focus groups (with students and teaching artists), in-depth interviews (with 11 students—7 males and 4 females), and participant observation conducted in the spring of 2019. The research was carried out using the case study method (Stake, 2005; Yin, 2009), which takes up a particular case to understand phenomena. In this case, the SWP program is used to explore the phenomena of urban young people's general experiences of HHBE in their self-efficacy and occupational identity.

I was the only researcher conducting fieldwork at the elementary schools. As I conducted fieldwork at the SWP program, I was also communicating with a number of school staff members in an attempt to gain better access to the school environment for a holistic view of the sites' context. There was no incentive for interviewed or observed participants. Study procedures were approved by the Institutional Review Board at the sponsoring institution. Finally, pseudonyms were assigned to all students and teachers observed unless otherwise noted. Additionally, pseudonyms were given to the names of the schools so as not to give identifying information regarding the participants.

## The SWP Classroom Studio, Defined

The SWP program was designed to produce connected learning through academic engagement with digital media production, sociopolitical awareness, and civic imagination through rap songwriting. The courses I attended met for 60 minutes two times a week for 10 consecutive weeks with a teaching artist named KP. While observing the way in which KP structured his 60-minute classes, I noticed that he would generally use the first half of the class (25 minutes; see Evans [2019] for an overview of the program lesson themes) to lead students through a five-minute lecture and 20 minutes of discussion in response to the lecture, and he would use the second half of the class (25 minutes) to provide students a structured free time to work on their individual projects. For the final 10 minutes of the class, students were given the opportunity to share and/or critique their work as well as that of their peers.

The participants in the SWP program completed ongoing assignments that were framed as essential milestones to prepare them for their final projects, a finished song (written, produced, recorded, and mixed) about their everyday lives. For the first three weeks, the students learned how to create beats using GarageBand, Logic, and ProTools. During the following three weeks, the students began to learn about song structure and strategies for lyric writing, and during the final four weeks, the students in the program learned to record themselves on the microphone and worked to complete their songs independently while KP supervised their progress to completion.

It was an exploration of hip-hop composition, in which digital tools aided the processes of producing and recording of student songs. With the understanding that in previous research, hip-hop has been deemed questionable as a central element of music education, the program directors and advisory board of the SWP program sought to approach HHBE as a way to develop media literacy and critical consciousness to address the long-existing learning-equity gap for Black youth in America. In recognizing hip-hop as the most important cultural product in the last 50 years (Mauch, MacCallum, Levy, & Leroi, 2015), the parties involved in designing the SWP program sought to use HHBE to produce interest-driven learning in the urban classroom.

## Findings

While beyond the school walls many youths in this study were regularly involved in some conversations related to hip-hop culture, a majority of participants reported that school, the space where intellectual maturation should be performed, often failed to capitalize on a vital cultural practice that is central to hip-hop culture—dialogue. During our one-on-one interview, KP explained that the most effective results in the SWP program happened when he followed up student-led discoveries with discussions and activities that promoted true reflection about those discussions. He elaborated:

> Our classroom conversations are brutally honest and there's a freedom between the students and me in choosing how to craft every detail of every song. I purposefully empower the students that normally aren't considered leaders to lead classroom discussions and I also allowed them to speak to me in the way they would outside of a school building. Hip-hop has always been about keeping it real and being authentic but many of these kids don't even have an experience with using hip-hop to be critical about social issues. They only know a more gang violence–centered, club-hopping, and drug-taking type of rap. Still, I didn't tell them their music was negative. I simply asked them questions about why they liked that music and often challenged them to think deeper about what they produce and/or consume. This often sparked really great conversation. You saw how much they shifted their song ideas, right?

KP went on to explain to me that though the majority of the students in the SWP program were considered "bad," "at-risk," and/or "remedial," the critical concepts that they discussed during their class sessions indicated an aptitude for learning that was more than adequate when engaged with themes respectful of their lived experience:

> Amaya, who you met during one of our early sessions at the school, was probably considered by the principal to be the biggest troublemaker at the school. No one wanted her to be in their classes because she was disruptive, oppositional, and defiant. With all that said, she probably was my best student since I have been teaching in this program. She made about five songs about growing up in Austin, made plenty of beats for her peers, and consistently contributed to class discussions about race, social justice, and misogyny in rap. I gave her the first A she ever received in her life and it was in a hip-hop class! But still, she deserved it!

Before a performance at Foundations of Music's End of the Year Celebration, Wade shared his feelings about why he felt so strongly about the benefits of the SWP and how it increased his school participation:

> I would never be at a school banquet like this [normally]. I really wouldn't be caught dead doing anything school related, really. This program was really the only reason I was coming to school this year. We were working on our mixtape and now we're doing performances in front of crowds like this. It's crazy when I think about it but now I see everything differently. I feel respected by people at school. I see why I was tweaking before. I wasn't really giving school a chance. Now, I'm like cool with [Principal] Freeney and all my teachers. I don't know if they believed in me. Shit, I ain't really believe in myself at that point! [laughs]

Though their academic records often reflected poor performance, the SWP program showcased a determination to learn and great critical thinking when lesson themes piqued their interest. In particular, SWP students engaged regularly in self-regulated learning. During the second half of the class curriculum, SWP students routinely used the full class period to plan their workday with the equipment, perform a task, monitor performance, and ultimately, reflect on the experience with their peers in a community of practice. This is something that many students said made them feel empowered. During our one-on-one meeting after his focus group, Randy commented how he appreciated that independence in the classroom:

> It was like it was our classroom. I ain't never had nobody that really cared about what I think, or how I was doing. … In this class, we always talk about shit that's going on in our life or in the world or whatever. … I feel like I learned as much about life as I did about music and the fact that we got to perform for the whole school made me feel good. I can't really explain it but it really made me look forward to coming to school to make my own music.

Though many people in their home lives have described hip-hop as a negative type of music to stay away from, the students talked about how the SWP program helped them to see how participation in hip-hop culture can also serve as a healthy exercise that is beneficial to learning and development. To that end, Raquel commented:

> Kendrick Lamar won a Pulitzer. I read about how some kid at Harvard did a rap mixtape to graduate. You [the researcher] mentioned to us about how someone did their dissertation as a rap performance. I think this class is like … inspiring us to like … to do great things. It's like we could use music to do big things or like it doesn't have to be afterschool. We can make stuff that we like outside of school and people in school should care about it.

Beyond getting the chance to learn about how to make music, many participants spoke of the SWP program as being an opportunity to publicly communicate and make meaning of their personal stories. For many musicians, storytelling in music often "sustains and directs how individuals understand their past self and how they transcend that self-moving forward" (Baym, 2018, p. 39). To that end, in many instances songs served as public memorials for peers who were victims of gun violence, pleas for peers to receive restorative justice while incarcerated or on trial, and they also critiqued the practices of law enforcement toward Black men in Chicago. On this subject, Wade stated:

> Bro, it was fun to play my music for my mom because she liked it and I worked hard on it but it just made me think about all the stuff I should do, bro. Like if I listen to my mom and dad I could be graduating, playing basketball, and headed to a community college or something.

Wade's comments are evidence that when group identities are collectively believed in, groups tend to behave collectively (e.g., Scheitle, Corcoran, & Halligan, 2018). In other words, group identity can often lead to group cohesion and the creation of a more liberating space. Many students in the SWP program spoke about feeling as though they could now excel in their schoolwork because they thought their interests were being taken seriously by some of the adults they interacted with regularly. In speaking on how the SWP experience might particularly carry on with him to adulthood, Wade explained:

> In this class, I learned that my voice can be heard as is and be meaningful. For the most part, I be quiet in classes because I'm scared that the teacher is going to correct me or someone will think I sound stupid. In here, I learned that asking questions actually makes you smarter. Like in the music business, you can't shut down a person because they don't speak all proper. All my ideas ended up being used in the songs that we made. I know now I have good ideas that could be big and I don't need to be quiet so much anymore. I want to be like a film director or something. KP said it would be good for someone like me.

The SWP participants discussed how, by providing opportunities to youth who come from communities where opportunities for access to legitimate success are few and far between, the program promoted their hip-hop identity and allowed them to have a safe space to celebrate their Blackness and express their innermost uncensored feelings about society and their place within it. At the onset, the main goal of the program was to get students comfortable with the technology and creative strategy used to make professional-level music. Unintentionally, a main outcome of the program was that many students were taught how to develop a public voice and articulate their thoughts on social and personal issues in a constructive manner. For participants of the SWP program, the experience of analyzing and critiquing media created by one's own peers, considering why these critiques matter, for whom they matter, and what difference such critiques make for the community, was specific to the songwriting and production process. In this sense, the program opened the possibility for students to see their work in the media as a form of media activism, in that it raised awareness of the problems inherent to the structure of the media industries. Reflecting on these issues helped students think beyond their individual experiences to consider the need to work toward structural changes in society, and it may have assisted in developing a civic imagination that students could take with them into their work within media industries.

## Summary of Findings

Hip-hop is a rich and complex art form that is a major facet of Black adolescence and young adulthood. A primary goal of this paper has been to examine how this digital media ecology can possibly impact the academic achievement gap and learning outcomes of Black students. Synthesizing the evidence about how interventions can influence occupational identity is challenging because few programs explicitly measure these types of outcomes, focusing instead on academic outcomes. Rather than arguing over the influence of representations on young people's self-concept and occupational identity, this study is tracking the impact of a specific intervention, something that has rarely been done in social science research. Using an interdisciplinary case study research approach that weds communications research and learning research, I have sought to show that the SWP program's exposure to popular media-making practices can have significant and lasting impacts on the occupational identity and public voice of its participants.

In their class sessions, SWP participants talk with one another about what is going on in their respective territories and view these events from the perspective of the community members they regularly interact with. In doing so, they view their stories as an urgent need to respond to events as advocates for the communities of Chicago. Throughout their hip-hop artistic practice, the SWP songwriting process emphasized students' coming together to create narratives about who they saw themselves as within their neighborhood and hip-hop's larger community. In trusting KP, students described the music-making process in the SWP as being legitimate, not just a disingenuous attempt to engage their occupational interests in curricular design. The youth continually reflected on how much they appreciated having this opportunity, even though they were skeptical it would happen regularly, if ever again.

Previous research has shown that the "achievement gap conversation" generally reinforces ideologies that Black youth are intellectually inferior, and that narrative often undermines how Black youth are viewed by others and themselves. However, SWP participants often spoke of learning how to use hip-hop as a theory of knowledge or a philosophy of learning that was much like a religion or a literacy of freedom that would help them throughout their lives. These young people did not define themselves as youth or as Black and Brown people, but as emerging professionals and seekers of truth in marginalized spaces. They socialized with each other into their unique form of professionalism that reflects their shared values. In my eyes, they were using their class discussions, in which critical peer feedback plays a key role, to develop their occupational identity as media makers obligated to accurately represent the Black and Brown communities in which they resided.

Ultimately, by supporting educators in designing and implementing in-school hip-hop–based education programs for young people that are grounded in connected learning, the SWP program leveraged the hip-hop identities of young people to help them create and complete substantive identity projects. This form of helping youth in discovering their passions gave them a buffer from challenging life circumstances and sustains them as they continue to discover their place in the world. Technology, much like popular music, has always sparked some to succumb to a utopian vision of solutions to complex problems. However, my findings within the SWP program suggest that HHBE creates civic opportunities that build on Black youth's passions for local community issues and creates an ethos of reciprocity with youth by showing youth they are cared for, valued, and heard.

## References

Barron, B., Gomez, K., Pinkard, N., & Martin, C. K. (2014). *The digital youth network: Cultivating digital media citizenship in urban communities*. Cambridge, MA: The MIT Press.

Baym, N. K. (2018). *Playing to the crowd: Musicians, audiences, and the intimate work of connection*. New York: NYU Press.

Clark, L. S., & Marchi, R. (2017). *Young people and the future of news: Social media and the rise of connective journalism*. Cambridge, UK: Cambridge University Press.

Evans, J. M. (2019). "Deeper than rap": Cultivating racial identity and critical voices through hip-hop recording practices in the music classroom. *Journal of Media Literacy Education*, *11*(3), 20–36.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., … Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub.

Larson, K., Ito, M., Brown, E., Hawkins, M., Pinkard, N., & Sebring, P. (2013). *Safe space and shared interests: YOUmedia Chicago as a laboratory for connected learning*. Irvine, CA: Digital Media and Learning Research Hub.

Mauch, M., MacCallum, R. M., Levy, M., & Leroi, A. M. (2015). The evolution of popular music: USA 1960–2010. *Royal Society Open Science*, 2(5). https://doi.org/10.1098/rsos.150081

Peterson, J. (2013). Rewriting the remix: College composition and the educational elements of hip-hop. In M. L. Hill & E. Petchauer (Eds.), *Schooling hip-hop: Expanding hip-hop based education across the curriculum* (pp. 47–65). New York, NY: Teachers College Press.

Rheingold, H. (2008). *Using participatory media and public voice to encourage civic engagement*. MacArthur Foundation Digital Media and Learning Initiative. In W. L. Bennett (Ed.), *Civic life online: Learning how digital media can engage youth* (pp. 97–118). The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA:

The MIT Press.
Rideout, V. J., Scott, K. A., & Clark, D. K. A. (2016). The digital lives of African American tweens, teens, and parents: Innovating and learning with technology [Executive summary]. Tempe, AZ: Center for Gender Equity in Science and Technology.
Rowan, B. (1995). Learning, teaching, and educational administration: Toward a research agenda. *Educational Administration Quarterly*, *31*(3), 344–354.
Scheitle, C. P., Corcoran, K. E., & Halligan, C. (2018). The rise of the nones and the changing relationships between identity, belief, and behavior. *Journal of Contemporary Religion*, 33(3), 567–579.
Seidel, S. (2011). *Hip hop genius: Remixing high school education*. Lanham, MD: Rowman & Littlefield Education.
Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 443–466). Thousand Oaks, CA: Sage.
Watkins, S. C. (2019). *Don't knock the hustle: Young creatives, tech ingenuity, and the making of a new innovation economy*. Boston, MA: Beacon Press.
Watkins, S. C., & Cho, A. (2018). *The digital edge: How Black and Latino youth navigate digital inequality*. New York: NYU Press.
Yin, R. K. (2009). *Case study research: Design and methods*. London, UK, and Singapore: Sage.

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# 7. Using Online Spaces for Collaborative Learning of Jewish Texts

SHAI GOLDFARB COHEN

**Abstract:** Online learning tools may reflect how the social and textual act of interpretations built a community of readers and writers and learners and teachers. This paper presents a case study of an online *havruta* (paired-couple) platform called *Project Zug*. In this Jewish educational setting, 2 people virtually meet weekly to learn and discuss Jewish ancient texts while making connections to their personal lives. The main research question is how do online learning spaces create communities of practice through the collaborative interpretation of Jewish sacred texts? Using sociocultural frameworks of learning, I analyze data from semistructured interviews with Project Zug's team members and a sample of learners and find that this online learning space creates a community of practice through the collaborative interpretation of Jewish sacred texts. As adult lifelong learners, participants describe a sense of online community with a shared purpose of exploring Jewish content with others while actively creating connections between texts and their own life experiences. It enables an old pedagogical tradition to continue while using technology for more accessible, creative, engaging, and active learning participation. I hope that the implications of my research on Jewish studies and educational technologies will provide a deeper understanding of Jewish education in the 21st century.

## Introduction

More traditional models of Jewish paired-couple learning (*havruta*) are often seen by the community as the intellectual predecessors of modern computer-supported collaborative teaching and learning practices. *Havruta* is an Aramaic term meaning "friendship" or "companionship" and these pairs learn with the same partner through a period of time. This Jewish learning pedagogy offers learners opportunities to interpret the texts together, to make meaning by raising questions and seeking answers collaboratively. This practice has great value for learners of varying ages, in different contexts, and different learning goals, and it does not require an instructor's close guidance. Through discussing and interpreting the texts, the *havruta* constructs and reconstructs the meaning of the text (Kent, 2010). Recently, social and religious changes in Jewish education have been shifting from being more "provider centered" to more "learner centered"; learners are taking a more active role in shaping their learning, making it relevant to their lives, as learning becomes more accessible with the option of developing personal growth (Rubin Ross, 2017). Perhaps, as a result, there has been an increase in online platforms that make Jewish history, Jewish thought, philosophy, and religion more accessible. However, "how people use technology to gather and generate information about Jewish life remains largely unknown" (Kelman, 2018, p. 64). This paper is part of a larger study addressing such questions to better understand how online platforms are used to learn Jewish texts in collaboration with others.

In their report, *The Future of Jewish Learning Is Here: How Digital Media Are Reshaping Jewish Education*, Kelman, Garcia, Zielezinski, and Bruch (2019) present several online Jewish learning platforms that reflect changes in current Jewish learning. Their key findings discuss how Jewish educational online media enable learners to accomplish five goals: "(1) Connect with others around Jewish learning; (2) Access Jewish knowledge beyond Jewish institutions; (3) Learn in sync with the Jewish calendar; (4) Utilize different platforms for different ends and, (5) Integrate online learning and offline practice" (Kelman et al., 2019, p. 4). These findings suggest that as online learning becomes more accessible, the Jewish learning opportunities and experiences are also changing. These changes include more approachable learning materials, creating new social connections, and engaging with Jewish content in new ways that reflect learning in the 21st century.

Despite the increase in online Jewish education platforms, little research has been done on how or what students learn through this medium. This paper presents an informal online collaborative learning space called *Project Zug* as a case study of online *havruta* learning. My central research question, therefore, is: How can online Jewish learning spaces create communities of practice through the collaborative interpretation of Jewish sacred texts? I investigate how this website supports (or does not support) collaborative learning through the lenses of connected sociocultural frameworks of learning: communities of practice (Lave & Wenger, 1991), computer-supported collaborative learning (Dillenbourg, Järvelä, & Fischer, 2009), and knowledge-building communities (KBC) as a pedagogical approach for knowledge creation and innovation (Scardamalia & Bereiter, 2014). In this paper, I present preliminary findings highlighting how participants have created a community of practice through an online collaborative interpretation of Jewish texts.

## Jewish Education in the Age of Google

More than five decades ago, the German Jewish philosopher Franz Rosenzweig called for a "new Jewish learning" that "no longer starts from the Torah and leads into life, but the other way round, from life, from a world that knows nothing of the Law, or pretends to know nothing, back to the Torah" (Rosenzweig, as cited in Woocher, 2012, p. 199). I wish to draw on this notion of a dialogue between Jewish texts (usually referred to as *Torah*) and learners through the use of online platforms.

Rubin Ross (2017) found that Jewish education organizations work on "(a) utilizing technology as a vehicle for empowering learners; (b) teaching involving guiding student learning; and (c) Jewish education encompassing content that is both Jewish and broadly human, and connecting the two" (p. 197). In addition, there are innovative shifts in the roles of learners, teachers, community, text, and social justice. This is part of a broader change occurring in Jewish education in the "age of Google."

According to Woocher (2008), some of these characteristics include the challenge that requires the reader to be able to determine which information from which sources is reliable. Woocher writes that Jews, as "People of the Book," need to adjust to the reality in which learning no longer occurs only through the written word, as multisensory and experiential learning is becoming the norm, and that both "virtual" and "real" networks strengthen existing ties and create new connections and new types of communities that otherwise would not exist. Learning is also about building communities around shared interests while using different tools for communicating, both face-to-face and electronically mediated.

In addition to shifts in Jewish education toward becoming more learner centered, relationship infused, and life relevant, there is the desire of individuals to be active co-creators of products they consume and in their experiences. This phenomenon is called *prosumerism* and in the religious and social context, prosumerists wish to co-create in their learning practice with others and not simply participate. This is also part of the shift from a "provider-centered" to a "learner-centered" perspective. Adults and children both seek to be active in deciding where, how, when, and what to learn while wanting to learn more as they do so (Woocher, 2012).

This also implies that there is a connection between one's personal life and the Torah, looking at the benefits of the wisdom that the Torah may provide. This is part of a 21st-century learning point of view that focuses on education that is "life relevant" and thus develops skills one will need to succeed in the world. This approach often speaks of the "five C's" that contemporary learners will need: create, connect, communicate, collaborate, and be critical thinkers. Similarly, "Jewish education becomes not only more relevant to the diverse population of today's learners, but a richer and fuller expression of Judaism itself" (Woocher, 2012, p. 201). Part of the transition to a digital age includes technological and cultural transformations, like "the transition from oral tradition to written text, and then from written to printed text" (Woocher, 2012, p. 190). Therefore, Jewish education is changing as well and these online tools or online learning communities are examples of such changes. They also reflect a broader phenomenon of free choice and lifelong adult learning.

## Free-Choice and Lifelong Learning in Jewish Education

Adults turn to free-choice learning resources to satisfy their intellectual curiosity as well as to fulfill the needs of other emotional, enjoyment, or spiritual fulfillment (Falk, 2005). Similarly, when seeking information on the Internet, adults enjoy new opportunities to learn new things. Therefore, people engage in free-choice learning for various reasons, although not many do so to become experts. "The term *free-choice* learning is used to refer to the type of learning that occurs when individuals exercise significant choice and control over their learning. Free-choice learning typically, but not necessarily, occurs outside school" (Falk, 2005, p. 270). Also, free-choice learning represents a bottom-up and individual-driven way of thinking about learning, as societies become more knowledge driven. Falk also points out the importance of understanding each individual's lifelong learning journey and his or her role in his or her social context as well as how that determines the direction of this journey.

Learning should be viewed across the lifespan and not according to traditional notions of a separation between education followed by work. Therefore, in the information society today, an educated person is someone who considers learning as a lifelong process. As Fischer (2001) describes: "Lifelong learning is more than adult education or training—it is a mindset and a habit for people to acquire. It creates the challenge to understand, explore, and support new dimensions of learning such as (1) self-directed learning, (2) learning on demand, (3) informal learning, and (4) organizational learning" (p. 1). The Project Zug platform is a lifelong learning tool as it represents a way of informal learning enabling learners to be self-directed and learn on demand.

Lifelong learning involves engaged learners of all ages creating and acquiring knowledge and skills through self-directed and authentic learning situations while taking advantage of the possibilities offered by new media. However, new media and technology are not sufficient by themselves to achieve certain learning goals. Therefore, educators and online learning designers should focus on how these spaces are best used to achieve these learning goals (Fischer, 2001). This is true in the case of Project Zug as an online learning tool discussed in this paper. Project Zug enables learners of all ages and levels of expertise to participate in the interpretation and learning of Jewish sacred texts.

According to Fischer (2001), "We must rethink and reinvent learning, working, collaboration, and education in the context of new media, and simultaneously we must invent and create new media in the context of learning, working, collaboration, and education" (p. 4). Project Zug, for instance, enables learners to create their connections across texts to their personal lives using new media for collaboration, as it also strengthens the ancient practice of Jewish textual dialogue and interpretation of texts with a *havruta* learning partner.

There are many reasons Jewish adults engage in adult Jewish education. As examples, Jews who have not had strong Jewish educational experiences in their childhood are more interested in exploring their Jewish identity (Grant & Schuster, 2011; Krakowski, 2011). In addition, college students who want to increase their knowledge and understanding of Judaism, and parents who feel "ill-equipped to properly respond to their own children's Jewish education" (Krakowski, 2011, p. 309) might turn to online Jewish learning. Krakowski (2011) claims that these examples reflect a need and an opportunity to change and enrich meaningful Jewish adult lives. This also shows that sometimes Jewish adults seek exploration and, given the constraints of adulthood, do so through alternative educational settings rather than through traditional classroom formats. The alternatives include experiential education, nonformal settings such as camps, informal settings such as *shul* (synagogue) attendance, or even formal settings such as schools. Adult Jewish learning in these contexts provides the individual learner or Jewish families resources to use and integrate into their cultural realities.

Adult Jewish learning is not only valued as normative Jewish behavior but is also embedded in Jewish tradition and "even elevates to sacred status" (Schuster & Grant, 2008, p. 162). This learning plays an important role in Jewish tradition since it is necessary to teach the next generation. Around the 1990s, adult Jewish learning emerged among contemporary American Jewry. This is also part of contemporary adults' understanding of adulthood as a time of change rather than continuity. As for adult Jews, these changes lead them to look for new Jewish learning and the meaning of Judaism in their lives. Also, when adults connect to discuss issues of meaning and religious faith, this collaboration leads to communal responsibility to other learners. However, adult Jewish learning has a wide range in terms of learners' backgrounds, learning styles, and interests (Schuster & Grant, 2008). This can be seen through the wide range of Jewish-content websites available today.

At all levels of participation in the Jewish community, people feel a degree of alienation and many adults still need support for finding their way "from the periphery back to the center; from the outside in" (Grant & Schuster, 2011, p. 683). Given the possibility of exchanging ideas through online spaces and tools, there is an increase in the number of Jewish adults who have access to online sources of knowledge in all aspects of Judaism. According to Grant and Schuster (2011), "Adult Jewish learning programs that encourage learners to gain a broad understanding of Jewish texts, history, philosophy, law, and values help such individuals to make responsible and personally meaningful decisions about their Jewish lives today and in the future" (p. 674). This also aligns with the goal of the Jewish pedagogy of *havruta* learning, as it provides learners opportunities for engaging with Jewish texts while making them personally meaningful.

One characteristic of the adult Jewish learner is independence; the learner typically looks for learning opportunities outside "traditional" communal organizations, with a preference to find and develop his or her study resources and learning partnerships. Such learners are attracted to the multiplying online Jewish learning opportunities that promote democratic participation in the teaching-learning process (Grant & Schuster, 2011, pp. 672–673). This participation can be found in the online *havruta* learning in Project Zug, for example, since the learner does not need to attend a "traditional" communal organization but does participate as a learning partner in a digital space.

## Meaning Making

Meaning making is an important practice in Jewish literature and history. Jewish sacred texts are textually connected, as they include commentaries and further interpretations that became the Jewish canon. Today, the tradition of interpretation and commentaries may continue as learners in online learning platforms use digital features to share how they understand the text and therefore create and construct meaning together. This includes a wide learning community as the learners may be from different countries and even speaking different languages.

As learners become participants in this learning community, they also practice their digital media skills and "digital literacies," in the form of writing, reading, and using the language for consuming and producing meaning. Essentially, language, like all internal experience, is social, as is the external experience (Todorov, 1984). Through participation in online Jewish learning spaces such as Project Zug, learners could practice their digital discourse of Jewish sacred texts while using tools the platforms provide.

If we view the use of language from a sociocultural approach and a *socially distributed cognition* framework, learning is something that is not solely in the mind of the individual but is "distributed across people, tools, technologies, and social settings working together in intricate alignments" (Gee, 2015, p. 100). For example, in online *havruta* learning, when the *havruta* couple read and discuss a certain text, their thoughts, interpretations, and meanings that they create collaboratively are distributed across both learners, the tools they use such as computers, and the online digital space in which they interact and communicate.

Smagorinsky (2001) claims that in the process of reading, "each text is produced as a conversational turn in dialogue with prior and anticipated future texts regardless of whether or not they are acknowledged" (p. 141). Meaning is constructed through two processes. First, as we try to make sense and articulate the text, meaning emerges. Second, through this process, some sort of image is produced, a newly constructed text, that serves as a place in which we keep meaning. It is this articulation that serves as a tool for new transformations. This process of concept development is at the heart of meaning construction. While being an online space, Project Zug enables the learners to search for additional texts or other information on other websites that might assist them in understanding the ancient texts.

In addition, understanding a text also implies that the learner is familiar with certain Discourses. *Discourses* (with a capital *D*) include much more than just language: "Discourses are ways of behaving, interacting, valuing, thinking, believing, speaking and, often, reading and writing that are accepted as instantiations of particular identities by specific groups" (Gee, 2015, p. 4). In other words, Discourses provide us with our sense of self and our culturally specific language in which we speak and act. Therefore, if the learner is not familiar with a certain Discourse, one goes through a process in which he or she learns to participate in a specific social practice within a specific Discourse. For example, Segal (2013) found that during the learning process with a *havruta* partner, the partners learn to use a certain dialogue applying *epistemic appropriation*. This occurs when "the learner claims interpretive rights and almost authorship rights to the text, even as he may not add to or even truly understand it" (p. 160). This is perhaps a Discourse in which the learner's background can shape how he or she can develop a Discourse of epistemic appropriation. Such Discourses and social participation can be identified through discussions in the online *havruta* platform of Project Zug.

## Case Study: Project Zug

Project Zug (https://www.projectzug.org/) is an informal online *havruta* learning platform in which two people meet weekly to learn and discuss Jewish ancient texts while making connections to their personal lives. To learn together, they use an additional online communication tool of their choice, such as Skype or Zoom. Project Zug partners meet for a 10-week session while learning together a course of their choice. Each learner enters the homepage where course materials are published. During every session, the *havruta* couple study a set of texts with guiding questions for about an hour. They read, interpret, and discuss a text together, trying to fill the "spaces" in the texts with personal stories and experiences. Similar to traditional *havruta* learning, they may discuss a biblical story, a phrase, or even a single word without the assistance of a teacher. It is an independent learning process in which the *havruta* couple decides when to meet online and how to approach the weekly learning section. If they choose to expand the discussion beyond the *havruta*, there is a course forum in which they can raise further questions with other course participants.

## Methods: Data Collection and Analysis

Qualitative data-collection methods were used, which included two semistructured interviews with participants (i.e., the learners) as well as an interview with one of Project Zug's team members. Since I chose to take a case-study approach, this inductive research looks at the data of the online space to understand how Jewish online learning occurs. To answer my research question, I began with an open coding technique. I looked for themes that I found related to the participants' learning experiences, such as collaboration, sense of a learning community, digital learning, as well as understanding their backgrounds in Jewish learning. Second, I used In vivo coding in which the code refers to a word or short phrase from the actual language found in the qualitative data record, that is, the terms used by the participants themselves. Through this analysis, I unearth the main characteristics of online Jewish studies as a community of practice shared by participants and how one learns to become a member of such a community.

## Findings

The data suggest that Project Zug enables multiple, meaningfully different learning practices. It also provides an opportunity to form new memberships through a digital *havruta* learning community as well as taking advantage of digital networks and online resources to find partners with shared interests. Considering these themes, I contend that this online learning tool supports a growing community of Jewish learning. Table 1 is a summary of analytical themes and examples for how Project Zug functions as an online community of practice for studying Jewish texts.

| Analytic Theme | Examples |
|---|---|
| Forming memberships in the online community | "We got to build community in that way and like get to know each other more deeply."<br>"I'm building trust with people so that you can, you feel comfortable arguing with them."<br>"I think that we definitely succeeded at, you know, like building, you know, good communication and trust and we're able to have really good discussions about texts."<br>"[*Project Zug* is] something that I know I'm committed to and […] carve out time in my week to do."<br>"I don't have a lot of the background knowledge, I'm sure many other learners do. So, I liked that there was a very low bar for entry."<br>"It's odd how you never have to meet those people, but it's just kinda there, um, as a, this feeling of community in the background."<br>"Having a digital, uh, a platform on which to learn with other people, um, that may become my only community."<br>"My official title is *associate director of community learning* […] the bulk of my role is in partnership building […] to use products as a community building tool." |
| Learning with the online tool | "I guess it kinda changed my identity as a learner in that I feel like a lot of, you know, a lot of learning that I do is kind of passive."<br>"This definitely felt like an opportunity to be a very active and intentional learner."<br>"I feel like, you know, a lot of the productiveness of a *havruta* discussion as people kind of, arguing and disagreeing and trying to come to some truth from that process."<br>"It was new to experience it in a meaningful way. Like I said, I felt I was learning in a way I had never learned before."<br>"Overall, it was a, it was a good experience […] and it opened up new learning opportunities and a new connection." |
| A shared purpose of Jewish learning | "It definitely reinforced that, like, Jewish learning is a value of mine."<br>"For me it's also been connection with interesting other Jewish people."<br>"The joy of learning with another human being […] it's not just any human being. It's someone who is Jewish who has background enough- even if they don't identify as religious- background enough in Judaism."<br>"There also is just a kind of nice feeling that there's thousands of other Jews, they're doing this."<br>"[Jewish learning is the] content, context. Lots of different things. Purpose, um, basis. We're using the text, the Torah and then the Midrash […] to understand today and apply it. You can challenge what you can do if you see something that's wrong […] and you can also do it from a totally secular basis, just looking at it historically though, you don't have to be a religious person." |

*Table 1. Project Zug as an online community of practice.*

## Conclusion

Based on this data analysis, I present how Project Zug supports a growing community of practice for Jewish learning. The learners describe a strong sense of being a member of a community of learners as they also emphasize the importance of Jewish learning. These adult learners actively create connections between the online learning content and their own life experiences, thus making it relevant. As lifelong learners, they also participate and explore their Jewish identity while collaborating with others through discussions of Jewish texts. Creating a community of practice through this informal online learning platform, the participants seek new ways of making meaning, as they value the importance of Jewish learning, making it a shared purpose as a community. With further data collection and analysis, I hope to be able to create a theoretical scheme of a Jewish online learning community. The implications of my research on Jewish studies and educational technologies will provide a deeper understanding of Jewish education in the 21st century, focusing on the formation of a community of practice through the digital collaborative interpretation of Jewish sacred texts.

## References


Dillenbourg, P., Järvelä, S., & Fischer, F. (2009). The evolution of research on computer-supported collaborative learning: From design to orchestration. In N. Balacheff, S. Ludvigsen, T. de Jong, A. Lazonder, & S. Barnes (Eds.), *Technology-enhanced learning: Principles and products* (pp. 3–19). Dordrecht, The Netherlands: Springer.

Falk, J. H. (2005). Free-choice environmental learning: Framing the discussion. *Environmental Education Research*, *11*(3), 265–280.

Fischer, G. (2001). Lifelong learning and its support with new media. *International Encyclopedia of Social and Behavioral Sciences*, *13*(41), 1–7.

Gee, J. P. (2015). *Social linguistics and literacies: Ideology in discourses* (5th ed.). New York, NY: Routledge.

Grant, L. D., & Schuster, D. T. (2011). Adult Jewish learning: The landscape. In H. Miller, L. Grant, & A. Pomson (Eds.), *International handbook of Jewish education* (pp. 669–689). Dordrecht, The Netherlands: Springer.

Kelman, A. Y. (2018). Learning about learning in Jewish education. In J. A. Levisohn & J. S. Kress (Eds.), *Advancing the learning agenda in Jewish education* (pp. 53–72). Boston, MA: Academic Studies Press.

Kelman, A.Y., Garcia, A., Zielezinski, M., & Bruch, M. (2019). *The future of Jewish learning is here: How digital media are reshaping Jewish education*. San Francisco, CA: Jim Joseph Foundation.

Kent, O. (2010). A theory of havruta learning. *Journal of Jewish Education*, *76*(3), 215–245. https://doi.org/10.1080/15244113.2010.501499

Krakowski, M. (2011). Challenge and response in Jewish education. *Journal of Jewish Education*, *77*(4), 307–325.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Rubin Ross, R. (2017). Networked but no system: Educational innovation among Bay Area Jewish organizations. *Journal of Jewish Education*, *83*(3), 196–208. https://doi.org/10.1080/15244113.2017.1344821

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed.; pp. 397–417). New York, NY: Cambridge University Press.

Schuster, D. T., & Grant, L. D. (2008). Adult Jewish learning. In R. L. Goodman, P. A. Flexner, & L. D. Bloomberg (Eds.), *What we now know about Jewish education: Perspectives on research for practice* (pp. 161–172). Los Angeles, CA: Torah Aura Productions.

Segal, A. (2013). Schooling a minority: The case of havruta paired learning. *Diaspora, Indigenous, and Minority Education*, *7*(3), 149–163.

Smagorinsky, P. (2001). If meaning is constructed, what is it made from? Toward a cultural theory of reading. *Review of Educational Research*, *71*(1), 133–169.

Todorov, T. (1984). The individual and the social. In *Mikhail Bakhtin: The dialogical principle* (pp. 29–33). Manchester, UK: Manchester University Press.

Woocher, J. (2008). Jewish education in the age of Google. In R. L. Goodman, P. A. Flexner, & L. D. Bloomberg (Eds.),

*What we now know about Jewish education: Perspectives on research for practice* (pp. 31–38). Los Angeles, CA: Torah Aura Productions.
Woocher, J. (2012). Reinventing Jewish education for the 21st century. *Journal of Jewish Education*, 78(3), 182–226. https://doi.org/10.1080/15244113.2012.700636

# 8. Family Coding Days: Engaging Children and Parents in Creative Coding and Robotics

MADHU GOVIND AND MARINA UMASCHI BERS

**Abstract:** Various models for bringing families together to engage in coding activities have emerged in recent years, but few studies have explored the affordances of different coding technologies for fostering family engagement. This project examined family coding in early childhood with 2 different programming interfaces: the ScratchJr app (a graphical interface) and the KIBO robotics kit (a tangible interface). Data from parent surveys and facilitator observations were collected from informal coding workshops called "Family Coding Days," in which young children and their parents were invited to learn about the interface (either ScratchJr or KIBO), create a coding project together, and share their project with other families. Findings indicated no significant differences between ScratchJr and KIBO Family Days in regard to families' coding interest before and after the event, the nature of parent-child interactions, and children's engagement in key computational thinking skills. Study limitations, implications, and future directions for research and practice are discussed.

## Introduction

Coding technologies, such as those that involve robotics or apps with programming languages, allow children to extend their learning in new ways by becoming producers, rather than consumers, of their own creative artifacts (Bers, 2018; Resnick & Silverman, 2005; Yu & Roque, 2018). Although coding in schools has increasingly become more popular with the adoption of K–12 computer science standards and frameworks (Code.org, 2020), schools often have limitations on the amount of time students can spend using coding technologies. Children's early coding experiences with family members may foster children's interest in coding and promote parent-child interactions (Roque, 2016).

Family-oriented programming has thus emerged as a fun, informal way for children and parents to come together and jointly engage in coding activities. Existing models of family-oriented programming include Family Creative Learning (Roque, 2016) and Family Code Night (Pearce & Borba, 2017), which enable children and parents to work together on creative computing projects or jointly play with coding software. Findings from these events indicate that these events are enjoyable for both parents and children and stimulate their interest in project-based tasks and creative problem solving.

Furthermore, family-oriented programming events conducted in informal settings such as libraries and afterschool programs function as connected learning environments (Ito et al., 2013). Ito and colleagues (2013) defined connected learning as "broadened access to learning that is socially embedded, interest-driven, and oriented toward educational, economic, or political opportunity" (p. 4). In the connected learning model, opportunities for children to connect learning across formal and informal settings can enhance children's social and academic competencies. Through coding together, parents can facilitate children's engagement in key computational thinking skills such as algorithmic thinking, debugging, and design process, which are important skills that can benefit children's learning in other areas (Bers, 2018; Martin, 2017).

However, different types of coding technologies may offer different types of user experiences. Graphical interfaces, such as tablet-based apps, use screens and visual elements such as icons, images, and windows to engage users, whereas tangible interfaces allow users to connect their digital environment to the physical world by manipulating objects (Sapounidis & Demetriadis, 2013). Studies comparing graphical versus tangible interfaces indicate that tangible interfaces are better suited for sharing because they have multiple access points, or different ways for users to touch and engage with the interface (Shaer, 2009). Younger children also tend to find tangible interfaces more enjoyable, whereas older children who have had more experience with computers find graphical interfaces easier to navigate (Sapounidis & Demetriadis, 2013). Particularly in early childhood when parent involvement is crucial for promoting children's technology and media experiences (Donohue, 2016), how might families engage in coding activities with tangible versus graphical interfaces? Does the type of technology impact parent-child interactions during creative coding? This study sought to explore these questions.

Our research team piloted "Family Coding Day" workshops, one- to two-hour coding workshops for children ages 5–7 and their parents to jointly program using either the ScratchJr app, a graphical coding interface (Flannery et al., 2013), or the KIBO robotics kit, a tangible coding interface (Sullivan, Bers, & Mihm, 2017). Anecdotal evidence from pilot ScratchJr and KIBO Family Day workshops (including researcher observations and conversations with parents) indicated that the ways in which parents and children co-engage in coding activities may be directly influenced by the type of coding platform. However, little research has been done on comparing the affordances of different coding technologies for fostering family engagement. This study fills this gap by providing information on parents' perceptions before and immediately after the family coding workshops. In accordance with the connected learning model, we focused our comparison of ScratchJr and KIBO Family Days on three key constructs: (a) parents and children's coding interest before and after the event, (b) type of parent-child interaction during the event, and (c) children's engagement in key computational thinking skills.

## Method

Family Coding Day workshops were conducted by researchers as well as by individuals around the country who expressed interest in bringing coding to their institutions. These individuals (termed *facilitators*) received a detailed protocol with recruitment strategies, event tip sheets, sample agendas, activity prompts, and instructions for collecting data via parent and facilitator surveys.

Both ScratchJr and KIBO Family Days consisted of similar activities: *learning* about the technology, *co-creating* a coding project, and *sharing* projects with peers. First, children separately engaged in off-screen coding games while parents completed a pre-event survey and received a step-by-step ScratchJr or KIBO tutorial. Then, families were reunited to work together on an open-ended coding project. Researcher-facilitators provided families with sample prompts, such as "Program a ScratchJr character/KIBO robot to perform a dance, be an animal, or act out a scene from a favorite book or movie," but encouraged families to come up with their own creative ideas. As families worked collaboratively on their projects, researcher-facilitators would walk around to assist and encourage families to learn from one another and provide feedback on their projects. Finally, parents completed a postevent survey and joined their children as they shared their final projects.

### Sample

Fourteen Family Coding Day workshops around the United States were conducted between Fall 2017 and Summer 2018, attracting more than 100 families with children primarily between 5 and 7 years old. Younger and older siblings were invited to attend, but the activities and survey items targeted this specific age range. Seven of the 109 families attended both ScratchJr and KIBO Family Days. In order to explore differences between independent samples, we removed these seven cases from analysis, resulting in our sample of N = 95 families (see Table 1 for participant demographics).

| | ScratchJr ($n$ = 52) | KIBO Robotics ($n$ = 43) |
|---|---|---|
| Mean Child Age (years) | 6.43 | 6.23 |
| **Parent Gender** | | |
| Mother | 40 | 32 |
| Father | 12 | 11 |
| **Parent Education** | | |
| High school degree or equivalent | 1 | 1 |
| Some college, no degree | 0 | 2 |
| Associate degree | 4 | 3 |
| Bachelor's degree | 15 | 14 |
| Master's degree | 18 | 12 |
| Professional degree | 11 | 7 |
| **Parent in STEM Profession** | | |
| Yes | 22 | 11 |
| No | 27 | 27 |
| **Prior Experience with Coding Interface** | | |
| Yes, child only | 23 | 7 |
| Yes, adult only | 2 | 1 |
| Yes, both child and adult | 3 | 0 |
| No, neither child nor adult | 24 | 35 |

*Table 1. Family Coding Day participant demographics by condition.*

**Graphical condition.** Nine ScratchJr Family Days were hosted by both researchers and external facilitators. A total of 52 families participated. Events were primarily held at elementary schools or children's museums after school or on weekend mornings. All families either brought their own tablet from home or borrowed a tablet to use for their ScratchJr project.

**Tangible condition.** Five KIBO Family Days were conducted, all of which were facilitated by researchers. A total of 43 families participated. Events were held in the local Boston area, either at the research university in a large open classroom space or in elementary schools where the researchers recruited co-facilitators to help recruit families to attend. For the open-ended projects, researcher-facilitators placed large bins of KIBO parts and tangible programming blocks in a central, easily accessible part of the room.

## Data Collection and Analysis

Parents consented to research participation, which consisted of surveys before and after the event. Presurveys, completed by parents at the beginning of the workshop, included questions related to demographics and parents and children's prior experience and interest in coding. Postsurveys, completed at the end of the workshop, consisted of open-ended and Likert-type scale questions regarding parents and children's levels of engagement, collaboration, and learning during the event.

Statistical comparisons were drawn between the two conditions (ScratchJr vs. KIBO) to explore whether there were differences in parents' reported experiences. Specifically, the following dimensions related to the key principles of connected learning were examined: (a) parents and children's coding interest before and after the event, (b) type of parent-child interaction, and (c) children's engagement in key computational thinking skills. In order to account for the risk of Type I error due to multiple comparison tests, the Bonferroni correction was applied, resulting in an adjusted alpha value for statistical significance of .006. In addition to quantitative data, this paper also presents qualitative observations from facilitators and excerpts of parents' open-ended survey responses to further illuminate families' experiences at Family Coding Days.

**Research constructs.** We asked parents in both the pre- and postsurveys to report their and their children's coding interest using a 1–5 Likert-type scale from "1 = not at all interested" to "5 = very interested." In the postsurvey, parents reported the type of parent-child interaction during the event as child directed, adult directed, or collaborative. Child- or adult-directed interactions were defined as the child or adult "leading the majority of the discussion and activity," whereas a collaborative interaction was defined as one in which "adults and children shared initiation of the discussion and activity." Children's engagement in key computational thinking skills focused on three skills: *algorithms*, defined as "coding with a logical sequence of steps," *debugging*, defined as "finding and correcting errors; troubleshooting," and *design process*, defined by six iterative steps: "ask, imagine, plan, create, test and improve, and share." Parents reported their children's engagement in these three skills during the event using a 1–5 Likert-type scale. Because computational thinking skills are often difficult to assess, even by professionals of assessment and teaching, the survey items included specific indicators for the 1, 3, and 5 markers, 5 being the highest level of engagement.

# Results

## Coding Interest

Independent sample *t*-tests indicated that parents and children's reported coding interest before and after the event did not differ significantly by interface (ScratchJr vs. KIBO), all *p*'s > .05. Dependent sample *t*-tests indicated that parents' coding interest increased significantly after participating in a Family Coding Day, $t(82) = 6.20$, $p < .001$. Parents also reported significantly higher coding interest among children after the event, $t(84) = 7.36$, $p < .001$ (see Figure 1).

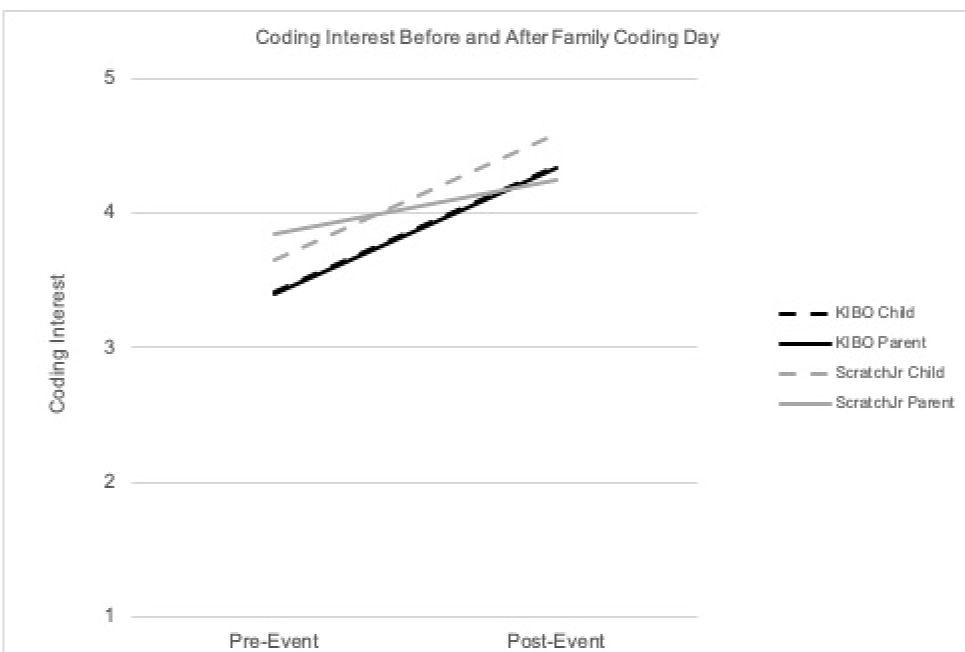


*Figure 1. Parents and children's coding interest increased significantly after participation in a Family Coding Day event.*

Parents and children were generally enthusiastic about learning to code and eager to showcase their creations at the end of the event. One parent from a ScratchJr Family Day reported, “Before this I knew nothing about coding, but it has piqued my interest to take a class in this, so later on I would be able to do this with my daughter when it becomes more advanced.” Parents were also pleasantly surprised by how much children enjoyed their introduction to coding. One parent from a KIBO Family Day reported, “Our son was very interested. He frequently complains of being bored and has a hard time focusing on activities for longer periods of time, but he was very engaged in this and wanted to continue doing it.” Another parent wrote, “This activity sparked an interest in my children (and myself) to enroll them in more coding activities and to acquire simple robots for them to code at home.” These comments suggest these one-time coding workshops may encourage parents to seek additional opportunities to continue fostering children’s interest in coding.

## Parent-Child Interaction Type

A chi-square test of independence indicated that the type of reported parent-child interaction was not significantly associated with the interface used (ScratchJr vs. KIBO), X2 (2, N = 95) = 4.35, $p$ = .11. Of the 95 parents, 54.7% ($n$ = 52) reported their interactions with children as collaborative, 38.9% ($n$ = 37) as child directed, and 6.3% ($n$ = 6) as adult directed.

Family Coding Days were predominantly viewed as collaborative coding events. Most parents left positive feedback for event facilitators, remarking, “This was a great activity to do together with my child.” Some families divided tasks during the coding project. For instance, one parent reported, “My child led the first part of the coding session with the easier coding and then I led the more complex pieces (if/then statements) but with collaboration throughout.” Parents also engaged as coaches and encouraged their children to explore new concepts. One parent from a ScratchJr Family Day reported, “My daughter was most interested in designing her own scenes and characters. She was not as interested in making them move, but when coached she did become more engaged, and she really liked adding her voice.”

## Children’s Computational Thinking Engagement

Parents reported that their children did engage in key computational thinking skills during Family Coding Days. The three skills explored in this study—algorithms ($M$ = 3.22, $SD$ = 1.05), debugging ($M$ = 3.26, $SD$ = 1.37), and design process ($M$ = 3.69, $SD$ = 1.14)—were positively and moderately correlated, with Pearson’s $r$ ranging from .54 to .60, $p$ < .001. Independent sample $t$-tests indicated that children’s reported engagement in these three skills did not differ significantly by interface (ScratchJr vs. KIBO), all $p$’s > .05.

All families succeeded in creating a project to share with others at the end of the event. Whereas some families had decorated KIBO robots with various crafts materials or had personalized characters and backgrounds for their ScratchJr projects, other families chose to focus on the programming aspect and created complex codes with repeat loops or conditionals. One parent from a ScratchJr Family Day commented on her child’s engagement in iterative design and algorithmic thinking, remarking, “It was great seeing my daughter create and re-create stories using different algorithms.”

## Discussion

This study examined families' experiences at informal "Family Coding Day" events, in which young children and parents learned about coding, worked together on an open-ended project, and shared their creations with fellow participants. The purpose of the study was to explore whether parents' perceptions of their experiences at Family Coding Days differed based on the type of coding platform they engaged with, either the ScratchJr programming app (a graphical interface) or the KIBO robotics kit (a tangible interface). Our analyses revealed no significant differences between ScratchJr and KIBO Family Days in regard to families' coding interest before and after the event, the nature of parent-child interactions during the event, and children's engagement in computational thinking skills during the joint coding activity.

Both parents and children's coding interest increased significantly after participating in a Family Coding Day. This finding supports ScratchJr and KIBO as accessible and engaging coding platforms for learners of all ages. Furthermore, this finding suggests that framing coding as a creative and engaging activity for families to do together can promote their engagement and interest in coding overall. Regardless of interface, parent-child interactions during Family Coding Days were predominantly identified as collaborative. This finding is interesting because the two interfaces offer very different user experiences. ScratchJr, as a single-touch interface, enables only one user to interact with the app at any given time. Conversely, the KIBO robotics kit comes with many interlocking blocks and detachable parts, offering multiple access points for users. However, during ScratchJr Family Days, families would position themselves so that both the child and parent could view the screen or take turns clicking on the various icons. Parents also offered suggestions verbally or pointed to the various ScratchJr features while their children physically operated the app. This form of "joint media engagement" (Takeuchi & Stevens, 2011) permitted ScratchJr families to have a collaborative coding experience. Finally, children did engage in computational thinking during the course of designing and revising their coding projects with the assistance of their parents. Future work should explore the extent to which children's engagement in computational thinking skills is dependent on parent involvement, as well as the specific ways in which children's computational thinking can be enhanced through family coding.

Altogether, these findings suggest that the affordances of graphical versus tangible tools may not matter as much as having informal, open-ended opportunities for young children and parents to engage in creative programming. Regardless of interface, ScratchJr and KIBO Family Day events have shown themselves to be enriching spaces for families to engage in connected learning (TeachThought, 2018). These events are *interest-powered* and *production-centered*, inviting parents to co-design robotic creations or digital stories that are personally meaningful and interesting to their young children. These events are also *peer-supported* and have a *shared purpose*, welcoming various opportunities for collaboration, feedback, and community building. Finally, these events are *academically oriented* and *openly networked*, offering children the opportunity to learn new skills and connect their learning across different settings. As family coding workshops expand in coming years, future research should continue to explore how families' experiences are shaped by different kinds of coding technologies.

## Limitations

There were several limitations to this work. One was that both child and parent survey data were reported by parents themselves. Self-reported survey responses are prone to some level of bias, particularly social desirability bias, in which parents may over-report socially desirable traits and under-report undesirable traits. Future work should employ validated observation measures to supplement parent reports and collection of data directly from children to understand their perceptions of coding alongside their parents. In addition to response bias, another limitation of this work is self-selection bias, which limits generalizability. Families self-selected to attend ScratchJr and KIBO

Family Day events and participate in pre- and postsurveys for research purposes. Although recruitment methods varied among events, the analytic sample for this study comprised highly educated parents from middle to high socioeconomic backgrounds. Future research should explore whether families that do not belong to these demographic characteristics report similar family coding experiences.

Another study limitation is facilitator resources. Event facilitators require a large space for families to come together, as well as access to the technologies themselves (i.e., tablets and KIBO robotic kits). Although ScratchJr is a freely downloadable app, KIBO robotic kits are more expensive. These possible logistical and financial obstacles may be why KIBO Family Day events were hosted solely by the research team. Future research might explore how access to resources may affect the nature of families' experiences at Family Coding Days. More important, individuals and organizations seeking to bring coding to their respective communities should seek adequate funding and resources to ensure positive experiences for families.

### Practical Implications

In the larger conversation of the graphical versus tangible debate and which might be considered more suitable for different settings, this work suggests that both ScratchJr and KIBO foster positive experiences for young children and parents to jointly engage in creative computing activities. Parents, educators, and practitioners seeking to promote family-oriented coding opportunities for young children should keep the following considerations in mind. By programming stories on ScratchJr or creating robotic artifacts with KIBO, children not only engage with advanced technological tools, but also learn how to produce creative artifacts. Facilitators should encourage families to create projects that are meaningful and personal to them. Similar to when reading a book or playing a board game with their children, parents can play an important role in facilitating children's creativity, personal expression, and problem-solving skills through the activity of coding together.

In addition, the ways in which parents and children engage with different kinds of coding tools depend on the availability of resources, such as time, space, number of tablets or robotic kits, and facilitators. Family Coding Days should be long enough to allow families to successfully complete a coding project but concise enough to keep families fully engaged. Events should also ensure that the environment offers adequate tools and appropriate spaces for both children and parents to easily access the interface and collaborate with one another. Facilitators should be trained on how to use the interface and to offer scaffolding strategies to encourage families to problem solve on their own before asking facilitators for assistance. Taking these considerations into account will benefit both facilitators and families.

## Conclusion

As coding becomes an increasingly important priority in schools and other formal learning settings, connecting children's learning of coding outside of school through family engagement will also become increasingly salient. This study was the first to explore family-oriented coding in early childhood in informal settings using different types of coding technologies. More than 100 families participated in Family Coding Days, which were informal coding workshops conducted in settings such as afterschool programs, museums, and community centers. Findings from parent surveys and facilitator observations indicated that families' experiences at Family Coding Days did not differ based on the type of coding platform they engaged with, either the ScratchJr programming app (a graphical interface) or the KIBO robotics kit (a tangible interface). These findings may serve to position creative coding as an engaging family-oriented activity and propel future research on parent-child interactions at family coding events.

## References

Bers, M. U. (2018). *Coding as a playground: Programming and computational thinking in the early childhood classroom*. New York, NY: Routledge. doi:10.4324/9781315398945

Code.org. (2020). *Landscape of CS action in states*. Retrieved from https://docs.google.com/document/d/15zBdBbXUA-yEzxEq0VeWAEb9nXuGjmNFWNrYp6UdM8U/edit?usp=embed_facebook

Donohue, C. (Ed.). (2016). *Family engagement in the digital age: Early childhood educators as media mentors*. New York, NY: Routledge.

Flannery, L. P., Silverman, B., Kazakoff, E. R., Bers, M. U., Bontá, P., & Resnick, M. (2013). Designing ScratchJr: Support for early childhood learning through computer programming. In *Proceedings of the 12th International Conference on Interaction Design and Children-IDC '13* (pp. 1–10). doi:10.1145/2485760.2485785

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., … Watkins, S. C. (2013). *Connected learning: An agenda for research and design*. Irvine, CA: Digital Media and Learning Research Hub. Retrieved from https://dmlhub.net/publications/connected-learning-agenda-for-research-and-design/

Martin, C. (2017). Libraries as facilitators of coding for all. *Knowledge Quest*, 45(3), 46–53. Retrieved from https://files.eric.ed.gov/fulltext/EJ1125376.pdf

Pearce, J., & Borba, S. (2017, December 7). What is Family Code Night? [Blog post]. Retrieved from https://www.naesp.org/blog/what-family-code-night

Resnick, M., & Silverman, B. (2005). Some reflections on designing construction kits for kids. In *Proceedings of the 2005 Conference on Interaction Design and Children-IDC '05* (pp. 117–122). doi:10.1145/1109540.1109556

Roque, R. (2016). *Family creative learning: Designing structures to engage kids and parents as computational creators* [Doctoral dissertation]. Massachusetts Institute of Technology, Cambridge, MA.

Sapounidis, T., & Demetriadis, S. (2013). Tangible versus graphical user interfaces for robot programming: Exploring cross-age children's preferences. *Personal and Ubiquitous Computing*, 17(8), 1775–1786. doi:10.1007/s00779-013-0641-7

Shaer, O. (2009). Tangible user interfaces: Past, present, and future directions. *Foundations and Trends® in Human–Computer Interaction*, 3(1–2), 1–137. doi:10.1561/1100000026

Sullivan, A. A., Bers, M. U., & Mihm, C. (2017). *Imagining, playing, and coding with KIBO: Using robotics to foster computational thinking in young children*. Retrieved from https://ase.tufts.edu/devtech/publications/Sullivan_Bers_Mihm_KIBOHongKong .pdf

Takeuchi, L., & Stevens, R. (2011). *The new coviewing: Designing for learning through joint media engagement*. Retrieved from https://www.joanganzcooneycenter.org/wp-content/uploads/2011/12/jgc_coviewing_desktop.pdf

TeachThought (2018). *6 design principles of connected learning*. Retrieved from https://www.teachthought.com/the-future-of-learning/6-design-principles-connected-learning/

Yu, J., & Roque, R. (2018). A survey of computational kits for young children. In *Proceedings of the 17th ACM Conference on Interaction Design and Children-IDC '18* (pp. 289–299). doi:10.1145/3202185.3202738

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# 9. Maker Ed in the Art Studio: Preparing Preservice Artist/Educators to Integrate Maker Education Into P–12 Art Studio/Classrooms

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**Abstract:** This paper presents a model for preparing preservice artist/educators to integrate digital and analog materials and methods in P–12 art studio/classrooms. Over the past 3 years, as part of a precertification art education program, I redesigned and taught a course, Learning in Digital Visual Cultures (DVC). Art teacher candidates with little to no previous knowledge of digital tools, circuits, or coding learn to adapt these new methods and materials borrowed from maker education to suit the learning objectives of the art studio. This approach flips the popular STEAM approach: Technology is put at the service of art education, rather than art's being used to enhance STEM education. The arts prioritize conceptual and material exploration in the service of personal meaning making and aesthetic expression. In DVC, staples of the maker movement, such as simple circuits, Arduino, and Scratch coding, are used to expand students' personal engagement, arts learning, and connections across the curriculum. Preservice artist/educators study the history and current potential of digital visual cultures in art and education. They research and present on contemporary artists who incorporate digital technology in their work, and they design lesson plans that use these artists as mentors.

## Artists Are Makers

Artists think through materials (Hafeli, 2014). Ideas emerge in the process of making. Artistic thinking can be distinguished from design thinking, in that artists often engage in making for its intrinsic rewards, rather than to please a client or solve a predefined problem. Art making, in this case, can be a process of what has been called problem construction or formulation rather than problem solving (Csikszentmihalyi & Getzels, 1988).

Through the art-making process, an artist externalizes internal thoughts, feelings, and perceptions in physical form and is able to play and respond to unforeseen possibilities. As an artist's "first thoughts" accumulate in the process of transforming material into form, she begins to respond, not only to procedures, techniques, and concepts she brings with her, but also to what is happening in the moment. A dialogic process ensues between bottom-up perceptions interacting with top-down concepts and strategies. Preservice artist/educators need to learn how to cultivate artists' ways of thinking and doing in their future classrooms.

## Learning in Digital Visual Cultures

Learning in Digital Visual Cultures (DVC) is a required course for undergraduate art education students as part of a precertification program in a regional public university with a strong arts program. The majority of students have no experience with technology except as consumers. At the start of the semester, there is a high level of anxiety and reluctance to engage with technology among most students. In previous iterations, DVC was taught with a greater emphasis on visual culture. I have shifted and redesigned the course to be much more hands-on, incorporating the kinds of activities more typically found in maker education, such as simple circuits, while maintaining a strong connection to contemporary arts and arts education practices. Students also consider the historical relationship between art and technology. Design thinking processes are introduced and adapted to help students learn how to plan lessons based on course methods and materials.

## The Curriculum

Students in DVC are guided through a series of collaborative and individual projects that build confidence and competence with digital materials. They progress through assignments that move from step-by-step instruction through guided practice to student-driven research. We begin with marble runs and simple circuits, making LED circuit cards and then Arduino via ATtiny microcontrollers. Laser cutting and 3D printing come next, and toward the end of the semester, they create interactive stories and games with Scratch. For their final project, they combine at least two of the technologies from the class, along with prior knowledge and experience in art making in an independent project (see Figure 1). Every step of the way, they are asked to reflect on what they bring as artists and art educators into these new making experiences.

*Figure 1. This is an example of student work: a laser-cut lantern that incorporated LEDs programmed with Arduino.*

## Keeping Future Budgets in Mind

Most of the preservice teachers in our art education program will end up teaching in public schools with very limited budgets. With this in mind, in DVC there is a heavy emphasis on open platform software such as Tinkercad and Scratch (see Figure 2). When working with microcontrollers, we focus on ATtiny 85s rather than the more expensive Lillypad or MicroBit. This limits what we can do, but it introduces the concept of physical computing in the art studio classroom, and makes it possible for students to realistically project doing these kinds of activities in their future classrooms with public school budgets.

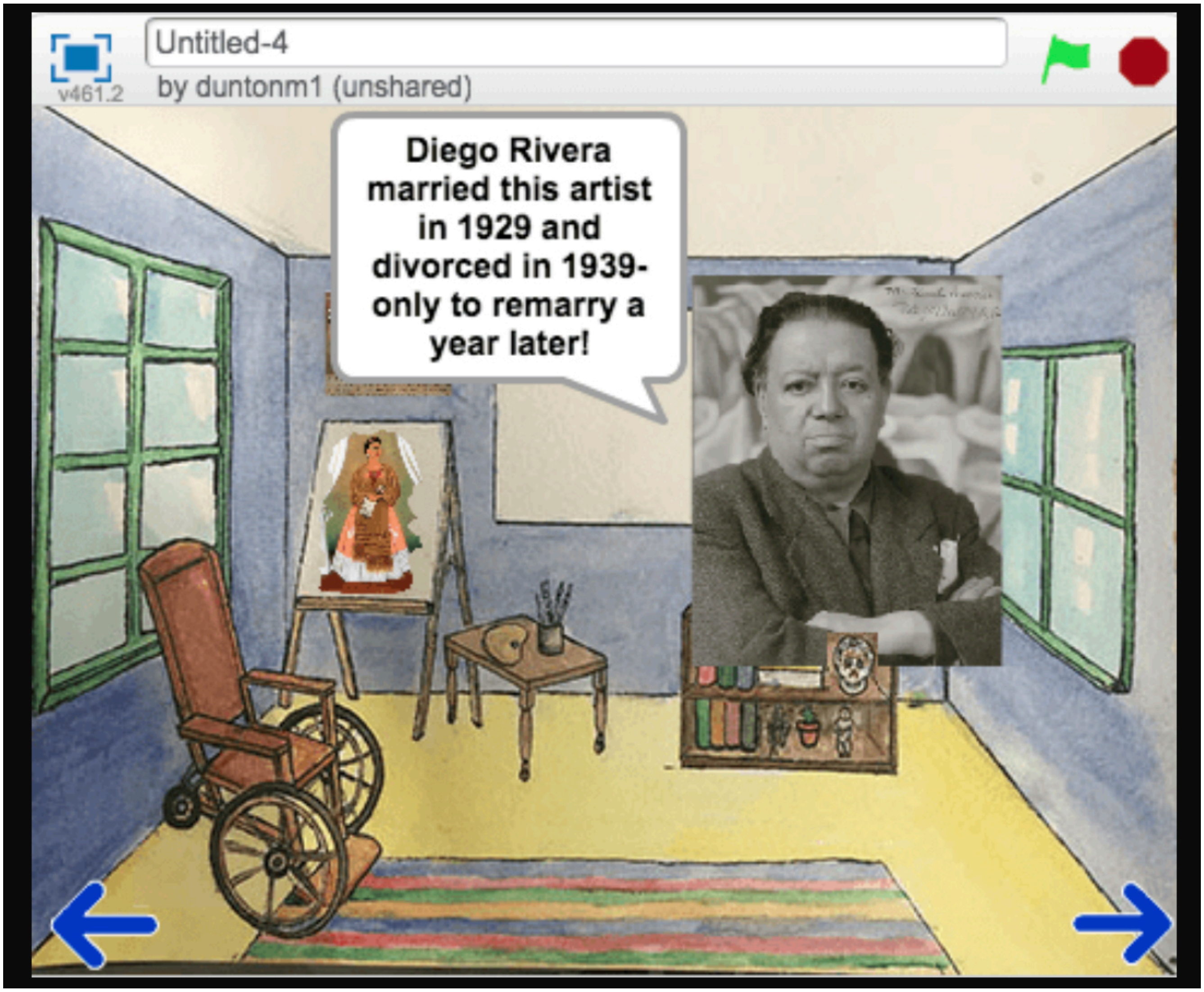


*Figure 2. A screen shot of a student's Scratch game, based on La Casa Azul, artist Frida Kahlo's home.*

## Family Maker Day

During the first week of class, students learn that they will be organizing a Family Maker Day. Families from the local community are invited to participate in open-ended "maker activities" on a Saturday afternoon around the 10th week of the 15-week semester (see Figure 3.) Students are challenged to design their own arts-based maker activities, based on what they have learned so far, and workshop them in class. I point them toward resources and offer technical advice, but they decide what and how to structure their activities. This takes place as an introduction to our Saturday Arts Lab, a student-run art program that is an integral part of our teacher-preparation program, and students have used many of our actual Maker Day activities in subsequent semesters in the Saturday Arts Lab.

*Figure 3. A Family Maker Day activity inspired by research on phosphorescent fish, using simple circuits, LEDs, and pipe cleaners combined with a variety of other art materials.*

## Class Blogs

Students reflect on each activity or project in personal blogs, in which they are asked to describe their learning process and how this activity connected (or not) to their prior knowledge of art and art education. They are also asked to consider how they might use and/or adapt each activity in an art classroom. These reflections often dig deeply into aesthetic and conceptual concerns that are characteristic of visual art as a discipline. For example, reflecting on her laser-cut lantern (see Figure 1) as inspiration for her final independent project (a plexiglass laser-cut piece incorporating programmed LEDs), one student wrote:

> It's been interesting for me to try and wrap my head around the idea of light in my life, and how light can be expressed symbolically in my art. I did some research to see how light has been represented historically, its role scientifically, and its place in spirituality. My research has [led] me to more questions than answers … the fairly broad association of light as the sun and the moon, and the ways in which they sustain and influence life on earth. In addition to this literal concept of light as a means for one's livelihood, I thought about the things in my life that I believe are brightest and bring me warmth in the way that light does so well. For me, one of the greatest and brightest parts of being a person is our ability to empathize and have compassion for one another.

This student's thought process, moving from the literal to the conceptual and metaphorical, typifies the kind of inquiry that is encouraged and supported in the DVC class. Her thinking demonstrates that technology has become just another tool in her artist's toolbox. She has figured out how new tools and materials can be used in the service of her personal aesthetic and creative goals.

## Conclusion

During the first couple of iterations of this course, students often struggled and grew frustrated with projects and questioned why it was necessary for them, as future art teachers, to master these new skills. In the current iteration, through carefully scaffolding tech skills, such as soldering and coding, while keeping artistic and creative goals at the forefront and leveraging students' prior skills and knowledge in the visual arts, all students can be successful in this course.

### Results

In their final semester as student teachers, and as students approach the job market, they incorporate lessons and projects from DVC alongside a more typical visual arts curriculum. They have adapted DVC skills and techniques into various media, such as painting and ceramics, and several recent graduates are continuing to incorporate this knowledge in their teaching.

### Broader Value

Artist/educators can bring unique perspectives and ways of thinking and working to maker education. At the same time, the methods and materials of the maker movement can feel quite foreign and daunting for preservice artist educators who are much more comfortable with clay and paint. STEAM approaches, adding the Arts to STEM education, tend to add arts-based materials and methods as an afterthought. By foregrounding contemporary art practices and leveraging students' personal artistic and creative experience and goals, a successful and distinct approach to the integration of art and technology can be forged.

## References

Csikszentmihalyi, M., & Getzels, J. W. (1988). Creativity and problem finding in art. In F. H. Farley & R. W. Neperud (Eds.), *The foundations of aesthetics, art, and art education* (pp. 91–116). New York, NY: Praeger.

Hafeli, M. C. (2014). *Exploring studio materials: Teaching creative art making to children*. New York, NY: Oxford University Press.

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# 10. Cultivating Counter Space: Evoking Empathy Through Simulated Gameplay

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**Abstract:** This report presents initial findings from use of a computer simulation that was designed as narrative for cultivating counter space for students, a space to practice communicative and analytic behaviors that support humanitarian values, social equity, respect for diversity, and socially just action. The computer simulation encourages and rewards ethnocultural empathy and prosocial behavior among students who are learning professional helping skills. Ethnocultural empathy involves understanding and empathizing with the experiences of those who are from racial and ethnic cultural groups different from one's own. Prosocial behaviors are voluntary behaviors that intend to benefit, to assist, and to comfort others. The simulation induces students to confront and question legacies of institutional racism, classism, and sexism in their personal judgment and nascent professional helping behaviors. The basic necessities of decent human survival are implicated with the messiness of human relationships as fundamental components of practicing socially just helping behaviors. In the simulation, the student completes an assessment and plan of action that must identify ethical principles involved when dealing with the lives and situations of others, while recognizing and awarding value to a character's culture, gender, age, developmental stage, and life situation. Findings indicate that the simulation evokes a significant increase in empathetic response from a diverse group of students. The ability to increase or renew ethnocultural empathy is a hopeful sign in a world where active violence toward difference and diversity has found a place in public gatherings as well as our schools and local communities.

## Introduction

Empathy, the ability to understand, appreciate, act on, and share another's emotions, has been investigated by Zaki (2020) as a primary, renewable behavioral resource. Empathy is a fundamental component of effective social interaction that can be evoked in a manner that has the potential to increase the practice of humanitarian values. Empathy is reflexive, and individuals have the capacity to alter, diminish, or increase empathy in their reflexive response to context and situation. This capacity has been described by Zaki and others (Decety & Jackson, 2004) as *interpersonal emotional regulation*. Such regulation can be a conscious activity for professionals in their encounters with others. Most helping professionals encounter situations in which they must help another person during emotional moments. In those cases, interpersonally regulated empathy can support helping goals and be relationally authentic (Koole & Tschacher, 2016). In this case, our experimentation is investigating the question of how and to what degree a technology simulation can evoke a type of empathy known as *ethnocultural empathy* in a manner that supports learning, and, at the same time, leads to an overall increase in ethnocultural empathetic capacity and prosocial behavior.

Ethnocultural empathy is a form of empathy directed toward people from racial and ethnic cultural groups who are different from one's own ethnocultural group (Wang et al., 2003). Provocation of this form of empathy has been viewed as one possible path to promote mutual affective and cognitive understanding between various racial and ethnic groups (Rasoal, Ekland, & Hansen, 2011). Empathy has also been shown to increase understanding and motivate prosocial behaviors (Herrera, Bailenson, Weisz, Ogle, & Zaki, 2018). Empathy is reflexive, and individuals have the capacity to alter, diminish, or increase empathetic concerns in their reflexive response to context and situation. As Zaki (2020) points out, it has been demonstrated that it is empathetic concerns, not experience sharing, that supports well-being and close relationships (Crocker & Canevello, 2012; Morelli, Lee, Arnn, & Zaki, 2015; Morelli, Ong, Makati, Jackson, & Zaki, 2017).

Further, empathetic concerns can protect educators and helping professionals from burnout and other associated problems (Gleichgerrcht & Decety, 2013; Lamothe, Boujut, Zenasni, & Sultan, 2014). The capacity for empathetic concerns prompt choices that require us to understand and forecast others' emotions as fundamental components of their prosocial goals and actions. In other words, the evocation of an empathetic concern acts as a prompt to examine one's emotional state, to form goals that imply changing or maintaining emotions, and to enact tactics that are believed to be effective in the accomplishment of those goals. In social work practice, this is described as the purposive use of self. The conduct of these activities in response to empathic concern has been studied as connected to extended models of interpersonal emotional regulation (Gross, 2015). Additionally, a number of learning models suggest that empathy must be invoked to engage the learner (Shin, 2018). In this research brief, we present preliminary results from our first attempts to use a simulation to motivate multicultural empathic concerns and allow for meaningful rehearsal and enactment of prosocial behavior. The enactment of those concerns has been shown to be related to health and to increased prosocial behavior (Batson, 2009; Jordan, Amir, & Bloom, 2016; Zaki, 2020). In fact, persuasive arguments from Hoffman's work (2000, 2008) have encouraged us to consider empathy as one of the key antecedents and corollaries to prosocial behavior and a social justice orientation.

Similar to empathy, prosocial behavior has been examined as an expressive emotion that can be reflexive (Levine, Barasch, Rand, Berman, & Small, 2018). Prosocial behavior is generally described as behavior that is intended to help another person (Keltner, Kogan, Piff, & Saturn, 2014). In this study, participants are asked to help another person by conducting a simulated home visit and applying principles they have encountered in an academic setting to a simulated context and situation. The simulation also places extra burdens on the student's ability to engage in forecasting based on those principles. Forecasting seems critical to the regulation of empathic concerns and, by extension, to the use of ethnocultural empathy and prosociality. The simulation demands reflective and forecasting activities by engaging the student in an assessment of a family's situation and the completion of a plan of action for the family, while assembling the evidence for his or her personal inferences and judgments throughout the simulation.

At a most general conceptual level, we consider serious educational play to be premised on the view that in any practice profession an epistemic frame for learning is fundamental. Following Shaffer, Squire, Halverson, and Gee (2005), we theorize that helping behaviors can be understood within an epistemic frame composed of knowledge, skills, values, and identity linked by a particular educational epistemology, which we define as a technology of making decisions and justifying actions. Shaffer was an early forecaster of the potential impact of the educational use of experiences in video games, computer simulations, and other interactive learning environments to help deal more effectively with situations outside the original context of personal learning. In general, epistemic frames have been described as a way of affiliating a body of knowledge with practice. One premise of our work with serious educational games is the view that in the teaching and helping professions, practice-based learning can be primary, whether it be through life's personal encounters, internships, or play, such as that experienced in a simulation.

## Brianna's World

Brianna's World (Krysik, 2018) was intentionally developed to expose player values and biases in a context where students could apply their academic knowledge, personal experience, and nascent practice skills to help a family and teenager. The player assumes the identity of a school social worker whose supervisor gives him or her a school referral that describes a series of concerns about a teenager in high school. The player must visit the home of the teen, complete a situational assessment, and propose a plan of action. In the simulation, reflections about identity are provoked by the game and interactivity is required in each encounter with simulated characters and their situation. The encounters demand appraisal of self and other such that interpersonal emotional regulation (IER) can be evoked in each interaction and decision. In Brianna's World, participants use IER when they must choose their helping strategies based on inferences. For example, players interact with characters in the simulation by selecting a response from a set of texts. Each selection is judged dynamically for empathy, authenticity, and cultural awareness with ribbons of different colors that appear and add or subtract color to their respective meter. The simulation also pauses periodically, and at those points, the players interact by selecting evidence that has concerned them, such as a hidden cell phone, and registering their inferences about that observation in preparing an assessment. The players must identify and arrange their sources of data and their inferences, building what will become the argument for their ultimate plan of action. When the simulation is completed, the players will have built an assessment and plan of action by selecting and arranging data and evidence to support their primary and secondary inferences. The completed assessment and plan of action are available after ending the simulation as a document that can be studied, shared, and discussed with others.

The simulation was designed as an opportunity to provide the learner with dynamic feedback while focusing on the production of prosocial behavior and the use of the self-regulating and forecasting aspects of empathy (Grecucci, Theuninck, Frederickson, & Job, 2015; Williams, 2007). The extent to which a social worker might depend on empathy in practice has been the subject of many articles (Segal & Wagaman, 2017; Stanley, Mettilda, & Meenakshi, 2018), including a social work model of empathy (Gerdes & Segal 2009, 2011). In the simulation we have developed, participants use IER when they must choose their helping strategies based on inferences. But the fact that empathy is valuable does not imply that it is always positive. When empathy is generated by exposure to suffering, it can foster burnout and "compassion fatigue" (Gleichgerrcht & Decety, 2013; Wagaman, Geiger, Shockley, & Segal, 2015).

As we have indicated, empathy regulation has special importance to those in professions such as social work, education, and health. Thieleman and Cacciatore (2019) demonstrated that generating simulated exposure to the major life events of others can assist students with learning the empathetic regulation they require in order to be helpful. An excess of empathy has also been shown to variably influence decision making (Hojat, 2016). There are a number of other issues when empathy is regulated and the goal to improve another's well-being presents difficulties for the person(s) for whom the goal is formulated. It is difficult to underestimate the influence and effects of empathic IER. For example, social workers, educators, and health professionals must respect the dignity of others and act in terms of their well-being, even though this may generate a negative experience, and, for the professional, could induce guilt, moral conflict, and weakened goals. It is also the case that even in the conduct of prosocial behaviors, the professional may experience value conflicts. For example, in the simulation, the player is presented with situations in which his or her response can worsen the emotional state of another but contribute to the achievement of a long-term goal.

Avoiding these issues might require the use of empathy in an instrumental manner that one hopes will benefit those being helped. In this regard, empathic IER requires two fundamental processes: affective forecasting and self-control. These processes are supported in the simulation in part through the production of empathic concern for the mother and teen. The design supports player self-regulation in assessment activities, such as with tasks that establish long-term goals for the family. Forecasting occurs when players must identify how possible future events will influence the emotional experience of themselves and other characters in an epistemic frame. Empathic concern can produce sophisticated prosocial goals that are informed by the student's educational preparation and necessitate significant cognitive effort as well as emotional regulation.

## Components of the Scale of Ethnocultural Empathy

In our investigation, the Scale of Ethnocultural Empathy (Wang et al., 2003) was used to measure player ethnocultural empathy. The global scale contains four subscales, empathetic feeling and expression (EFE), empathetic perspective taking (EPT), acceptance of cultural differences (ACD), and empathetic awareness (EA). EFE measures responses to the experiences of people from racial or ethnic groups different from the respondent's, as well as responses to discriminatory or prejudiced attitudes. EPT measures respondent efforts to understand the emotions and experiences of people from other races or ethnic groups. ACD has items that capture respondent understanding, acceptance, and valuation of cultural customs and traditions. The final subscale, EA, measures the degree to which the respondent is aware of or knows about experiences of racial or ethnic groups different from their own. Each of the 18 items on the scale are scored on a 6-point scale ranging from *complete agreement* with an item to *complete disagreement.* Total scores range from a lower level of ethnocultural empathy (0 to 79) to the highest levels (90+). The measure was completed by students playing the simulation both before and shortly after completion.

## Components of the Prosocial Tendencies Measure

Prosocial behavior was measured using a 20-item form of the Prosocial Tendencies Measure (Carlo, Hausmann, Christiansen, & Randall, 2003). The Prosocial Tendencies Measure assesses six different types of prosocial behaviors. *Altruistic* prosocial behaviors are those motivated by concern about the welfare and needs of another. *Compliant* prosocial behaviors are those that are enacted in response to a request for help. *Emotional* prosocial behaviors are those that are a response to emotional, distressing situations. *Public* prosocial behaviors are those calculated to gain the respect or attention of others. *Dire* prosocial behaviors are those that happen in a crisis or in an emergency situation. *Anonymous* prosocial behaviors are those in which the behavior is directed to an unknown person or cause, such as in donating to a nonprofit. Players were asked to rate the extent to which the item described them on a 5-point scale ranging from *does not describe me at all* to *describes me greatly.* The measure was completed after playing the simulation.

## Method

The research was approved by the Institutional Review Board of the associated university. Brianna's World was used in a set of 10 classes that dealt with the integration of field instruction and classroom learning at the senior undergraduate level. The 127 students were briefed about the contents of the simulation and were given an option not to participate in the research. Although none of the students took the non-participation option initially, 12 of the students did not respond. Of the remaining 115 students, another 10 did not complete all of the measures. The students were uniformly able to complete the game and measures during their normal class period. One of the researchers attended each of the participating classes and introduced students to the game. The researcher remained in the classroom until the session was completed. The ethnocultural empathy measure (Wang, 2003) was administered pre- and post-gameplay to all students.

## Results

Student responses were significantly higher on ethnocultural empathy on their posttest compared to their pretest. The results of the global score, $t(104) = 17.08$, $p = .00001$, indicated much more empathetic sensitivity from pre- to posttesting. In addition, the effect size (Cohen's $d = 1.54$) was large, indicating the magnitude of the difference. Table 1 indicates that across all races in this preliminary round of exposure to Brianna's World, there was a strong, positive effect on the experience of ethnocultural empathy. The largest score change from pre- to posttest was among Black participants. It is notable that American Indian and mixed-race students were the only two groups whose scores, though higher in the posttest, were not in the high ethnocultural empathy score range (90+).

| Race | Count | Average pre-test Ethnocultural global score | Average post-test Ethnocultural global score |
|---|---|---|---|
| Hispanic | 35 | 77.3 | 93.2 |
| American Indian | 6 | 74.2 | 83.7 |
| Black | 10 | 74.8 | 93.7 |
| White | 34 | 75.1 | 90.8 |
| Mixed | 11 | 76.4 | 84.2 |
| Not identified | 9 | 75.3 | 93.2 |
| **Total** | **105** | **75.8** | **90.9** |

*Table 1. Global ethnocultural pre- and posttest scores by race.*

As shown in Table 2, racial and ethnic minority (REM) women had higher average item scores on one of four subscales, ethnocultural perspective taking (EPT), and on the overall average item score at pretest compared to the other groups. REM men were highest on empathic feeling and expression (EFE) at pretest, whereas White men were highest on acceptance of cultural differences (ACD), and White women were highest on empathetic awareness (EA). That position changed at posttest with White men scoring highest on empathetic feeling and expression. Although the scores of racial minority women remained relatively the same from pretest to posttest, other groupings of students reported an elevated sense of overall ethnocultural sensitivity. In particular, White males had a significantly higher level of ethnocultural empathy in the posttest. Every other group result indicated small rises in ethnocultural empathy levels from pre- to posttest. Other studies have reported large differences in racial groups as well as fairly large gender differences in ethnocultural empathy (Cundiff & Komarraju, 2008; Wang et al., 2003). That was not the case in this sample, likely because these were students pursuing a professional social work degree who may have been more predisposed to empathy given their career choice, as well as having experienced considerable exposure to it during the course of their social work studies. Notably, White women were less likely to report sensitivity to ethnocultural perspective taking than others in both the pretest and posttest. On the other hand, they were highest in empathetic awareness on the pretest. Our preliminary findings lead us to hypothesize that the intersectionality of racism and sexism may contribute to a continuous, conscious awareness of ethnocultural empathy among racial ethnic minority women (Lu, Hancock, Hill, & Keum, 2019). In this sample, racial ethnic minority women registered a continuous level of ethnocultural empathy whereas other groups, especially White men, reported an immediate, heightened sense of overall ethnocultural empathy in the posttest.

| | Pretest | | | | |
|---|---|---|---|---|---|
| **Variable** | **EFE** | **EPT** | **ACD** | **EA** | **Overall** |
| REM Women | 4.96(1.15) | 4.81(.83) | 5.39(.68) | 5.29(.87) | 5.09(.47) |
| REM Men | 5.26(.53) | 4.66(1.02) | 5.05(.59) | 4.86(1.30) | 4.99(.71) |
| White Women | 5.04(.70) | 3.82(.92) | 5.59(.43) | 5.41(.64) | 4.98(.42) |
| White Men | 5.17(.66) | 4.25(1.07) | 5.41(.93) | 5.28(.56) | 5.04(.47) |
| All | 5.03(.71) | 4.47(.99) | 5.41(.64) | 5.28(.85) | 5.05(.48) |
| | | | | | |
| | **Posttest** | | | | |
| **Variable** | **EFE** | **EPT** | **ACD** | **EA** | **Overall** |
| REM Women | 5.08(1.19) | 4.72(.94) | 5.33(.90) | 5.17(1.09) | 5.08(.65) |
| REM Men | 5.18(.67) | 4.75(.75) | 5.11(.68) | 5.52(.62) | 5.15(.54) |
| White Women | 5.17(.64) | 4.05(1.08) | 5.66(.42) | 5.49(.50) | 5.10(.46) |
| White Men | 5.38(.52) | 4.44(.78) | 5.59(.60) | 5.47(.47) | 5.32(.47) |
| All | 5.13(.71) | 4.52(.99) | 5.42(.76) | 5.34(.87) | 5.11(.57) |

*Note: REM=racial/ethnic minority. Item averages are followed by SD in quotes. EFE=Empathetic Feeling and Expression, EPT=Empathetic Perspective Taking, ACD=Acceptance of Cultural Difference, EA=Empathetic Awareness*

*Table 2. Ethnocultural empathy average subscale item scores by race and gender.*

The Prosocial Tendencies Measure results were similar across all groups. Altruistic prosocial behaviors were reported the most (4.12, *SD* = .78). This was followed by compliant, emotionally motivated, and dire and anonymous forms of prosocial behavior. Public prosocial behavior tendencies were the lowest rated type of behavior. It seems sensible that this would be the case given that students in the helping professions would likely not be looking for public recognition for behavior that they deemed appropriate to their helping profession.

## Summary

We are encouraged that the preliminary results based on this single instance of simulated play were able to show significant positive gains in overall ethnocultural empathy. Further, we are encouraged at the magnitude of the gains, especially among White men and women, as well as REM men. The average item scores indicate students were inclined to value all forms of ethnocultural empathy, but the noticeably lower levels of ethnocultural perspective taking across all groups at both pre- and posttest are a sign that efforts to understand the emotions and experiences of people from other races or ethnic groups are a component worth strengthening in the simulation. Unlike in earlier research, there were not major differences in this sample by gender or REM group other than the valuation of empathetic perspective taking by White women. Although our measure of prosocial action was administered only post-simulation, it does indicate that student motivation to help others is strongly connected to a concern about the welfare and needs of others. This finding supports a recognized need to continue to develop the simulation with a focus on interpersonally regulated empathy that helps students critically think about their helping goals and yet retain the relational authenticity they value.

Since the current version of the simulation uses language suitable for social work, this version of the simulation needs to continue to be used across social work–training programs to further establish value and effects. However, small changes in the narrative could be made such that future research could continue with diverse students enrolled in other disciplines, including other helping professions. It does appear, however, from these initial findings, that this simulation can provide a narrative for cultivating a counter space for youth. We have no evidence yet that it supplies a source of renewal for a human sociality of ethnocultural empathy, but we do so far find that levels of ethnocultural empathy can be heightened, at least temporarily, by participation in the simulation. Further research needs to be directed toward examining the sustainability of simulation effects, such as those we have measured. In this case, we envision future simulation spaces where all people can practice acts of humanitarian value, social equality, respect for diversity, and social justice.

## References


Batson, C. D. (2009). These things called empathy: Eight related but distinct phenomena. In J. Decety & W. J. Ickes (Eds.), *The social neuroscience of empathy* (pp. 3–15). Cambridge, MA: The MIT Press.

Carlo, G., Hausmann, A., Christiansen, S., & Randall, B. (2003).Sociocognitive and behavioral correlates of a measure of prosocial tendencies for adolescents. *Journal of Early Adolescence, 23*(1), 107–134.

Crocker, J., & Canevello, A. (2012). Consequences of self-image and compassionate goals. In P. G. Devine & A. Plant (Eds.), *Advances in experimental social psychology* (pp. 229–277). New York, NY: Elsevier.

Cundiff, N. L., & Komarraju, M. (2008). Gender differences in ethnocultural empathy and attitudes towards men and women in authority. *Journal of Leadership & Organizational Studies*, 15(1), 5–15.

Decety, J., & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, 3(2), 71–100.

Gerdes, K. E., & Segal, E. A. (2009). A social work model of empathy. *Advances in Social Work*, 10(2), 114–127.

Gerdes, K. E., & Segal, E. A. (2011). Importance of empathy for social work practice: Integrating new science. *Social Work*, 56(2), 141–148.

Gleichgerrcht, E., & Decety, J. (2013). Empathy in clinical practice: How individual dispositions, gender, and experience moderate empathic concern, burnout, and emotional distress in physicians. *PloS One*, 8(4), e61526.

Grecucci, A., Theuninck, A., Frederickson, J., & Job, R. (2015). Mechanisms of social emotion regulation: From neuroscience to psychotherapy. In M. L. Bryant (Ed.), *Handbook on emotion regulation: Processes, cognitive effects and social consequences* (pp. 57–84). Hauppauga, NY: Nova Science.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry*, 26(1), 1–26.

Herrera, F., Bailenson, J., Weisz, E., Ogle, E., & Zaki, J. (2018).Building long-term empathy: A large- scale comparison of traditional and virtual reality perspective-taking. *PLoS One*, 13(10). https://doi.org/10.1371/journal.pone.0204494

Hoffman, M. L. (2000). *Empathy and moral development.* New York, NY: Cambridge University Press.

Hoffman, M. L. (2008). Empathy and prosocial behavior. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (pp. 440–455). New York, NY: Guilford.

Hojat, M. (2016). *Empathy in health professions education and patient care*. New York, NY: Springer.

Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion*, 16(8), 1107–1116.

Keltner, D., Kogan, A., Piff, P. K., & Saturn, S. R. (2014). The sociocultural appraisals, values, and emotions (SAVE) framework of prosociality: Core processes from gene to meme. *Annual Review of Psychology*, 65, 425–460.

Koole, S. L., & Tschacher, W. (2016). Synchrony in psychotherapy: A review and an integrative framework for the therapeutic alliance. *Frontiers in Psychology*, 862(7), 1–16.

Krysik, J. (2018). Brianna's world [Computer software]. Phoenix: Arizona State University.

Lamothe, M., Boujut, E., Zenasni, F., & Sultan, S. (2014). To be or not to be empathic: The combined role of empathic concern and perspective taking in understanding burnout in general practice. *BMC Family Practice*, 15(1), 15. doi:10.1186/1471-2296-15-15

Levine, E. E., Barasch, A., Rand, D., Berman, J. Z., & Small, D. A. (2018). Signaling emotion and reason in cooperation. *Journal of Experimental Psychology: General*, 147(5), 702–719.

Lu, Y., Hancock, G. R., Hill, C., & Keum, B. T. H. (2019). The effectiveness of helping skills training for undergraduate students: Changes in ethnocultural empathy. *Journal of Counseling Psychology*, 67(1), 14–24. https://doi.org/10.1037/cou0000404

Morelli, S. A., Lee, I. A., Arnn, M. E., & Zaki, J. (2015). Emotional and instrumental support provision interact to predict well-being. *Emotion*, 15(4), 484–493.

Morelli, S. A., Ong, D., Makati, R., Jackson, M. O., & Zaki, J. (2017). Empathy and well-being correlate with centrality in different social networks. In *Proceedings of the National Academy of Sciences of the United States of America*, 114(37), 9843–9847. https://doi.org/10.1073/pnas.1702155114

Rasoal, C., Eklund, J., & Hansen, E. M. (2011). Toward a conceptualization of ethnocultural empathy. *Journal of Social, Evolutionary, and Cultural Psychology*, 5(1), 1–13.

Segal, E. A., & Wagaman, M. A. (2017). Social empathy as a framework for teaching social justice. *Journal of Social Work Education*, 53(2), 201–211. https://doi.org/10.1080/10437797.2016.1266980

Shaffer, D. W., Squire, K. D., Halverson, R., & Gee, J. P. (2005). Video games and the future of learning. *Phi Delta Kappan*, 87(2), 104–111.

Shin, D. (2018). Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? *Computers in Human Behavior*, 78, 64–73.

Stanley, S., Mettilda, G. B., & Meenakshi, A. (2018). Predictors of empathy in women social workers. *Journal of Social Work*, 20(1), 43–63. https://doi.org/10.1177/1468017318794280

Thieleman, K., & Cacciatore, J. (2019). 'Experiencing life for the first time': The effects of a traumatic death course on social work student mindfulness and empathy. *Social Work Education*, (38)4,470–484. https://doi: 10.1080/02615479.2018.1548588

Wagaman, M. A., Geiger, J. M., Shockley, C., & Segal, E. A. (2015). The role of empathy in burnout: Compassion, satisfaction, and secondary traumatic stress among social workers. *Social Work*, 60(3), 201–209. https://doi.org/10.1093/sw/swv014

Wang, Y., Davidson, M. M., Yakushko, O. F., Savoy, H. B., Tan, J. A., & Bleier, J. K. (2003) The Scale of Ethnocultural Empathy: Development, validation, and reliability. *Journal of Counseling Psychology*, (50)2, 221–234.

Williams, M. (2007). Building genuine trust through interpersonal emotion management: A threat regulation model of trust and collaboration across boundaries. *Academy of Management Review*, 32(2), 595–621.

Zaki, J. (2020). Integrating empathy and interpersonal emotional regulation. *Annual Review of Psychology*, 71, 1–24. https://doi.org/10.1146/annurev-psych-010419-050830

# 11. Developing Critical Thinking Among University Students Through Curriculum-Embedded Participatory Activities

JESSLYN LAU

**Abstract:** The development of students' critical thinking is an important aim of many tertiary institutions today and is regarded as essential for graduates. In current times, digital tools are omnipresent in the everyday lives of learners who are already familiar with creating content outside their formal school settings. While students' online creations are often considered informal out-of-school activities, there is a need to understand how activities could be leveraged to help students develop critical thinking for academic purposes. One means of nurturing critical thinking is to develop learning environments that facilitate and support opportunities for students to engage in a participatory culture. This research elaborates the development of an active community of participatory culture to facilitate critical thinking through using knowledge blogs in a higher education program. Positive outcomes were observed in this study; the themes included *social support* and *co-learning*. This study calls upon further exploration into the understanding of the effects from participatory activities for learning in school and how participatory pedagogy could be applied across other domains.

## Introduction

Critical thinking is of increasing importance to students' employability after their graduation; many tertiary institutions regard critical thinking to be essential for today's graduates. Critical thinking was defined in *The Delphi Report* as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (Facione, 1990, p. 2). Various universities have acknowledged the importance of these skills and incorporated critical thinking as their desired graduates' outcomes (Moore, 2004; Mummery & Morton-Allen, 2009; Prasad, 2009). One means of developing students' critical thinking is to develop learning environments that can facilitate and support opportunities for students to engage in a participatory culture (McLagan & Nel, 1997; Zacharis, 2009).

While new media developments have allowed millennial learners to be involved in various forms of online and social media activities, students' online creation outside of their formal school settings has hardly been a topic area of discussion for education. Digital technology and involvement in participatory media activities have become integral in the lives of 21st-century students, but formal school settings often do not encourage students to express themselves academically in such ways. Moreover, most millennials' online postings are often seen as self-centered expression and hardly encouraged as an active form of participation that encourages critical thinking. A participatory culture as defined by Jenkins (2006) describes contemporary cultures in which members of society not only consume media content but are also creating and distributing it. Members in participatory culture believe their contributions matter and feel some degree of social connection with one another; in the process, informal mentorship is also passed along to novices (Jenkins, 2006).

Although most millennials own a social media account and are involved in some form of content creation and distribution, most of these activities are for recreational purposes and rarely involve mentorship or establishing discussions that could help critically further their thought. Research that investigates millennials' use of user-generated media found that Facebook is the most used social network among millennials for fulfilling their information, entertainment, and mood-management needs (American Press Institute, 2015; Shao, 2009). Most millennials were also cited as using the social network for recreational purposes such as sharing of personal photographs, seeing what their friends were talking about, and to find things that entertained them (Malik, Dhir, & Nieminen, 2016; Shao, 2009) rather than creating and distributing content or building social connection with one another. Bird (2011) stated that media engagement might take many forms other than the creation of more media; likewise, Ochoa and Duval (2008) suggested that perhaps only 9% of online users would contribute to a few elements online and the minority, 1%, would contribute a lot online. Although the possibility of learning through their online creation is relevant to our millennial learners today, the literature by Bird (2011), Ochoa and Duval (2008), and Malik et al. (2016) showed that there possibly have been more users who are passive consumers of media than those who are actively creating and distributing content.

To encourage students to develop critical thinking, it is central to connect teaching and learning to students' everyday lives in a way that could reflect the actual multimodal lifeworld that they are familiar with (Biesta & Lawy, 2006; Dewey, 1916/2005). It is hence important to understand the efficacy of students' online creation in detail and how these participatory activities could be scaffolded and transferred to help students develop critical-thinking skills for academic purposes. As such, continued research into effective design, implementation, and assessment of its learning outcomes is essential to facilitate successful student learning. This leads to the foci for this paper: Can participatory activities help in developing students' critical thinking? How can participation activities help encourage students' knowledge construction?

## Methods

A series of blogging activities that involve students to complete weekly blogging tasks both independently and in groups, collectively, were carefully designed and embedded as curriculum-participatory activities (CPA) in this study. Blogging was selected as there are many affordances offered by blogging; for example, the commenting function through which instructors, peers, or external reviewers can provide feedback on student-created content could serve social constructivist approaches to learning that focus on students' active participation in knowledge construction through social interactions (Ferdig & Trammell, 2004; Fessakis, Tatsis, & Dimitracopoulou, 2008; Franklin & van Harmelen, 2007). The participants in the study were 13 students enrolled in a communication module for their psychology degree from an Australian university based in Singapore. Through an online learning community, students created and constructed knowledge blogs over a 15-week course. The International Critical Thinking Reading and Writing Test (ICTRWT) served as the main framework for the design of the CPA and also the coding template for the thematic analysis (Paul & Elder, 2006). The ICTRWT was one of the critical thinking–assessment tools developed and designed by Paul and Elder, and it has been widely used to assess students' critical thinking (Aunurrahman, Hamied, & Emilia, 2017; Lu & Xie, 2019). The test consists of five forms—paraphrasing, explicating, analysis, evaluating, and role-playing (see Table 1). The primary sources of the data were the pre- and postblogging activities' writing samples as well as blog posts throughout the course. An informal group interview was conducted at the end of the course. The group-interview approach was an informal conversation to allow the opportunity for each participant to share his or her experiences openly (Kvale, 2008). The approach also served to minimize power structures between the students and interviewer; this helped to put each interviewee on a common standing. In the interviews, the students were encouraged to express their attitudes toward the CPA and explain their reasons.

| | | |
|---|---|---|
| First Level | Paraphrasing | Accurately translating an author's wording into our own |
| Second Level | Explicating | State main point in a sentence<br>Elaborate the key idea with greater detail<br>Provide examples of what you are saying<br>Generate metaphors, analogies, pictures, or diagrams of the basis thesis |
| Third Level | Analysis | Identify key elements of thought including purpose, question, information, interpretation and inference, concepts, assumption and, implications and consequences |
| Fourth Level | Evaluation | Appling intellectual standards such as clarity, precision, accuracy |
| Fifth Level | Role-Playing | Role-play the thinking of the author |

*Table 1. An example of codes developed a priori from the template of codes.*

The method of analysis chosen for this study was a hybrid approach of thematic analysis, which incorporated both the data-driven inductive approach of Boyatzis (1998; see Table 2) and the approach outlined by King and Brooks (2017), which was the deductive a priori template of codes (see Table 1). The research analysis was an iterative and reflexive process; this approach allows the researchers to cycle back and forth between the stages (King & Brooks, 2017) to devise themes more extensively "where the richest aspect of the data is found" (Brooks & King, 2014). The researcher and a colleague coded the student pre- and postblogging independently using the initial template. Word-processing software Microsoft Word was used for the coding and storing of data throughout the research project. The researchers compared their individual coding and discussed points of difference and similarity in their coding to achieve intercoder reliability (Creswell, 2003). Subsequently, some adjustments were made to the original coding framework to refine the domains and their descriptors. The revised coding framework then guided the researchers' final coding of the student writing data. Finally, memos and writing samples were reanalyzed using the revised coding framework to determine the themes in this work. The themes included *social support* and *co-learning*.

## Can Participatory Activities Help in Developing Students' Critical Thinking?

### Social Support

The CPA has encouraged students to develop critical thinking in several ways; codes derived from the postwriting data showed attitude, explicating, analysis, evaluation, role-playing, social relationship, and juxtaposition (see Table 2).

| Codes | Pre | Post | Definition |
|---|---|---|---|
| Attitude | | x | *Confident of self-expression*<br>*Demonstrates self-belief as a writer/reader/thinker, etc.; finds composing easy*<br>*Having a goal/self-believe/ambition* |
| Remembering | x | x | *Recognizing*<br>*Recalling* |
| Paraphrasing | x | x | *Accurately translating an author's wording into our own* |
| Explicating | | x | *State main point in a sentence*<br>*Elaborate the key idea with greater detail*<br>*Provide examples of what you are saying*<br>*Generate metaphors, analogies, pictures, or diagrams of the basis thesis* |
| Analysis | | x | *Identify key elements of thought including purpose, question, information, interpretation and inference, concepts, assumption and, implications and consequences* |
| Evaluation | | x | *Appling intellectual standards such as clarity, precision, accuracy* |
| Role-Playing | | x | *Role-play the thinking of the author* |
| Self-centred | x | x | focuses primarily on the bloggers' own needs as learners and writers, and it does not consider the needs of readers<br>Include photographs of him/herself/selfies |
| Social relationships | | x | Has the intended audience in mind, speaks directly to them and engages them in a conversation/dialogue<br>Seeks support, dialogue with feedback givers, blogging community, or makes friends with other writers<br>Addresses other peers/group writers on similar assignments |
| Juxtaposition | | x | Happy but sad that they have come to the end of the blogging journey |

*Table 2. Coding: Analyzing pre- to postwriting samples.*

Consistent throughout the study was a need for students to seek *social support* from their peers and teacher. To begin with, the CPA helped students realize that there is a real audience reading their work besides their teacher. The students in the current study began the course with a weak concept of the audience; in their prewriting samples, the audience was seen as an abstract concept. Most of the prewriting samples were directed to no one in particular or only to the teacher and focused primarily on the bloggers' own needs. This can be seen in Suzy and Jenny's (not their real names) prewriting samples (Note: Spelling in all student excerpts is quoted as in the original student writing.):

> Suzy: I may not work in the makeup industry, but I feel it is a good skill to have […] I like doing nails, and usually around Chinese New Year or any special occasions my friends will ask me to help them beautify their nails! Below is one if the nail design I have done for my friend for the upcoming CNY.

> Jenny: Greetings, Professor! Nothing to report! Hmm? What's that? You're curious about me Professor? Well, I

> don't know if I'm all that interesting but very well! Allow me to introduce myself! The name's Jenny! […] Surprised Professor? Don't you worry though! I do take my job and assignments seriously I assure you that.

Suzy and Jenny's prewriting samples demonstrated expression of self-centeredness that primarily focused on their own needs. Posting of *selfies* (self-portrait digital photographs) and travel photographs were also a common feature in almost all of the students' prewriting samples. This is consistent with McGrail and Davis's (2011) findings that show early student writing to be self-centered and often not addressed to anyone in particular.

In analyzing the students' blogs, it can be observed that the active engagement in using the comment feature helped them apprehend that there were readers other than their teacher (see Table 2). This finding is consistent from the group interview, in which students felt happy that there was an audience reading their blog entries; they felt further gratified when they received a *like* from their classmates. Motivation to continue writing and competition among the students to perform better were also observed. When asked about their feelings when they received a *like* from the teacher, most expressed that they felt a sense of acknowledgment and encouragement.

> Charlie: When I saw my friend received a *like* from teacher, I will think like what did she wrote and what's missing from my blog, so I will read her blog and try that [what she did and I didn't] in the next post

> Alice: Sometimes after reading my classmate's post, I was like, why didn't I think of this [the topic] in such way

Students felt encouraged that there was a real audience reading their post and someone was appreciating and anticipating their next blog entry.

> Suzy's comment to Shi: Aloha Shi my friend, let me start of by saying that I really like reading your blog post! It is always so entertaining! Not too like boost your ego, but I could like read your blog without getting bored at all! Love that you gave really concise information […] Anyways, it was great reading your blog post, can't wait to read the next one! Cheers

A juxtaposition of both relief and sadness can also be observed in their end-of-the-module post. Most students expressed that they felt relieved that they had arrived at the end of the journey but also expressed sadness that they are going to miss their classmates after the course. This shows connection and social interaction with their audience; the audience was perceived as real people and as personal friends.

> Suzy: Ah the day has finally come, where I upload my (maybe) last blogpost. I honestly do not know how you can beat the pure bliss in that, […] but, I have to say its rather sad I will miss all my readers ❤

> John: High Folks! Welcome back to my blogpost! It has been a long journey my friends, but we have finally made it! The final blogpost! Okay, let's not get too dramatic, shall we? I know I know, I am going to miss you guys too, BUT every end marks a new beginning, so, save your tears little penguins, for nothing is ever over!

> Natalie: Hey Alice! I'm so sad but a little happy that this will be our last blog post and this will be my last comment for you […] Take care Alice!

The students' blog posts showed increased social support and friendship formed over the course of 15 weeks. The students expressed receptiveness toward the CPA, and the blogging platform allowed them to engage in various discussions and the active blogging community helped them realize that they had an audience other than their teacher. Throughout their blogging journey, students received acknowledgment and support from their peers and teacher. This encouraged and motivated them to write more and to perform better in their subsequent posts.

## How Can Participation Activities Help Encourage Students' Knowledge Construction?

### Co-Learning

Students' postwriting samples demonstrated a shift from self-centered expression to a high level of explication, analysis, and evaluation, and most students demonstrated role-playing in their final blog post (see Table 2). While Lu and Xie's (2019) study omitted ICTRWT's level of *role-playing* because the level is challenging for EFL students, the students in this study were able to demonstrate the role-playing level. This was mainly due to the nature of the blog post task, which involved them to reflect and to take on the role as a producer to co-create a video that demonstrated their understanding of user-generated content (UGC). In this task, the students were given the agency to decide on the content of their UGC. After a few discussions and scaffolds from the teacher, the students were able to decide how their story should proceed. Most of the students had no prior experience with video editing, yet most of them expressed that they had no problem editing the video. They were also able to seek help and learn from members who were more experienced with video editing.

In addition, students improved each other's ideas and helped clarify each other's thoughts using the comment feature. For instance, in a reflection post about the understanding and interpretation of feminism, Joey's comment for her classmate highlighted that reading her friend's post had given her a new perspective on this topic.

> Joey: Hi groupmate!! I share the same thought with you that I think feminism is to fight for equal rights of women. You brought out another point that is to stop objectifying women. I don't know much about it but after reading your post I agree that it should be stopped […] We are still responsible for the consequences even if we didn't plan to hurt anyone or to cause a crisis. I love your informative post! Look forward to your next post!:))

Separately, in a reflection activity about the issues of media ownership, Shi's comment to his classmates shows that the use of local events in his friend's blog helped him to make the topic of discussion more relatable to him.

> Shi: Hey there Josephine! This is a well detailed blogpost you have written. It informs me of the drawbacks and the advantages of each types of media, and you made it more relatable through the use of recent local events. I do agree that people do easily get influenced by the any sort of controversial news that fiddles with their emotional state, especially the pioneer generations of Singapore[…]

This was also consistent with the responses received from the group interview, which asked about how the CPA helped their understandings of semiotic analysis:

> Yes it does improve my understanding about semiotic analysis as by commenting and receiving comments, we learn more from each other's mistakes.

> Yes It does improve my understanding about illustrative analysis. By listening to the perspectives of others allow me to further and cement my understanding about semiotics analysis.

> Allows us to understand different points of view and encourages critical thinking whether to accept or reject our peer's ideas

The students' responses above demonstrated their ability to improve their understanding by learning from each other's mistakes and critically seeing the different points of view from their peers. This is consistent with one of the principles of knowledge building. In principles of knowledge building, Scardamalia (2002) expounded that students would be able to rise higher through continuous improvement in ideas and understanding, which allows students to create high-level concepts in a knowledge-building community. The comments from the students show continuous improvement in ideas and understanding through their active engagement in the act of commenting and responding to each other. When asked during the group interview to compare their feelings of completing activities on their own and with their peers, the students said:

> When working on a task alone, you tend to have ideas only from yourself, so sometimes, it lacks in perspective since there is only so much one person can know. However, when you work in a group, it allows a variety of viewpoints that may clash, relate or be totally different, which can come off more interesting and knowledge-building than working alone (provided that knowledge is consolidated at the end of the activity)

> When working alone, I feel that you won't have another person to correct you or support your ideas and everything

> Working individually requires your own knowledge and research however working as a team you get to be exposed to different perspective and therefore brainstorm together

The above responses show students were receptive and appreciative of the CPA. With this informal mentorship, students were able to build knowledge by improving ideas and understanding, learning from each other's mistakes, seeing the topic from different perspectives, and helping make the topic more relatable in their lives.

## Conclusion

This research aims to understand the learning outcomes of students through CPA; the major themes that emerged from this study were *social support* and *co-learning*. The students in this study expressed receptiveness toward the CPA; specifically, the active blogging community helped them realize that they had an audience other than their teacher. There was evidence that students' awareness and understanding of the audience improved toward the end of this research, and the CPA also provided an opportunity for them to discuss various issues beside talking about themselves. Throughout their blogging journey, the acknowledgment and support received from peers and teacher encouraged and motivated students to write more and to perform better in subsequent posts. Through the 15-week journey, the students developed a friendship with classmates from whom they sought social support and with whom they co-learned. The active and participatory components of blogging in this research not only invited students to express and support their ideas but also fostered an informal mentorship among themselves. Students were able to build knowledge by improving each other's ideas, learning from each other's mistakes, seeing the topic from different perspectives, and the CPA helped to make the topic more relatable in their lives. The development of critical thinking is a complex process; while positive outcomes were observed further exploration of the effects of CPA is necessary. Future research can focus on how a participatory pedagogy could be applied across other domains. This will help in designing more socially engaging learning environments to facilitate an active community of participatory culture.

## References

American Press Institute. (2015). *How millennials use and control social media.* Retrieved from https://www.americanpressinstitute.org/publications/reports/survey-research/millennials-social-media/

Aunurrahman, A., Hamied, F. A., & Emilia, E. (2017). Modeling academic writing for university students. In *Proceedings of the Ninth International Conference on Applied Linguistics* (CONAPLIN 9). Atlantis Press. https://doi.org/10.2991/conaplin-16.2017.1

Biesta, G., & Lawy, R. (2006). From teaching citizenship to learning democracy: Overcoming individualism in research, policy and practice. *Cambridge Journal of Education*, 36(1), 63–79. doi:10.1080/03057640500490981

Bird, S. (2011). Are we all produsers now? *Cultural Studies*, 25(4–5), 502–516. doi:10.1080/09502386.2011.600532

Boyatzis, R. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, CA: Sage.

Brooks, J., & King, N. (2014). Doing template analysis: Evaluating an end-of-life care service. In *SAGE Research Methods Cases*. doi:10.4135/978144627305013512755

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Dewey, J. (2005). *Democracy and education*. Stilwell, KS: Digireads.com. (Original work published 1916)

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Research findings and recommendations.* Newark, DE: American Philosophical Association. (ERIC Document Reproduction Service No. ED 315423)

Ferdig, R., & Trammell, K. (2004). Content delivery in the blogosphere. *THE Journal*, 31(7), 12–20.

Fessakis, G., Tatsis, K., & Dimitracopoulou, A. (2008). Supporting “learning by design” activities using group blogs. *Educational Technology & Society*, 11(4), 199–212.

Franklin, T., & van Harmelen, M. (2007). *Web 2.0 for content for learning and teaching in higher education.* Retrieved from http://ie-repository.jisc.ac.uk/148/1/web2-content-learningand-teaching.pdf

Jenkins, H. (2006). *Convergence culture: Where old and new media collide.* New York: New York University Press.

King, N., & Brooks, J. (2017). Case examples of the use of template analysis. In *Template analysis for business and management students* (pp. 47–72). London, UK: Sage. doi:10.4135/9781473983304

Kvale, S. (2008). *Doing Interviews.* Thousand Oaks, CA: Sage.

Lu, D., & Xie, Y. (2019). The effects of a critical thinking oriented instructional pattern in a tertiary EFL argumentative writing course. *Higher Education Research & Development*, 38(5), 969–984. doi:10.1080/07294360.2019.1607830

Malik, A., Dhir, A., & Nieminen, M. (2016). Uses and gratifications of digital photo sharing on Facebook. *Telematics and Informatics*, 33(1), 129–138. doi:10.1016/j.tele.2015.06.009

McGrail, E., & Davis, A. (2011). The influence of classroom blogging on elementary student writing. *Journal of Research in Childhood Education*, 25(4), 415–437. doi:10.1080/02568543.2011.605205

McLagan, P., & Nel, C. (1997). *The age of participation*. San Francisco, CA: Berrett-Koehler.

Moore, T. (2004). The critical thinking debate: How general are general thinking skills? *Higher Education Research and Development*, 23(1), 3–18. doi: 10.1080/0729436032000168469

Mummery, J., & Morton-Allen, E. (2009). The development of critical thinkers: Do our efforts coincide with students’ beliefs? In *The Student Experience: Proceedings of the 32nd Higher Education Research and Development Society of Australasia Annual Conference* (pp. 306–313). Darwin, Australia: HERDSA.

Ochoa, X., & Duval, E. (2008). Quantitative analysis of user-generated content on the web. In *Proceedings of the First International Workshop on Understanding Web Evolution* (*WebEvolve2008*; pp. 19–26). Retrieved from http://journal.webscience.org/34/

Paul, R., & Elder, L. (2006). *The international critical thinking reading and writing test*. Dillon Beach, CA: Foundation for Critical Thinking.

Prasad, D. (2009). Empirical study of teaching presence and critical thinking in asynchronous discussion forums. *International Journal of Instructional Technology and Distance Learning*, 6(11), 3–26. Retrieved from http://itdl.org/index.htm

Scardamalia, M. (2002). *Collective cognitive responsibility for the advancement of knowledge*. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago, IL: Open Court.

Shao, G. (2009). Understanding the appeal of user-generated media: A uses and gratification perspective. *Internet Research*, 19(1), 7–25. doi:10.1108/10662240910927795

Zacharis, N. (2009). Fostering students’ participation in online environments: Focus on interaction, communication and problem solving. *Journal of College Teaching & Learning* (TLC), 6(2), 25–34. doi:10.19030/tlc.v6i2.1169

# 12. Learners' Perceptions of Participating in STEM Hands-On Activities in an Out-Of-School Community-Based Organization Program

AREEJ MAWASI, RUTH WYLIE, AND ELISABETH GEE

**Abstract:** This paper investigates the potential for STEM hands-on activities to support adolescents' (5th and 6th grade) participation in STEM practices in an out-of-school community-based organization in an Arab town in Israel. In this study, we observed 4 hands-on activity sessions (total time = 395 minutes) at Al-Rowad for Science and Technology, a community-based organization for STEM education. In addition, we conducted interviews with the 10 participants to understand their perceptions of their learning processes and their perceptions of the activities. When prompted to describe the activities, procedures, outcomes, final products, and their learning process, learners responded in diverse ways. Our analysis reveals 3 findings: (a) These activities show potential for helping learners connect STEM practices to their daily lives; (b) learners have some misconceptions about science, art, engineering, and invention as disciplines, but also as a field of practice, even after engaging in out-of-school science activities; and (c) learners readily connect the STEM practices in the program with perceptions of science in their daily lives.

## Introduction

Learning happens across multiple places, spaces, and times (Bell, Tzou, Bricker, & Baines, 2012), enabling learners to participate in opportunities in formal settings such as schools, and across informal settings such as community clubs, online, and in public spaces (Barron & Bell, 2015; Ito et al., 2013). In STEM education, learning environments that help young people participate in out-of-school science practices are essential for encouraging individuals from nondominant populations to participate in STEM activities (e.g., Pinkard, Erete, Martin, & McKinney de Royston, 2017). These informal environments help learners position their identities in relation to STEM and develop ways to connect their everyday practices with STEM fields (e.g., Calabrese Barton et al., 2013; Pinkard et al., 2017).

Prior work demonstrates that participation in informal learning activities can afford opportunities for nondominant populations in STEM (including historically marginalized and oppressed groups) in which their perceptions about themselves and their practices are affected (e.g., Barton & Tan, 2010). For example, Pinkard et al. (2017) explored how a narrative-based STEM learning environment designed to engage young women positively affected their interest in computational activities. The young women took part in an out-of-school program that leveraged their existing interests and encouraged them to participate in STEM hands-on activities to create narrative-based digital artifacts. This enabled the young women to participate in STEM practices and reposition their identities and capabilities in relation to STEM. Similarly, in a study that investigated the development of agency in learning science among low-income students from historically marginalized ethnic and racial backgrounds, Barton and Tan's (2010) findings suggest that when activities are situated in community-based contexts, students increase their science learning agency and level of participation in community work, and begin to view themselves as capable of participating in science activities.

In this study, we build on work that addresses participation in out-of-school STEM education programs for historically marginalized and nondominant populations. Specifically, we seek to answer three questions: (a) How do learners perceive the connection between science and other disciplines? (b) How do out-of-school STEM activities help learners make connections between everyday science and school science? and (c) How does participating in these activities shape students' perceptions of scientists, artists, engineers, and inventors? The goal of the current study was to investigate the learning processes of people engaging in science and hands-on activities, specifically in a community-based program designed for the nondominant population of Arab Palestinian adolescents.

## Methods

### Context and Research Site

For this study, we collaborated with Al-Rowad for Science and Technology, a community-based organization situated in an Arab town in the Haifa district. Al-Rowad is led by Arab Palestinian scientists, science educators, and youth in Israel to provide access to science-education programs both in and out of schools. The organization serves historically marginalized populations from the Palestinian minority in the country. The need for these programs for Palestinian learners in Israel derives from multiple factors, including: (a) Palestinians in Israel are underrepresented in STEM fields, and this underrepresentation is reflected in the job market and higher education; (2) significant gaps in reading, math, and science literacy exist between Hebrew speakers and Arabic speakers in Israel, reflected in the most recent PISA reports of the 2018 Organization for Economic Co-operation and Development (OECD, 2019); and (c) historically, public science education within schools in this context has been shaped by dominant colonial narratives of Western science. This situation requires action from both public education and civil organizations to address these challenges and design equity-oriented learning environments that leverage the potential of Palestinian learners to engage and participate in STEM-related fields while also attending for how STEM impacts their lives.

One of Al-Rowad's programs is centered on engaging learners with high-quality, hands-on activities that go beyond the formal school science experience. The goal of these activities is to improve learners' attitudes toward STEM, help them better understand science concepts, forge connections between science and everyday life, and build an infrastructure for STEM leaders within the Arab Palestinian society in Israel. In this study, we observed four days (approximately 100 minutes each; total learning time approximately 395 minutes) of an out-of-school program in which learners completed hands-on activities that were designed, engineered, and facilitated by the organization.

Two instructors from the organization led the activities. The lead instructor facilitated discussion and guided learners through activities. This instructor has a degree in biotechnology engineering and has been part of the organization for five years. A second instructor served as an assistant and helped learners with the equipment and building during the hands-on activities. This instructor has a nursing education background and has been part of the organization for eight years.

### Activities

The hands-on activities are designed to engage learners in science learning in an out-of-school environment. Each day over the course of four days, learners engaged with one activity that covered diverse topics related to science. These activities (see Figure 1) have features that demonstrate science, engineering, art, and math as interconnected disciplines that are complementary to one another. The first activity, titled SAP (Super Absorbent Polymer), focused on concepts that combine diffusion, primary colors, and observing how chemicals change through time. The instructor began with an introduction that involved discussion with students about the major concepts. Next, students received instructions to complete the activity. To do this, they used test tubes, pipettes, and wood to build an artifact. In this activity, students separated a solution of three primary colors with a white substance and then observed the diffusion process when colors begin to merge. The second activity, Newton's Disc, began with an overview of the previous day's activity to emphasize connections across activities. In the introduction, the instructor discussed concepts related to movement, primary and light colors, and gear-wheel movement. Then, students did a physics experiment in which they built a Newton disc using a laser-cut gear. The third activity centered on building an illuminated drawing board. In this activity, participants learned about phosphorescence phenomenon and applied their understanding by creating drawings on their boards. The activity began with reviewing content from the previous day. Students then viewed slides about major concepts, completed an activity with lights on the board, and then engaged in a hands-on activity to create the drawing board. On the fourth day, students did an experiment with oil and water to learn about density and then created soap. Through the four activities, the instructors engaged students in discussions and presented slides with examples of science in everyday life, such as rainbow colors, animation, volcanoes, cooking, and wheels. The two instructors also encouraged participation from all learners by assigning roles, acknowledging individuals' contributions, and assigning voluntary homework to explore further information and present it the following day with other participants.

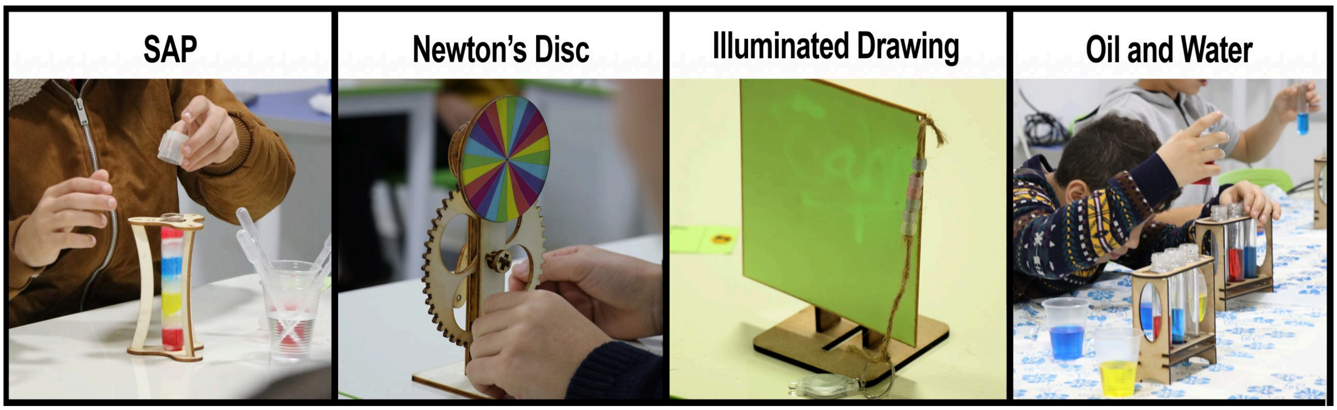


*Figure 1. These are examples of final outcomes of activities artifacts.*

## Participants

With assistance from Al-Rowad's coordinators, we recruited 10 learners to participate in the study. The participants (five boys, five girls) were all Arabic-speaking, from five different schools, and all were students at Arab public schools in Haifa District in Israel.

Participants were currently enrolled in fifth grade ($n$ = 5) or sixth grade ($n$ = 5). While the students predominantly speak Arabic and it is the first language for all of them, they also learn English and Hebrew as second and third languages in school. The interviews, lecture, and instructions were all conducted in spoken Arabic; thus, this was a diglossic environment, meaning that both academic and informal Arabic was used—informal during sessions and academic when using science concepts and filling out postactivity questionnaires.

## Data

We collected multiple sources of data, including observation notes, videos of activity sessions, interviews with instructors, motivation measures, postactivity reflections, and interviews with learners. In this paper, we focus on the postactivity reflections and semistructured interviews with learners.

After each day of instruction, learners completed a postactivity reflection that consisted of seven items designed to gather their perceptions of the experience, an explanation of what they learned, and examples that illustrate their explanation, either in the context of the activities or from their everyday lives. Interviews were conducted after all four days of instruction were completed. One researcher, who is fluent in Arabic, conducted the interviews. Interviews were 40–60 minutes long (average time = 48.4 minutes, *SD* = 8.9 minutes). All interviews were recorded. The interview protocol consisted of several questions that aimed at reviewing the activities and understanding students' perceptions of what they learned. In addition, we asked students about their perceptions of people in a variety of roles—scientists, artists, engineers, and inventors—in an effort to understand whether they see connections between these roles and the artifacts they created during the four days, and how they relate these roles to their daily lives. Finally, we asked questions regarding their overall STEM activities in daily life to understand whether they see a difference between informal learning and school science. To help with recall and provide context, the interviewer displayed photos of the final artifacts on a laptop screen, and learners chose which activity to discuss. On average, learners discussed 2.9 out of the four activities.

### Data Analysis

We conducted an inductive initial coding process for the postactivity questionnaire and identified students' perceptions of scientists, artists, engineers, and inventors in the interviews by asking them what they think people occupying these roles do, or what they think their characteristics are. We identified students' overall STEM-related activities in daily life through notes collected during interviews. Following Saldana (2015), one member conducted two coding cycles of the postactivity questionnaires to identify major themes derived from student reflections. The data from the postactivity questionnaire were aggregated and analyzed as a whole. These reflections were also compared to and aligned with student interview responses.

## Learners' Perceptions of the Activities

In this section, we describe learners' perceptions of the activities through the dominant themes derived from the coding of the postactivity questionnaires and also reflected during the interviews.

### Perceptions of Science

All learners mentioned that they found the activities fun. Learners who articulated reasons for their opinions did so in multiple ways: (a) providing general examples, (b) recalling specific information discussed during the activity, and (c) describing specific characteristics of the final artifact. Specifically, learners made statements such as "it was fun" ($n$ = 4) without explanation, or "I liked the outcomes and results" and "working hard to get results" ($n$ = 2), or general statements such as "I learned new things" ($n$ = 2). Examples of specific information students provided include "we learned about volcanoes," "I learned that oil and water do not interact or mix," "Newton's Disc move," and "I saw how animals could see." Finally, learners provided descriptions of the activity characteristics: The activity is beautiful and nice ($n$ = 5); it looks nice and has nice colors, compositions, and changes its colors ($n$ = 3); it has a nice structure for the model ($n$ = 2); it involves a hands-on experience ($n$ = 2); and it is magical ($n$ = 1). When asked during interviews, students operationalized "beautiful" and "nice" in multiple ways: aesthetic, useful, beneficial and respectful to others, and well designed. Similarly, when students were prompted to describe whether *science* (in general) is fun, their answers were all positive.

When learners were prompted to compare the activities they completed in this program with their school science classes, they described that “there are not as much hands-on activities, fun, and experiments [at school].” Learners framed school science as “writing, reading, using textbooks, and doing assignments.” Learners described this program’s activities as fun and entertaining because of the friendly environment and friends they could make in the program, while describing school science as boring ($n$ = 7) and requiring more reading and writing compared to the workshop ($n$ = 6). Learners also provided examples of how the science they are learning in the program is beneficial and useful ($n$ = 3) as it helps them “solve problems” and “connects to daily life.” They also described the program activities once again as “beautiful and nice” ($n$ = 3), and they recalled specific information from slides and instructions presented during the sessions as beneficial ($n$ = 3).

When asked what they learned, they often recalled lecture or discussion material rather than knowledge acquired during the hands-on part of the activity, suggesting that they viewed the hands-on part as “fun” and the more didactic part as “learning.” For example, learners provided information such as “I learned about primary colors” and “oil and water do not mix” ($n$ = 9), or they mentioned procedures they learned ($n$ = 2) such as “I learned how the eye works” without describing it, or they made general statements such as “I learned a lot,” “it is magical,” and “fun” ($n$ = 4). Other students mentioned that they learned information that was useful for their daily lives ($n$ = 3). During the interviews, learners particularly appreciated that the environment was friendly, that the instructors engaged everyone in the discussion, and that “everyone was able to participate” respectfully.

When learners were prompted to describe how they like doing science activities, their responses were consistent with previous items. All learners viewed science positively, except for one student who did view it positively in the postactivity questionnaire but not during the interview. This student described science activities she did as fun; however, she insisted that science in general and school science are not. Learners mentioned that they like science because it is fun and entertaining ($n$ = 8), made general yet positive statements (e.g., “I like it a lot”; $n$ = 4), recalled specific information from activities they did ($n$ = 3), expressed that they enjoyed the hands-on part of science ($n$ = 3), mentioned that science is beautiful ($n$ = 3) and that it is useful and beneficial ($n$ = 2), shared that they liked that they produced a take-home product ($n$ = 2), and said science cultivates intelligence and curiosity ($n$ = 2). When learners were asked whether they specifically liked the science activities they just completed, they mentioned qualities of the activity (useful, beautiful, has suspense, magical, smart, changes in shape; $n$ = 6), and, once again, provided specific examples of an observation during activities (“fun because of the sparkling substance,” “I learned about lava,” “it lights up”; $n$ = 4). They described the activities in terms of novelty ($n$ = 4) by mentioning general statements such as “new activities,” “different type of activities,” “did not see it before,” “it taught me new things,” and other statements such as “wonderful” ($n$ = 2), “they did activities in front of us” and “we could take it home” ($n$ = 2), and “it taught me new things.”

## Hands-On Activities in Relation to Science, Art, Engineering, and Invention

During the interview, we asked students which discipline was practiced as they completed the activities (science, art, engineering, or invention) or whether they felt like a scientist, artist, engineer, or inventor when doing the activities. Learners’ answers were mixed, even though all of the activities were framed by the instructors as science experiments with interdisciplinary features. For the scope of this paper, we provide two specific examples, one for a learner who talked about all four activities in the interview, and another who talked about three activities in the interview. In Table 1, we provide a high-level description that synthesizes learners’ responses of roles and qualities of scientists, artists, inventors, and engineers during the interviews.

The first student said that the SAP activity felt like an art project because of the colors. According to the learner, when doing this activity, she felt like an *artist*. When prompted to describe what an artist does, the student said, “He plans, thinks about the premise of what will happen in colors, and has a hypothesis about it,” and mentioned that she does that when she draws. When prompted to describe artists, she said, “An artist is smart, focuses, knows what he or she wants, benefits the world, improves and develops solutions, discovers, hypotheses, and [is] diligent.” Likely, she was trying to relate the artist qualities to activities she engages in as someone who likes art and drawing. When she described the oil and water activity, the student described it as a scientific experiment since it involved laboratory equipment such as test tubes and pipettes, and because there was a reaction when citric acid was added. When prompted to describe what a scientist does, she said, “He knows, builds, makes inventions, develops, innovates, does experiments, tries over and over again like Thomas Edison.” When the learner described the illuminated drawing activity, she said that she felt like an artist because the activity involved drawing on a phosphorous board. She provided examples of how she does this when she draws. Finally, when discussing the Newton’s Disc activity, the learner described it as encompassing multiple roles: an artist since it involves colors, a scientist since she discovered something new, an inventor since she was inventing something for herself, and an engineer since she managed to build everything correctly. When prompted to describe an inventor, she said, “He endures risk and fatigue and strives,” and when prompted to describe engineers she said, “Smart, bear challenges, and ask others to know their needs.”

The second learner described the SAP activity as an art activity because of the colors and learning about colors. The learner described an artist as someone who draws and plans. When describing the oil and water activity he referred to it as a science experiment, since it involves a chemical reaction. When prompted to describe what a scientist does, he said, “A scientist is intelligent, has a lot of knowledge, he has patience, and ethics, meaning he reasons about outcomes and consequences.” When asked about Newton’s Disc, the learner mentioned he felt like an engineer and inventor doing this activity, because “it involved installation and steps, stages, and discovery.”

Overall, student perceptions for roles of scientists, artists, inventors, and engineers were diverse. Some of these perceptions indicate an incomplete image about the roles and reflects how learners connect these roles to their daily lives in two ways: (a) traits they themselves have and (b) traits they think these professions have, based on things around them in daily life or normative views of STEM. For example, one participant described that she likes drawing a lot; when she described artists, she described their activity in relation to her own practices of art: “When the artist tries and experiments with things, if something does not work the artist tries it again. For example, when I want to draw little things I need to be patient and have the ability to fix it instead of damaging my drawing.” The same learner referred to engineering as a matter of “constructing engineering,” a theme that was dominant among all learners: associating engineering with building, designing and constructing buildings and physical infrastructure. Specifically, when asked about the characteristics of engineers she said, “I think … [my dad who is an engineer] loves building, treats people respectfully, engineers in a right way, meaning builds things that cause no harm or damage to people, has trust and honesty.”

| | Examples of Activities |
|---|---|
| Scientists | Scientists have patience and persistence, are smart, ethical, and socially responsible, and work alone. |
| Artists | Artists draw and paint, use imagination to plan and implement drawings, think and plan what they want, care about aesthetics, and have patience and persistence to experiment with things like colors and drawings. |
| Inventors | Inventors are smart and have patience. They need to be accurate in terms of mastery and focus, they have ideas and imagination, they experiment and try, and they build things and have equipment to do that. |
| Engineers | Engineers build things like buildings, they think about the pros and cons of things they build, they have to be accurate so they do not cause damage, they work with people, they plan things, do high- quality work, draw things on paper, and use imagination. Engineering is like geometry. |

*Table 1. Examples of perceptions for roles of scientists, artists, inventors, and engineers derived from learners' answers.*

## Discussion and Implications

As described earlier, all learners reported that they enjoyed the four activities. This was reflected in the postactivity questionnaires and also during the interviews. They also reported that the activities made them perceive science as fun. Incorporating fun, joy, and play was an essential component in supporting learners and helping them to connect to the program activities. Fun, joy, and play create learning opportunities that provide multiple modes of participation (e.g., planning, building, joining discussions, asking questions) (Gee 2017; Resnick, 2018). This allows students to participate in the activities and also helps learners perceive that doing science also could be a social activity.

At the same time, not all learners perceived these activities as science activities, with some describing them as "art only." This could stem from these activities being quite different from their school science activities—participants may have had difficulty connecting STEM practices with the science facts and phenomena often taught in school. Although learners described the scientific process used to create the artifacts, some learners viewed the final outcome as art. Many learners reported that these activities were very different from their school science experiences because they did not include "writing and reading." This study suggests that there is a need to help learners make deeper connections between school science and out-of-school STEM programs and to help students expand the way they conceptualize science (e.g., Barton & Tan, 2010; Calabrese Barton et al., 2013).

When describing the qualities and roles of scientists, artists, inventors, and engineers, as well as the artifacts, students often used examples related to their personal traits (e.g., smart, patient, ethical), activities they often do at home or at school (e.g., drawing), or normative views of scientists, inventors, engineers (e.g., have a hypothesis). They often described incomplete images of a certain discipline (e.g., viewing art as drawing or coloring, describing engineering as building houses). Expanding learners' perspectives on what these disciplines offer and how they intersect can be beneficial to help them draw connections between multiple fields and explore STEM practices beyond normative definitions or school science. Expanding perspectives can offer pathways for interdisciplinary STEM learning in which nondominant learners can see themselves as actively engaged in understanding STEM and its relevance to their everyday lives (e.g., Barton & Tan, 2010; Tzou, Scalone, & Bell, 2010; Vossoughi, Escudé, Kong, & Hooper, 2013).

Finally, learners' descriptions of artifacts reflect that their sense making around the term *beautiful* has multiple meanings: aesthetic, useful, beneficial and respectful to others, and well designed, reflecting that the learners were trying to label these artifacts with qualities they consider to be positive as they complete their work or projects. These qualities were also consistent with some learners' articulations about ethics. These responses create an opportunity for researchers and educators to understand the societally and ethically expansive ways that these learners are thinking about the act of creation as they learn (Bang & Vossoughi, 2016).

Despite the small sample size, we believe this study sheds light on how community-based efforts could leverage and support STEM learning among learners from nondominant populations. In future work, taking into consideration heterogeneity among learners (e.g., Rosebery, Ogonowski, DiSchino, & Warren, 2010) may help in understanding the diverse epistemologies and ways of knowing reflected by participants from this nondominant population, which might be more or less profoundly affected by the social, economic, and political situation, and systematic oppression. While these results show promising outcomes, suggesting that this type of environment could help learners participate in and benefit from hands-on science activities, future work should investigate in-depth the learners' cognitive engagement when doing these activities. It should also examine how connections made by learners between these activities and their everyday lives can transfer and expand beyond the scope of the program.

## References


Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and Instruction*, 34(3), 173–193.

Barron, B., & Bell, P. (2015). Learning environments in and out of school. In L. Corno & E. M. Anderman (Eds.), *Handbook of educational psychology* (3rd ed., pp. 323–336). New York, NY: Routledge.

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences*, 19(2), 187–229.

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, 55(5–6), 269–284.

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal*, 50(1), 37–75.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, W. R., Rhodes, J., Salen, K., … Watkins, S. C. (2013). Connected learning: An agenda for research and design. Irvine, CA: Digital Media and Learning Research Hub.

Gee, J. P. (2017). *Teaching, learning, literacy in our high-risk high-tech world: A framework for becoming human*. New York, NY: Teachers College Press.

Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital youth divas: Exploring narrative-driven curriculum to spark middle school girls' interest in computational activities. *Journal of the Learning Sciences*, 26(3), 477–516.

Resnick, M. (2018). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. Cambridge, MA: The MIT Press.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. London, UK: Sage.

OECD (2019). *PISA 2018 results: Combined executive summaries (Vols. I, II & III)*. Retrieved from https://www.oecd.org/pisa/Combined_Executive_Summaries_PISA_2018.pdf

Rosebery, A. S., Ogonowski, M., DiSchino, M., & Warren, B. (2010). "The coat traps all your body heat": Heterogeneity as fundamental to learning. *The Journal of the Learning Sciences*, 19(3), 322–357.

Tzou, C., Scalone, G., & Bell, P. (2010). The role of environmental narratives and social positioning in how place gets constructed for and by youth. *Equity & Excellence in Education*, 43(1), 105–119.

Vossoughi, S., Escudé, M., Kong, F., & Hooper, P. (2013, October). *Tinkering, learning & equity in the after-school setting.* Paper presented at the annual FabLearn conference, Stanford University, Palo Alto, CA.

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# 13. “This Is How I Can Fit”: Barriers and Facilitating Factors to Gender Inclusion in Makerspace Education

EILEEN MCGIVNEY AND BERTRAND SCHNEIDER

**Abstract:** Makerspaces are increasingly seen as a way to draw diverse and interdisciplinary learners together to teach a variety of skills. This qualitative interview study explores the experiences of women in 1 such interdisciplinary makerspace course at a graduate school of education. Drawing on findings from Margolis and Fisher’s (2002) study of women in computer science education, we find that this makerspace course was a productive environment to engage women’s diverse motivations for making and computing, increasing their confidence across domains. Additionally, we find their learning was tied closely to their identities, which shaped how they experienced the course and instructional support, particularly sexism, the congruence of their thinking and learning with course pedagogy, and collaboration and community. The diversity of experiences these women described provides a challenge for instructors but suggests that gaining an understanding of women’s motivations and identities can inform course design and personalized support.

## Introduction

Makerspaces are promising learning environments in schools, with the potential to engage diverse groups in interdisciplinary learning opportunities that in other contexts may be reserved for those in science, technology, engineering, and math (STEM) fields. In this way, they offer promising opportunities to draw women into computing recommended by Margolis and Fisher (2002) for “computing with a purpose,” by situating STEM learning in an interdisciplinary and social context that women find more motivating (p. 49). Widening participation in makerspaces poses challenges to course designers and instructors, however, as women with varying backgrounds navigate an often unfamiliar learning environment. How to support learners with varied motivations, knowledge, skills, and disciplinary lenses is therefore an important question for fostering belonging when incorporating makerspaces into formal education.

This paper describes an exploratory study of women participating in one such interdisciplinary makerspace course, at a graduate school of education, to teach both digital fabrication tools and pedagogy in maker education. Throughout the semester, six women were interviewed about the course, how their backgrounds and motivations shaped their experiences, and how the teaching team was or was not supporting them. Drawing on findings from Margolis and Fisher’s (2002) study of women in computer science (CS) education, we find that this makerspace course was a productive environment to engage women’s diverse motivations for making and computing, increasing their confidence across domains. Additionally, we find their learning was tied closely to their identities, which shaped how they experienced the course and instructional support, particularly sexism, the congruence of their thinking and learning with course pedagogy, and collaboration and community. The diversity of experiences these women described provides a challenge for instructors but suggests that gaining an understanding of women’s motivations and identities can inform course design and personalized support.

## Related Literature

In their study of computer science students at Carnegie Mellon, Margolis and Fisher (2002) found that women's underrepresentation in CS was in part due to the decontextualized way computing was taught, which did not speak to women's motivations for "computing with purpose," and recommended drawing women in by teaching CS in an interdisciplinary and social context. Makerspaces are a promising answer to this call; their "blending of traditional and digital skills, arts and engineering creates a learning environment in which there are multiple entry points to participation and leads to innovative combinations, juxtapositions, and uses of disciplinary knowledge and skill" (Sheridan et al., 2014, p. 526), particularly as university makerspaces aim for broader participation outside of engineering (Hynes & Hynes, 2018).

Despite this, women remain underrepresented and express feelings of exclusion and intimidation in makerspaces (Lewis, 2015; Richard & Giri, 2017; Roldan, Hui, & Gerber, 2018). While some work has pointed to the physical characteristics of these spaces and features of the community that can attract or deter women from participating, there is also a push to critically examine how makerspaces "marginalize certain groups from participating and succeeding" in sustained ways (Roldan et al., 2018, p. 753). In CS education, Margolis and Fisher (2002) found that in addition to different motivations for majoring in CS, women felt less confident in their abilities than men, which through time led to decreased interest in computing. Women's interest in makerspaces is similarly affected by issues of self-efficacy, including how women's work is recognized, how their expertise and ways of working are valued, and overt or subtle sexism faced from male-dominated communities (Buechley, 2013; Faulkner & McClard, 2014; Keune, Peppler, & Wohlwend, 2019). This may be especially true for how women see themselves in relation to making, as women whose skills and identities are more congruent to makerspace culture may not perceive barriers related to their gender (Bean, Farmer, & Kerr, 2015).

Supporting learners in makerspaces within formal education environments is complex, requiring instructors to employ practices not typical of traditional whole-group or lab instruction (Clapp, Ross, Ryan, & Tishman, 2016). As maker courses are increasingly seen as an inroad to STEM fields for underserved populations, including women, these spaces also challenge instructors to better understand how notions of making and computing interact with individual learners' motivations, identities, and skills (Peppler, Halverson, & Kafai, 2016; Vossoughi, Hooper, & Escudé, 2016).

## Research Questions

Part of a broader study to assess the effectiveness of personalizing instruction in a makerspace course, this exploratory study contributes to the growing literature on diverse experiences of women learning in makerspaces to identify ways instructors can better support them and foster a sense of belonging. To do so, we asked (a) what were these disciplinarily diverse women's motivations for learning in an education-focused makerspace course, and (b) what hindered or supported their learning and belonging?

## Methods

### Sample

This study was conducted in the Spring 2019 course Digital Fabrication and Making in Education. The course was taught in the Graduate School of Education, aiming to equip teachers and other students interested in implementing "making" in education or designing educational tools with digital fabrication. The class had a total of 22 students from the Graduate School of Education and two students from the Graduate School of Design. The class comprised 16 women and eight men.

The focus on women was emergent based on all students' responses to weekly surveys that aimed to capture their personas and experiences with the instructors (for details see Chng, Zeylikman, & Schneider, 2020). In the first month of the course, women reported more extreme positive and negative responses than men. Because we used a purposive sampling design meant to represent contrasting experiences (e.g., satisfaction and dissatisfaction with instructional support) and personas (e.g., novice and expert), the sample evolved into six women who were interviewed throughout the semester. Two women were interviewed three times (Emily and Lucy), one twice (Erin), and three one time each (Jessica, Sarah, and Maya), for a total of 11 interviews. Figure 1 depicts the final project for each participant.

While the course and also our sample are not representative of typical makerspace courses and users, there is increasing demand for teachers and others in education to possess the skills needed to teach in makerspaces. The class is more diverse in terms of experience with fabrication, motivations, and professional backgrounds than currently found in many makerspaces, and it is more gender balanced (Roldan et al., 2018), but it may represent the more diverse spaces expected in the future.

## Methods

Semistructured interviews were conducted by the lead author, a researcher not on the teaching team, using a protocol developed in collaboration with the course instructors. Participation was voluntary and participants granted consent with assurance that responses would not influence grades in the course, and that they could withdraw from the study at any time with no recourse. Interview protocols varied based on the week of the course; for example, in the beginning they focused on students' self-description of their personas' learning in the makerspace, while the middle of the semester focused on their self-reported challenges and assessment of feedback or support received from the teaching team. Interviews conducted after the conclusion of the course focused on participants' learning trajectories and explicitly asked them to discuss how their identities and gender did or did not influence their experience of the course. Interviews lasted approximately 30 minutes (range: 25–41 minutes) and consisted of an open-ended line of questioning and at times a discussion of the weekly surveys to elicit participants' thoughts.

Interviews were transcribed and coded using iterative, hybrid thematic coding that developed codes through both grounded or bottom-up procedures (emic) and drawing on prior literature (etic; Creswell, 2012; Rubin & Rubin, 2011). Initial coding was organized by etic themes identified from the literature and the broader study on personalizing instruction in makerspaces, including collaboration with peers and instructors, competence, and motivation, and emic themes that emerged such as identity and different ways of thinking and learning. Transcripts were independently coded by the lead author and graduate student research assistants to verify the reliability of the coding scheme, and discrepancies were resolved through discussion among the research team. Final themes were identified and transcripts re-coded; this thematic analysis is presented as the results. We aim to provide evidence of validity by using direct quotes that exemplify the findings wherever possible to allow the reader to judge our interpretation and sources of bias (Maxwell, 2010).


*Figure 1. Final projects from interview participants. Top: Emily: Pretty Pretty Princess; Erin and Sarah: FrequenC; Maya: Carbon Cruncher. Bottom: Lucy: Plant Craft; Jessica: Sounds of Speech.*

## Results

### Motivation, Interest, and Confidence

Participants described how they found the course motivating, particularly how the interdisciplinarity of the course allowed them to pursue their interests. In addition, we found that the participants described these motivations attached to their identities, but that different types of identities were more central to the experiences of each woman. Here, we describe each participant in turn—the identities, motivations, and learning gains they described.

Emily, an education graduate student, identified first and foremost as an artist, and she was motivated by the opportunity to add "new tools" to her artistry by learning how to use the makerspace. While in the beginning she described herself as a "newbie," "taking baby steps," she drew on the familiarity of the creative process from studio work to feel comfortable with the work. However, she describes the greatest gains she took from the class as increasing her confidence in coding and STEM work, which before the course she thought were "opaque" and unattractive to her when growing up, particularly because she identifies as very feminine and did not see herself in STEM fields. Yet by the end of the class she felt she belonged in the makerspace and was capable of a career in technology, even applying for a job as a makerspace facilitator. At the end of the course, she felt "way more comfortable in what STEM would be. … I think that I didn't realize just how creative coding can be, and how intertwined it could be with an eye for design and with arts … it's way less intimidating now, and that's because of this class."

Erin, also an education student, described herself as a "planner and a huge organizer," that she was "rigid" at the start of the course, and a cognitive scientist interested in understanding hands-on learning. Motivated by better understanding herself and her learning, Erin was up front in her reflections on the course related to her identity, actively thinking about tying her identity to her work, and finding her gender and ethnicity salient in her experience in the course. She described her biggest learning gains as unlearning her notions that "learning isn't fun … but you just have to push through," finding that it was possible to become motivated to learn through a playful and contextualized approach in the makerspace. She said that by the end of the semester, "I was taking more risks, I was trying new things, throwing out ideas. … I did a lot of projects and activities that I thought I could never do at the beginning. Which is really empowering for me."

For Lucy, a design student with a CS background, the ways of thinking and problem solving from her academic and professional work were most salient for her experiences in the course. However, a budding interest in education and designing for children led her to the makerspace in the education school, and the ability to explore those interests are what motivated her in her learning. Her greatest learning came from the ability to apply making skills to educational problems that interest her. She said, “The class has enabled me to pursue projects that I find personally interesting. Whereas if I were in an engineering class, there may be other learning goals that that class has, that is not aligned with my interest.” Through this, Lucy also learned that she enjoys working collaboratively with others more than she enjoys working alone, which she had previously thought, and feels comfortable as part of a broader education community.

Maya, an education student, approached her experience in the makerspace with an eye toward how it aligned with her culture, motivated by the promise of using maker education in developing countries. She discussed how the makerspace was an environment that welcomed her way of learning, which she deemed “hard-fun,” as she is motivated primarily by tackling difficult challenges. She said, “The way I see the makerspace often is within my own cultural context. … I see [the ocean as] a lot like a makerspace … the terrain of possibilities and I can go anywhere … so I just am curious about those notions, and the idea of a makerspace as culturally relevant.” For Maya, her greatest learning in the course came from seeing this approach from her culture applied in formal education, and the confidence that gave her to feel she belonged in her master’s program, saying, “Yeah, this is how I can see myself, this is how I can fit.”

Sarah, a design student, has a highly interdisciplinary background, and she described herself as a “tourist,” taking classes and working across five different schools in the university. She described taking this course in the School of Education because fabrication courses offered by other departments were not suited for beginner-level entry into fabrication. She felt her background gave her a lot of confidence in the making tasks of the course but felt she was “dropping in out of context” on the educational material and struggling to connect to it and other students. But for Sarah, the greatest learning came from recognizing how teaching and learning were in fact important and relevant for her, grounding her passion for making, and feeling an affinity for her classmates, saying, “I could completely see them in my program. … [We are the] same kind of scrappy person. … I think teachers have to be scrappy.”

Jessica described herself as a teacher and an experienced maker who was motivated in the class to learn new tools and practices for teaching in makerspaces. For Jessica, working with and helping others motivated her experience, both in her goals for engaging in the class and what she hoped to learn for her future work. She said, “Because I’m like a teacher at heart so if someone needed help and I had free time—or honestly even if I didn’t have the free time—I’m going to help them.” She also drew on experiences from other makerspaces and enjoyment of the creative process of making that she described as relaxing, helping her enter a state of “flow.”

Taken together, the experiences of these women in the makerspace course suggest that makerspaces can indeed offer the interdisciplinary, purpose-driven computing opportunities that Margolis and Fisher (2002) recommended to engage women in CS and STEM fields. Participants described myriad goals and interests in the course, as well as a wide variety of self-doubts and struggles, but on the whole their experiences helped them build confidence and interest in a positive way that Margolis and Fisher found lacking in traditional CS education in the 1990s.

However, we also found that women tied these motivations and their own learning closely to their identities. Largely unprompted, participants framed their own experiences and motivations in the course around their identities, whether professional academic such as designer, teacher, artist, but also their gender, culture, and ways of knowing and learning. These identities provided a powerful backdrop for their experiences, particularly which identities each participant chose to discuss, and this suggests that how women see themselves within the makerspace can provide valuable insight into ways of supporting them to build their confidence and motivate them.

## Barriers in Makerspace Learning

While the experiences of these women do suggest the success of makerspaces as a formal learning environment that can provide engaging and motivating STEM learning opportunities for diverse groups of learners, they also highlighted barriers to fully participating in maker education. In particular, some of the women described gender bias and sexism, that the pedagogy of the course did not align with their ways of thinking and learning, or that they struggled with the community.

**Gender bias and sexism.** The women had varying experiences of sexism and gender bias and the role it played in their sense of belonging in the space (see Table 1). Emily discussed how being feminine was an important barrier to working in STEM before taking the course, and that she worried about how her opinions on gender would be received within this community at the university; however, she did not describe sexism or gender as salient in how she experienced this course in the makerspace. For her, the makerspace was a comfortable place to explore STEM through her interest in art without being intimidated by her gender.

However, Erin described her gender identity as a very important barrier, and that she experienced sexism in how her classmates and the teaching team interacted with her. In particular, men were more likely to be thought of as experts, whether or not they worked hard, and women were assumed to need help in coding. She discussed the importance of the male-dominated teaching team, and how she thinks that the only female member of the teaching team was undermined by others. This led her to feel as if she needed to work harder, she had something to prove, and she was careful about how she asked for help. She mentioned that she was not alone in these experiences, and that other women in the class expressed similar concerns to her.

| | |
|---|---|
| Emily | ***Yeah, not at all. [Gender issues] really didn't [play a role]…*** *nah, I felt like there was space for me, and I didn't think it mattered who was there.* |
| Erin | ***I mean like being a woman, and being a woman of color, that's definitely something I thought a lot about, in the space…*** *sometimes there are these assumptions or bias... and I talked about it often with some of the other females in the class and like, it's definitely a thing that happened to not just me. And it's not-- I think it just says something about maker culture. That it's still very like male-driven, and like white male-driven as well. So yeah, that's something I thought about a lot… [The men were seen as] someone to refer to for questions, even though they didn't do an assignment or didn't really like follow along in class. But for females, we had to kind of prove ourselves and actively answer questions, actively advocating for ourselves.* |
| | *I think that yeah,* ***definitely having a more diverse teaching team would be helpful, just because like everyone was white, or there's only one female staff member****. I think that played a big role in the culture of the class…I couldn't really open up about my experiences that much or things like that. I think having a more diverse staff team would be helpful.* |

*Table 1. Gender bias and sexism.*

**Ways of thinking and learning.** Participants whose ways of thinking and learning did not align with the pedagogical approaches in the makerspace struggled more to feel comfortable and to achieve the mastery levels and increased confidence that are important to motivate sustained work and interest in making (see Table 2). For Erin, accustomed to more traditional learning environments, the open-ended and student-directed nature of the course was overwhelming and discouraging. She described being frustrated by a lack of support and feedback from the teaching team, particularly when she struggled with hardware that did not work and could not bring herself out of it. She pointed to confusion over a lack of structures such as learning goals, rubrics, and organization that made it difficult for her to learn what she wanted. Similarly, Sarah discussed frustration with the pedagogy of the course, desiring more "sage on the stage" from the teaching team and their expertise rather than fully student directed. Jessica also discussed how her philosophy on teaching and learning did not align with how the class was taught, finding frustration in the limited hours of the space and the constraints of the assignments that impeded her from experiencing her own creative process.

This is in contrast to the experiences described by Emily, who found her artistic creative process supported her experiences in the space, Maya, whose culture aligned with learning in the class, and Lucy, whose professional and academic background were congruent with the pedagogical approach.

| | |
|---|---|
| Erin | *[Projects are] very open-ended. Or like,* ***they don't have specific times we need this draft in by this time… There aren't really any rubrics in this class either so I don't know how they're grading… Because it's all student-driven****, and like all the presentations that we have in class, or any discussion about the readings are all led by students. So I don't know if that's like the best approach to like teaching concepts.* ***So I'm struggling with that.*** |
| | ***The teaching team doesn't give as much feedback as I thought they would be****. Which is interesting. And I thought that would be a bigger part, them reaching out to us and giving us feedback or helping us…They do have office hours, drop-in hours, but they're usually in the evenings, so I can't make them all the time… I think that part, we probably need more facilitation…* |
| Sarah | *I almost wish there was more structure around, be* ***like a little bit more "sage on the stage."*** |

*Table 2. Ways of thinking and learning.*

**Community and collaboration.** All the women discussed the community of the class and collaboration as important for their sense of belonging and their learning in the makerspace (see Table 3). Negative interactions and lacking a sense of community were barriers for Jessica's experience in the makerspace. To her, the space was competitive, and others' competition for materials and time with the machines was disengaging. Early in the semester her assignment was broken by another student, and she felt that a member of the teaching team discouraged her from helping another student. These interactions discouraged her and impeded her learning and sense of belonging. Erin also points to a lack of community as late as the fifth week of the semester as a barrier to her tying her identity into her work or feeling comfortable taking risks, and her negative experiences related to sexism in the course made her wary of how she asked questions or responded to others (see Table 4). Despite the positive interactions that motivated Sarah, Lucy, and Emily, for example, the community and social environment was perceived as hostile and unwelcoming for a number of women.

| | |
|---|---|
| Jessica | *Honestly I was more willing [to help others] in the beginning... But then there were a couple of instances where I felt like, "Why you gotta act like that?" Not out loud but like in my head. Like* ***why you gotta be so aggressive, you don't need to act like that****. Or when I helped someone in that earlier class and someone was like "don't like try to help, make that person do it." And I was like okay, that's weird…because I'm like a teacher at heart so if someone needed help and I had free time- or honestly even if I didn't have the free time- I'm going to help them.* ***I guess it's more like disengagement. From the class. Or being in the space.*** |
| Erin | *Because* ***we don't have that community yet... And do I want to share my personal experiences with the people in this class? I don't know yet****. So I think maybe, I don't know, doing activities or things that kind of form the community and help foster this community, might be more important before diving into projects.* |

*Table 3. Community and collaboration.*

## Discussion

That women's experiences varied in how they responded to the course is not surprising, as women do not represent a monolithic group, but rather represent diverse identities and varied experiences. However, the relation of these barriers to the types of identities that participants discussed as most salient to their motivations, interests, and learning within the course may provide valuable insight for instructors who aim to not only attract women into makerspaces and STEM learning opportunities, but who also support their sustained engagement in them. The women who identified with the ways of thinking and learning employed by the pedagogy of the course, for example, did not need the same level of instructional support. Women who feel their gender identity is central to their experience of the course may be more likely to perceive subtle forms of sexism and bias, highlighting the need for instructors to gain a deeper understanding of when students feel marginalized.

While the teaching team measured students' personas in terms of their feelings of competency and some of their learning preferences (e.g., collaborative or independent), our findings suggest personalizing learning requires going beyond this. Instructors should aim to more deeply understand each learner's professional, ethnic, and gender identities, their motivations, and how they relate to maker culture to better support students. Additionally, instructors should prioritize understanding individuals' ways of thinking and knowing relative to makerspace pedagogy to better anticipate the level of support needed. In our context, the challenges and successes related to these issues appeared to be more extreme for women in the course than for men. Further work is needed to understand whether this is true in other makerspaces as well.

Additionally, based on how these women described their experiences, our findings do point to a number of areas that instructors bringing makerspaces to environments such as schools of education can consider to make the space welcoming and productive for all women. For one, even having one woman feel discriminated against cannot be ignored, despite others' finding the space to be gender neutral. Simply having a larger female-male ratio of students did not hide the masculinity of maker culture for Erin, or the gendered lens of STEM on the periphery for Emily. Instructors may be able to mitigate this by having a diverse and representative teaching team, as well as being explicit in identifying instances of sexism and bias by providing anonymous reporting opportunities. Second, the ways student-directed pedagogy and open-ended, hands-on learning environments were welcoming or challenging for different learners highlights the need for certain supports in order not to alienate those who prefer more structure. Based on the experiences of these students, it appears instructors can mitigate these challenges by having office hours accessible for everyone and providing feedback and explicit expectations early in the course when students feel particularly overwhelmed. Finally, because collaboration is at the heart of learning in makerspaces, the class community is crucial. Instructors should prioritize building community in the start of a makerspace course to help advance students' learning by allowing them to feel comfortable with each other and overcome intimidation they may feel if they perceive themselves as outsiders.

## References


Bean, V., Farmer, N. M., & Kerr, B. A. (2015). An exploration of women's engagement in Makerspaces. *Gifted and Talented International, 30*(1–2), 61–67.

Buechley, L. (2013, October). *Thinking about making.* Presented at the FabLearn Conference, Stanford University, CA.

Chng, E., Zeylikman, S., & Schneider, B. (2020). The double-edged sword of automating personalized interventions in makerspaces: An exploratory study of potential benefits and drawbacks. In *Proceedings of the International Conference on Artificial Intelligence in Education* (pp. 64–68). Switzerland: Springer International.

Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2016). *Maker-centered learning: Empowering young people to shape their worlds.* San Francisco, CA: John Wiley & Sons.

Creswell, R. (2012). *Qualitative inquiry and research design.* Thousand Oaks, CA: Sage.

Faulkner, S., & McClard, A. (2014). Making change: Can ethnographic research about women makers change the future of computing? In *Ethnographic Praxis in Industry Conference Proceedings*, 2014 (pp. 187–198). doi:10.1111/1559-8918.01026

Hynes, M. M., & Hynes, W. J. (2018). If you build it, will they come? Student preferences for makerspace environments in higher education. *International Journal of Technology and Design Education, 28*(3), 867–883.

Keune, A., Peppler, K. A., & Wohlwend, K. E. (2019). Recognition in makerspaces: Supporting opportunities for women to "make" a STEM career. *Computers in Human Behavior, 99*, 368–380.

Lewis, J. (2015). B*arriers to women's involvement in hackspaces and makerspaces.* Retrieved from

http://eprints.whiterose.ac.uk/144264/
Margolis, J., & Fisher, A. (2002). *Unlocking the clubhouse: Women in computing* (Rev. ed.). Cambridge, MA: The MIT Press.
Maxwell, J. A. (2010). Validity: How might you be wrong? In W. Luttrell (Ed.), *Qualitative educational research: Readings in reflexive methodology and transformative practice* (pp. 279–287). New York, NY: Routledge.
Peppler, K., Halverson, E. R., & Kafai, Y. B. (Eds.) (2016). *Makeology: Makers as learners* (Vol. 2). New York, NY: Routledge.
Richard, G., & Giri, S. (2017). Inclusive collaborative learning with multi-interface design: Implications for diverse and equitable makerspace education. In *Proceedings of the 12th International Conference on Computer Supported Collaborative Learning (CSCL)* 2017 (Vol. 1; pp. 415–422). Philadelphia, PA: International Society of the Learning Sciences.
Roldan, W., Hui, J. S., & Gerber, E. M. (2018). University makerspaces: Opportunities to support equitable participation for women in engineering. *International Journal of Engineering Education*, 34(2), 751–768.
Rubin, H. J., & Rubin, I. S. (2011). *Qualitative interviewing: The art of hearing data* (3rd ed.). Thousand Oaks, CA: Sage.
Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, 84(4), 505–531.
Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review*, 86(2), 206–232.

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# 14. It's Not About Programming, It's About a Way of Learning: Evolution of Teacher Perspectives on Computer Programming Education

YUMIKO MURAI AND HIROYUKI MURAMATSU

**Abstract:** Integrating computer programming into the standard school curriculum has become an emerging trend around the world. In addition to the difficulties of implementing a new learning approach, teacher professional development for programming education often leaves out the potential of programming as a tool for creative learning. To address this issue, the researchers developed a teacher professional-development program targeting elementary and middle school teachers, focusing on the role of programming to support creative learning in schools. This 4-month-long, blended (i.e., in-person and online) program focused particularly on providing teachers with means to engage in creative programming themselves, reflect on the process, design and try out a lesson idea, and iterate on the lesson idea. This paper reports on the shifts in the teachers' understanding of programming education and challenges that emerged through this professional-development experience. The most compelling shift we observed was how teachers started to see programming education as an opportunity to teach their students how to learn. The paper also shares a few lessons learned from this study as recommendations for practitioners.

## Background

Integrating computer programming into the standard school curriculum has become an emerging trend around the world. This trend provides a unique and challenging contexts for teacher learning (Menekse, 2015); for example, most teachers have to teach computer science or computer programming without any prior background or training; programming education often requires cross-curricular instruction, which most teachers are not used to; and there is simply a lack of teachers who have taught programming in a classroom, creating few opportunities to learn from other teachers. In addition, early adopters state that the goals of programming education are not limited to skills in writing programs but also include abilities to design and build solutions to problems (Grover & Pea, 2013; Papert, 1980; Wing, 2006). Thus, teachers are required to not only deliver knowledge and skills about computer programming but also to facilitate students' development of their own knowledge through engaging in exploratory, creative learning processes (Resnick, 2017). These emerging needs of programming education triggered numerous new initiatives providing resources and professional-development opportunities targeting schoolteachers. However, too often those programs focus exclusively on how to write computer programs, rather than helping teachers gain an understanding about *why* students need to learn to program and *how* to facilitate their learning process using programming.

To address this issue, we created a professional-development program that provides teachers an opportunity to build their own understanding of how programming might help their teaching through engaging in the creative process that involves trying out, reflecting on, and iterating their teaching within their own contexts. This paper provides an overview of this professional-development program, held in 2018 at a rural prefecture (a political subdivision) in Japan, and reports on the experiences of several teachers who participated in this program, highlighting how this approach to professional development impacted the ways teachers view programming education and its pedagogy. The program was also held in 2019 and 2020, each time adding several revisions to the program design. The insights from those newer iterations have been shared in other publications (e.g., Murai & Muramatsu, 2020). Finally, we discuss lessons learned about teacher professional development for creative programming and offer recommendations for applying them.

## Creative Programming for Teacher Professional Development

Our professional-development program was built on an existing open online course (lcl.media.mit.edu). The course was focused on creative learning, a pedagogical method based on constructionism, a philosophy emerging from studies of children engaged in creative processes using programming (Harel & Papert, 1991). The original course was fully online; participants did not interact with one another in person. Taking the core ideas from the course, our professional-development program was designed as a blended course specifically modified to meet the needs of the teachers in the area. It was conducted in the local language (Japanese), and participants interacted with one another both in person and online.

### Overview

This professional-development program was designed to be four months long, starting with a two-day in-person kick-off camp followed by three months of individual preparation. During this preparation time, teachers implemented the activity idea they developed at their own school while engaging in biweekly online check-in calls with other participating teachers (see Figure 1). Each teacher tried out his or her lesson ideas by the end of the third month and shared the reflections and ideas for iteration at a final presentation in person.

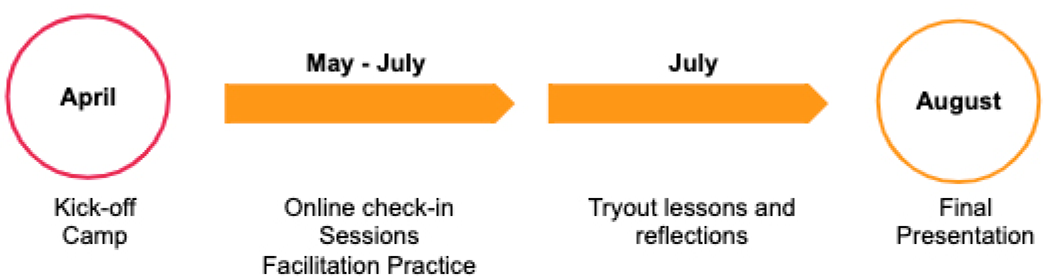


*Figure 1. Schedule of the program.*

### Kick-Off Camp

The two-day intensive kick-off camp consisted of four major types of activities: making, reflections, design, and discussions based on a presentation. Figure 2 shows the timetable of the program.

Day 1

| | |
|---|---|
| 9:00 | Opening |
| 9:15 | Icebreaking |
| 9:30 | Introduction to Creative Programming |
| 10:00 | Making Activity 1 + Reflection |
| 12:15 | Lunch |
| 13:00 | Making Activity 2 + Reflection |
| 15:15 | Conversation about the New Curriculum Standard |
| 15:30 | Making Activity 3 + Reflection |
| 16:30 | End-of-day Reflection |
| 18:00 | Reception |

Day 2

| | |
|---|---|
| 8:30 | Breakfast |
| 9:00 | Warm-up |
| 10:00 | Design Activity |
| 12:15 | Lunch |
| 14:00 | Share out |
| 15:00 | End-of-day Reflection |
| 15:15 | Closing |

*Figure 2. Timetable of the kick-off camp in 2018.*

**Making.** The making activities were designed to provide teachers with firsthand experience of creative programming. Instead of step-by-step instructions for how to create a particular project, these making activities provided open-ended themes (for example, "make something that makes the classroom funny") to encourage teachers to engage in tinkering, one of the core components of creative learning (Resnick, 2017). These activities were also used as opportunities to introduce different technologies to teachers, such as an educational electronic circuit board micro:bit (microbit.org). During and after the making activities, several minutes were allocated for teachers to showcase their activities and exchange feedback with one another.

**Reflections.** Teachers were asked to reflect on their experience after almost every activity during the camp. Reflection is an important process to turn an experience into knowledge and skills that one can use in practice (Schön, 1992). Teachers were asked to look back on their own experience making or designing projects to gain a firsthand understanding of how it feels, what is helpful, and what might be challenging for their students. We prepared several reflective activities encouraging teachers to visualize their actions, thoughts, and emotions and help them adopt an objective perspective about their experiences.

**Design.** Design activities were another important component of the kick-off camp. In groups of three, teachers were asked to design a creative-learning lesson they could implement in their classrooms or after school. Following a workshop protocol called the Imagine-Create-Share framework, teachers brainstormed and prototyped how they would support students to come up with ideas (Imagine), how they could tinker with materials and create objects they envisioned (Create), and how they could share with others and gain constructive feedback (Share). Teachers prototyped the ideas by creating either slide shows or sketches. At each design activity time, teachers shared their ideas with members of their group as well as with the whole group, receiving feedback at multiple points during the camp.

**Discussions based on a presentation.** Although this professional-development program emphasizes the importance of hands-on making and designing, the program organizers offered a few lecture-style presentations to introduce the historical background of computer programming education and creative learning, and a basic understanding of the field. For example, a 15-minute presentation on the creative learning framework (Resnick, 2017) and a 15-minute presentation overviewing the new curriculum standard were given at separate times during the kick-off camp. These presentations were designed to be short and to invite conversation so they would not be a passive experience for participants.

### Online Check-in Sessions

Since one of the goals of this professional-development program was to cultivate a community of teachers in the local region, it was important to provide an environment where participating teachers could continue the conversation and stay connected with one another. After the kick-off camp, online check-in sessions held once every two weeks aimed to support teachers in sharing what they were working on, asking for help when needed, and giving feedback to one another. Each check-in consisted of 30–45 minutes of discussions based on a case or a talk, followed by up to one hour of sharing in which each teacher participated. Teachers were encouraged to comment on or share ideas with one another about what they had been working on.

### Tryout Lessons

Teachers were asked to brush up their lesson idea through online check-in sessions and then to select an opportunity to try out the idea with children. Several teachers selected their own classrooms, whereas other teachers selected afterschool environments such as club activities or weekend workshops. After the tryout sessions, teachers were asked to debrief and reflect on the experience, including what went well, what did not go well, and how they would do it differently.

### Final Presentation

Teachers were asked to put together a poster to share the lesson they eventually conducted (many teachers went through multiple changes during the check-in weeks), how students reacted, lessons learned, and recommendations to other teachers. All teachers stood next to their posters, gave a short introduction, and then explained the posters to their audience. Teachers were also asked to reflect on their professional development in small groups.

## Methods

In this section, we discuss the findings from the study of teachers who participated in a professional-development program in 2018 targeting public elementary and middle school teachers in rural Japan. In Japan, the Ministry of Education has announced new curriculum standard guidelines to be implemented starting in 2020, listing programming as a compulsory item for every public elementary school curriculum (Shoto-Chuto-Kyouikukyoku-Kyouikuka, 2016). Our professional-development program was prompted by the prefectural government's need to prepare teachers for the policy change. A case study method was chosen in order to gain deeper insights into teachers' experiences as a contemporary phenomenon in real-world contexts (Yin, 2017). In collaboration with several other learning designers and organizers, the two researchers for this study also played primary roles as designers and organizers of this professional-development program, reflecting on their own views, their understanding about the program, and the experiences of teachers in this program.

## Participants

A total of 14 teachers with varying teaching and programming experiences from across the prefecture participated in the program. All participants applied based on their interests, yet some of them applied because of a strong recommendation by their school administration and the prefectural board of education in order to balance out regional representation in the program.

## Data and Analysis

A primary source of data consisted of online pre- and postsurveys conducted with all participants before and after the program. The presurvey asked teachers about their expectations for the program and requested background information such as teaching history, while the postsurvey focused on their takeaways and feedback about the program. In addition, as part of the reflection process at multiple points during the kick-off camp, participants were asked to write down their expectations, concerns, and questions regarding computer programming education, using sticky notes. These sticky notes were collected and analyzed as data. The meeting minutes from a debrief meeting after the kick-off camp as well as records of the regular check-in sessions were also collected and examined in order to understand the experiences of participating teachers. Thematic analysis was conducted to identify emerging themes in participants' feedback. From the analysis, we examined and synthesized the lessons learned from this work that can be applied to other professional-development programs.

# Results and Discussion

Overall, 13 out of 14 teachers participated in the final presentation, sharing their tryout sessions and lessons learned from their experience. This completion rate was a positive result but not surprising given that it is culturally uncommon for teachers to drop out of professional development supported by formal institutions such as the board of education and universities. The format and length of the tryout sessions varied depending on the contexts of each teacher, including the age of his or her students, the size of his or her school, and the curricular freedom or restrictions in his or her school. For example, a few teachers conducted a one-off class lesson, while other teachers conducted afterschool workshops. All of them used one programming language as part of their tryout session.

One of the significant shifts we identified in teachers' way of talking about computer programming education was their change in focus: from *what* their students need to learn to *how* their students need to learn. For example, one teacher who was asked to participate in the program to represent his district initially expressed doubt about why he had to teach programming to students, arguing that there must be more important things they needed to learn than programming. As he engaged in the activities and a series of reflections, he realized his positive emotional reaction from the creative process might be something his students would need in everyday school life. Another teacher, previously involved in much professional development on computer programming, described before participating in this program how she was not convinced about the common notion of programming as another form of knowledge she had to teach her students. As she took part in our program, she described how approaching programming as a creative learning process started to make sense, and she came to think that "programming may create an opportunity to bring a fundamental change to how we teach at school." Through reflecting on their own experience, both teachers started to see programming as an opportunity to teach their students how to learn through engaging in creative learning.

Other teachers mentioned that their confidence and comfort about teaching computer programming had shifted. For example, one teacher who at first emphasized the importance of every student's having access to a laptop wrote, at the end of the program, that he realized technological kits were not necessarily a requirement to provide a good programming education. He had learned that there were other resources and ideas he could borrow from colleagues in the community. When he conducted his trial session with students during the club activity, he used an educational electronic circuit kit rented from a partner university while also implementing unplugged programming (i.e., a programming activity that does not use computers) for his own classroom with younger students, an idea presented by a graduate student. His case highlights that when teachers try out creative programming in their own environments and have a number of opportunities to work with their peers, they collectively gain more confidence and comfort to conduct programming in any environment.

Another change we observed was that several teachers shifted their attitude toward programming. When we asked teachers to write down their concerns and expectations toward programming education at the beginning of our professional-development program, many teachers expressed concerns and anxiety. In particular, several teachers described their concern about not being able to teach programming in "the right way." One of those teachers, however, mentioned that he started to realize that it is important to "try first" even when he was not sure how the trial might end up. Having the opportunity to ask questions during the online check-in meetings and reflect on things they could do helped him feel comfortable trying out an idea without complete preparation.

Some teachers also described that they started to notice challenges they did not see before about conducting creative programming. One example was the difficulty of getting support within the school. One teacher who had been actively implementing his own creative programming ideas described how difficult it was to get feedback from other teachers within the school about what he was doing because many teachers did not see the connection to what they themselves were doing. His remark was a reminder that even when teachers build a network of other teachers outside their school who can support them, it is still important for each school to support its own teachers.

In sum, through our professional-development program, we observed a number of changes in teachers' perspectives toward programming education. One of the major shifts was teachers' understanding of programming education as an opportunity not only to teach how to program but to introduce a new way of learning through trying, making mistakes, reflecting, and iterating. These changes in the way teachers experienced their learning suggest relative success of this professional-development approach. We also see opportunities for development and revision during future iterations.

## Recommendations

Based on our investigation of data collected before, during, and after the professional-development program, four lessons about professional development for creative programming have emerged.

First, professional development for creative programming should provide a space for teachers to experience learning activities themselves and gain firsthand experience of engaging in the process of learning. Our interviews indicated that teachers were used to a "sit back and listen" experience during professional development, which is consistent with many other teacher professional-development programs (Hawley & Valli, 2007). Having the experience of doing creative programming on their own enables teachers to truly adapt creative programming approaches to their own educational contexts.

Second, professional development for creative programming should promote a culture of iteration among teachers, encouraging them to be open to new ideas, take risks, and iterate as they go. Many teachers described being in an environment where a mistake was not allowed, which created much resistance to new ideas that might or might not result in good outcomes. It is important to promote a safe environment where teachers can try out and practice a new activity, tool, and idea, not only as part of professional development but also within the school where they teach. In the case of this study, we collaborated with the prefectural board of education, which also talked to each school where participants were coming from to enable them to try out, test, and iterate in their schools.

Third, professional development for creative programming should be an authentic experience for teachers, meaning that learning and discussion are always grounded in each teacher's classroom environment. Many professional-development programs fail to support teachers to implement the ideas shared during professional development because the learning experiences are decontextualized from the teachers' everyday lives (Borko, 2004). In this study, teachers were given abundant time to reflect on their experiences and write down expectations and concerns when they brought new ideas into their classrooms.

Fourth, professional development for creative programming should enable community development among teachers. The implementation of new ideas takes time and requires organizational adjustments. Many teachers described how they struggled to find support within their school; therefore, they appreciated the chance to ask questions, offer feedback, and share resources with one another during the program using an email Listserv.

## Conclusion

This paper has shared insights into how a teacher professional-development program focused on supporting creative learning might positively impact the ways teachers perceive programming education. Analysis of feedback from the participating teachers indicates that our program helped them look at programming education from a different perspective; many participants continued to iterate on the ideas and practices they started developing during the program. Although these insights are limited to one iteration of a professional-development event, they make a promising contribution to the field of professional development of computer programming education given that the many existing professional-development programs focused on a narrow scope of programming education.

The third iteration of this professional-development program is ongoing with a new group of teachers. Several revisions were made based on the analysis of the first iteration in 2018; for example, the opportunity for teachers to practice facilitation of creative learning, such as programming camps and a summer camp on making, were added to the program. However, because of restrictions placed on in-person gatherings after the outbreak of the 2020 pandemic, the third iteration had to be transformed into a fully online format. For future research, closely analyzing participant feedback from the first, second, and third iterations of our professional-development program should provide further insights into successfully implementing professional development for teaching computer programming while supporting creative learning.

## References


Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, 33(8), 3–15.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, 42(1), 38–43.

Harel, I. E., & Papert, S. E. (1991). *Constructionism*. New York, NY: Ablex.

Hawley, W. D., & Valli, L. (2007). Design principles for learner-centered professional development. *The Keys to Effective Schools: Educational Reform as Continuous Improvement*, 2, 117–137.

Menekse, M. (2015). Computer science teacher professional development in the United States: A review of studies published between 2004 and 2014. *Computer Science Education*, 25(4), 325–350.

Murai, Y., & Muramatsu, H. (2020). Application of creative learning principles within blended teacher professional development on integration of computer programming education into elementary and middle school classrooms. *Information and Learning Sciences* 121(7–8), 665–675.
Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic Books.
Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. Cambridge, MA: The MIT Press.
Shoto-Chuto-Kyouikukyoku-Kyouikuka. (2016). 小学校段階におけるプログラミング教育の在り方について [About how programming education should exist in elementary school level]. Retrieved from http://www.mext.go.jp/b_menu/shingi/chousa/shotou/122/attach/1372525.htm
Schön, D. A. (1992). *The reflective practitioner: How professionals think in action*. London, UK: Routledge.
Wing, J. M. (2006). Computational thinking. *Communications of the* ACM, 49(3), 33–35.
Yin, R. K. (2017). *Case study research and applications: Design and methods* (6th ed.). Thousand Oaks, CA: Sage.

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# 15. Narrative-Based Hands-On Activities for Science and Science Ethics Education: The Frankenstein200 Experience

PETER NAGY, AREEJ MAWASI, AND RUTH WYLIE

**Abstract:** This paper introduces the Frankenstein200 experience, which combines simple hands-on activities and narrative-based learning to enable learners to position themselves as scientists and learn about science and science ethics. Presenting findings from 2 studies in science museums, the current work describes how Frankenstein200 was implemented and tested in informal education settings and the impact it had on learners. Results from this research suggest that narrative-based learning experiences such as Frankenstein200 can serve as an effective tool for tackling complex and abstract issues in an approachable way, motivating people to engage in scientific conversations, and encouraging people to see themselves as scientists and creators.

## Introduction

In science education, narrative-based learning conceptualizes narratives as effective educational tools that allow people to make sense of, understand, and remember abstract theories and notions more easily (Arya & Maul, 2012). Narratives are important because they can pull learners in by showing a "why" or rationale behind abstract science concepts and theories (Adams, Mayer, McNamara, Koenig, & Wainess, 2012). Science narratives may also allow learners to become familiar with science concepts and apply them to solve problems, both in and out of the school context (Engel, Lucido, & Cook, 2018). This might take the form of role-playing experiences (e.g., players taking on the role of scientists or inventors), various challenges and puzzles (e.g., finding a cure to save other characters' lives), and dilemmas (e.g., should scientists test on animals?) (Dickey, 2006). Through these activities, learners are invited to position themselves as scientists and solve problems, meet and work with other scientists, and make discoveries about the world.

Educators can run narrative-based learning projects by designing experiences online (e.g., video games) and offline (e.g., hands-on activities) through which learners can develop new skills and competencies. These activities are compelling for learners because they are salient for the narrative context, helping characters reach their goals or resolving a conflict. Prior research shows great promise for narrative-based learning across a wide range of domains, such as English literature (e.g., Fleming, 2013), mathematics (e.g., McCarthy, Tiu, & Li, 2018), and engineering (e.g., Stansell, Tyler-Wood, & Austin, 2016). These studies demonstrate that narratives can have positive effects on learners' academic motivation, persistence, and achievement (Lee, Park, & Jin, 2006; Marsh, 2010; Pivec, 2007). However, there is still a great need for further research on how narrative-learning design can support learning activities in informal education settings (Andre, Durksen, & Volman, 2017). For example, it is not clear exactly how fictional science narratives support learners' engagement and contribute to pedagogies intended to bolster learners' performance in science (e.g., Mawasi, Nagy, & Wylie, 2020). One particularly important issue concerns the social aspects of narratives in informal settings. That is, informal learning activities often invite learners to collaborate with each other, educators, facilitators, and/or other people (e.g., siblings, parents) when partaking in science narratives.

This paper seeks to address this need through the example of Frankenstein200 (https://frankenstein200.org), a narrative-based learning experience inspired by Mary Shelley's legendary 19th-century novel *Frankenstein; or, The Modern Prometheus*. We were interested to explore how the culturally ubiquitous Frankenstein narrative can help learners engage in conversations about science, refine their images of scientists, and become more curious and confident in their own scientific capacities. We formulated the following research question: How can our narrative-based learning activities help learners build a more nuanced understanding of scientific concepts and prompt conversation about science?

The paper proceeds as follows. First, we describe Frankenstein200, which uses various hands-on activities ("Frankenstein's Footlocker") intended to help learners expand their knowledge about contemporary issues related to emerging technologies such as synthetic biology, biomechanical engineering, and robotics. This work incorporates themes from *Frankenstein* (e.g., science ethics, the limits of scientific exploration) to engage learners in conversations about scientific responsibility and creativity. Second, we show how Frankenstein200 was implemented in an informal education setting and present qualitative findings from data collected from museums across the United States. And finally, we propose guidelines and recommendations on how narrative-based learning experiences can be used for science and science ethics education in informal settings.

## Methods

### Context and Research Site

In conjunction with the global celebration of the bicentennial of the publication of Mary Shelley's *Frankenstein* in 2018, Frankenstein Footlocker kits were awarded to 51 science and children's museums throughout the United States. As a condition of being awarded a kit, museums were encouraged to organize two Frankenstein-themed events: one event in early 2018 to align with the bicentennial celebration (the novel was originally published in January 1818), and another event in October 2018 to align with that year's Halloween programming. Interview and observational data were collected from nine museum partners in January and February 2018 and from four sites in October 2018. In January and February, we collected observational data to learn about participants' engagement and about how museum educators facilitated the activities. We also interviewed museum visitors to investigate their perceptions of the activities. In terms of observational data, the research protocol focused on two areas regarding participant engagement: the interaction between museum facilitators and visitors, and the interaction between parents and children during activities. During January/February and October 2018, a total of 143 observations and 45 individual interviews with children between 5 and 12 years of age were conducted. Data sources encompassed field and observational notes and audio-recorded interviews.

### Activities

The Frankenstein200 experience consists of seven hands-on activities that prompt deeper conversations about scientific and technological creativity, the limits of scientific exploration, and social responsibility. Frankenstein200 took widely used science-education activities and connected them with a compelling narrative to engage participants in deeper thinking and conversation about the social and ethical issues surrounding scientific work. Each of the hands-on activities uses easily available and inexpensive materials, making them broadly accessible (see Table 1). The activities and facilitation guides are available at https://www.nisenet.org/frankensteinkit.

| Hands-on activity | Description |
|---|---|
| Scribbler | A mini-robot that participants create using an electric toothbrush motor, a foam pool-noodle piece, and markers that draw designs on paper. |
| Dough Creature | Participants create simple circuits using two types of homemade modeling clay, a battery pack, and an LED light. |
| FrankenToy | A stuffed animal created by recombining elements of existing stuffed animals. |
| Automata | Automata are mechanical sculptures that combine elements such as cams, levers, and linkages. After creating their devices, participants are asked to reflect on questions related to creativity, engineering, and responsibility. |
| Battery Stacks | Participants make a model of a voltaic pile, the first kind of battery that converts chemical energy to electrical energy. Participants also learn the history behind the invention and how it works. |
| Spark of Life | By placing their hands on zinc and copper sheets, participants experience how electricity can flow through their body. This activity is intended to illustrate how batteries and some medical technologies work. |
| Monster Mask | Participants make a mask with a special feature: an LED bulb that lights up. |

*Table 1. Description of hands-on activities used in Frankenstein200.*

For example, a Scribbler is made of simple materials: pool noodles, markers, and rubber bands. Learners animate their Scribblers with an electric toothbrush wedged inside the pool noodle so it can move and draw on a sheet of paper (see Figure 1). Creating the artifact is only the first step of the experience; after the child builds a Scribbler, a facilitator can ask questions such as: (a) Is your drawing art? If so, who is the artist? (b) If someone wanted to buy your drawing, should you get the money or should your Scribbler get the money? (c) What if your Scribbler was turned on and drew on something important? Who should be responsible? Depending on the age of the learner, the facilitator can then proceed to discuss ethical issues surrounding emerging technology such as autonomous vehicles and begin to introduce the concept of unintended consequences. The activity FrankenToy, on the other hand, is a "creature" assembled from different parts of toys. By mixing and matching parts of plush animals and dolls, learners create their own creatures, act out the story of their creation, and take photos of them (see Figure 1). This activity is guided by the following facilitating questions: (a) Could your creature be real? Why or why not? (b) Could it be dangerous? (c) What would happen if your creature did something bad? Who would be responsible?

*Figure 1. Example of the Scribbler (on the left) and FrankenToy (on the right) activities.*

Dough Creature uses play dough to provide opportunities for learning about electronics and circuits. Using two types of homemade play dough, a battery pack, and an LED light, participants create simple circuits. After completing the activity, participants are given a discussion card and encouraged to ask each other reflection questions (e.g., “Why did some of the circuits work and some not? What did you learn from this activity? What would your creature do if it was alive?”).

As illustrated by these three examples, each of the activities builds upon themes from the Frankenstein story. Frankenstein is an incredibly popular narrative, familiar even to those who have not read the novel. Despite being more than 200 years old, the story still serves as a cautionary tale about scientific discovery and responsibility. By creating a set of activities and facilitation questions wrapped within the Frankenstein narrative, we aspired to create an engaging and educational experience.

## Results

Observational findings show two main trends in engagement. First, facilitators boosted participants’ engagement and interest by invoking images from the Frankenstein narrative. While the activities were designed for children to be able to complete on their own, we saw a number of parents take part in the activities on their own or help their children create the products. Take the following example from a Scribbler activity: The museum facilitator invites a 7-year-old boy to the activity, telling him about how Dr. Frankenstein’s monster was assembled from different body parts. The boy gets excited and agrees to build “a monster.” After explaining how to create a Scribbler, the facilitator draws a parallel between this activity and scientists’ and engineers’ work in general. She also adds, “They [scientists and engineers] constantly try to figure things out.” The boy realizes that he has to change the battery in the toothbrush because it is not working. When the Scribbler starts vibrating and drawing on a sheet of paper, the facilitator asks the participant why he thinks “the monster” is working now. The boy says that the battery and the heights of the markers had to be changed. The facilitator mentions that this is how scientists and engineers work: They see a problem and try to find a solution. The boy agrees and says, “I am like a scientist. Cool!” The parent, who was watching her child working on the Scribbler activity, is very happy about how the boy managed to make the activity work. In other cases, learners made connections between the hands-on activity they completed and their everyday science knowledge about science and innovation. For example, a young boy aged 8 years was initially struggling to make his Automata work. He had created a green head, which he called "Frankenstein's head," and mounted it on top of a box. The wheels he had selected did not rotate properly, so he could not make the head turn around by itself. Later, he realized that he needed to make some adjustments and experiment with new designs. Seeing that the participant tried to come up with new ideas, the facilitator encouraged him by saying, "You're doing a great job! Engineers and scientists go through this every day with the things they build." After about five more minutes, the boy could make his Frankenstein's head move and he got very excited. The facilitator said, "You figured it out!" The boy said, "It was an accident … like the potato chips!" When the facilitator asked him what he meant, the boy said that the Automata reminded him about how potato chips were invented by accident. He added, "Sometimes you need to try really hard to make things work!"

In addition to encouraging participants to become creators, facilitators helped visitors gain a more complex understanding of science concepts and responsibility by asking facilitation questions. Grappling with these questions required participants to reflect on thematic issues that were salient to the activities, providing opportunities to reflect upon emerging science and engineering practices, such as robotics or synthetic biology, and connect them to questions around ethics and responsibility. Take the following example from another Scribbler activity. After an 8-year-old girl completed the activity and the Scribbler started drawing on a sheet of paper, the facilitator asked the participant who the artist was. The girl pointed at the Scribbler and said, "The machine." The participant also argued that if the Scribbler created something valuable, worth a million dollars, "the robot" should get the money rather than the inventor. However, if something went wrong and the Scribbler did something bad, the inventor should get the blame because it was she who created the machine and therefore she is responsible for its actions. In another case, an 8-year-old boy completed the Dough Creature activity. While the boy was working on the activity, the facilitator also asked questions about Victor Frankenstein. The boy said, "Frankenstein was made by a mad doctor." When asked whether he saw a connection between the activity and the Frankenstein story, the boy said, "Yes, they were both building a monster." The facilitator and the participant went on to talk about the responsibilities of scientists. The boy noted that responsibility is important because something bad can happen and things can go wrong in the course of scientific work. In his view, it is his responsibility as a creator to make sure his Dough Creature works safely and does not cause harm to others.

These examples illustrate that the Frankenstein story can serve as an effective tool to spark interest in science, allow participants to make connections between the Frankenstein's Footlocker activities and their everyday experiences, engage in ethical deliberations, and position participants as scientists and creators.

Results from the interview data suggest two additional trends. First, Frankenstein's Footlocker could help participants better understand how scientists think and work. When it comes to the figure of Victor Frankenstein, many young learners could see similarities between the work Victor did and the activities they as participants completed. Take the following example:

> Interviewer: What do you know about Frankenstein?
> Boy (10 years old): That he's a little—like he's a person and he got made up of scientist out of like human body parts, and that he doesn't like fire and that whole—like he would yell, "Fire," when there is a fire is close by. And he just runs all over the place and he's really silly, and it's just really fun.
> Interviewer: Cool. Do you think any of the activities today remind you of Frankenstein?
> Boy: Yeah. Especially the baby doll, like—because you get to make your own baby doll out of other parts, like a puppy dog or like a dinosaur or something like that. Like they have on the table.

Here, although the learner gets a little off track with describing the creature, he has knowledge of the story, including, with the fire detail, how it is expressed in movies and TV, and he manages to make a clear connection about how he is creating an engineered being in this activity, like Victor in the Frankenstein story.

In addition, by engaging in hands-on activities, learners could see how scientists create, learn from their mistakes, and overcome difficulties. Take the following example:

> Interviewer (after the participant completed the Automata activity): What was the most interesting thing that you learned from this activity?
> Boy (11 years old): Probably like how scientists think of one idea. And how they fail. They try again and sometimes things can be invented by accident.
> Interviewer: Do you see yourself as a scientist or an inventor?
> Boy: Yes, I can see myself as an inventor. I would like to invent things like this machine.

In this sense, the Frankenstein narrative helped some participants reflect on the responsibilities of scientists when they design and conduct experiments. The example below highlights one of the recurring themes from our interviews:

> Interviewer: So, one of the ideas around the story Frankenstein is that it's important that we take responsibility for things that we create, and so, how do you think that people can be more responsible for things that they create?
> Girl (10 years old): By knowing what they can do. Like if you make off a robot or something, you have to know what they can do before like putting it out into the world, because if you don't know, it can do something and it might hurt somebody or something.

For many of our participants, being a responsible scientist means that people need to take care of their creations. Otherwise, scientific experiments might lead to accidents and disasters. For our participants, no matter if the creation is organic or synthetic, scientists should be careful when they run experiments. Take the following example:

> Interviewer: So, we talked a lot about these activities, about being creative and being responsible for the things that you create. Do you think people should be responsible when they create something?
> Girl (8 years old): Well, if you're not responsible, the thing might get out of hand and destroys stuff.
> Interviewer: So, can you tell me a real-life example of somebody creating something and not being responsible for it?
> Girl: Well, it's like when you have a kitten. Your cat has kittens and you don't want to take care of the kittens. So, the kittens really need to be taken care of. And you don't take care of them.

Second, participants could learn about a variety of scientific and engineering concepts and practices through the Frankenstein's Footlocker. In connection with the Frankenstein story, even simple activities could help learners get a better grasp on the potential uses of technologies. Take the following example:

> Interviewer: Do you see any connection between Frankenstein and the activities that you did here?
> Girl (9 years old): Making the [Dough Creature]. Because you had to make circuits to bring it alive.
> Interviewer: And what did you learn from the Squishy Circuits?
> Girl: I learned that not everything can like electricity can go through.
> Interviewer: Why?
> Girl: Because it can't go through a table because we tried that.

Other participants learned about design and the capabilities of technologies. By experimenting and observing how different components, such as conductive dough or metal sheets, enabled or hindered certain actions (e.g., making sound, changing color), learners could develop a better understanding of the qualities of materials. Take the following example:

> Interviewer: What did you learn from that activity [referring to the Battery Stack]?
> Boy (11 years old): Let's see … I've learned from the activity, the battery stacking, the zinc sheets, the things. Well, that was pretty interesting how it could make any noise from that.

However, some participants could not fully articulate what new things they learned by completing the activities. Instead, they realized that creating scientific artifacts can be challenging and difficult. Take the following short passage:

> Interviewer: What did you learn from FrankenToy? Did you learn something new?
> Boy (8 years old): How weird it is to create things. And how hard it is.

These examples demonstrate that by completing the hands-on activities, young learners gained a better understanding of how technologies work and what purposes they can be used for.

## Discussion and Implications

Findings from our museum studies suggest three major conclusions for informal science education. First, narrative-based learning experiences can show participants that science learning can happen anywhere, in and beyond science labs. Frankenstein200 activities opened up new ways for participants to learn about science and engineering (e.g., how electricity works, how to build simple robots).

Second, narrative-based learning can serve as an effective tool for tackling complex and abstract issues in an engaging and nonthreatening way, by allowing even young learners to acknowledge that science has social and ethical implications. This project used Frankenstein as an imaginative tool to facilitate conversation and help learners conceptualize scientific responsibility and the limits of scientific exploration by providing hands-on experiences.

Third, and finally, narrative-based learning can motivate and inspire learners to recognize that anyone can be a scientist. Frankenstein's Footlocker provides physical activities for learners to create *and* position themselves as scientists. These experiences can help them recognize their potential as science learners and develop a stronger interest in science and science ethics.

While implementing facilitation practices in museum settings may pose various challenges to educators (e.g., activities with discussion require more time to complete), they can help younger visitors approach complex issues such as science ethics. We hope that our qualitative findings can help museum professionals and researchers develop, implement, and evaluate public programs that use narrative-based learning principles for informal science educational purposes.

## References


Adams, D. M., Mayer, R. E., McNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. *Journal of Educational Psychology*, 104(1), 235–249.

Andre, L., Durksen, T., & Volman, M. L. (2016). Museums as avenues of learning for children: A decade of research. *Learning Environments Research*, 20(1), 47–76.

Arya, D. J., & Maul, A. (2012). The role of the scientific discovery narrative in middle school science education: An experimental study. *Journal of Educational Psychology*, 104(4), 1022–1032.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development*, 54(3), 245–263.

Engel, A., Lucido, K., & Cook, K. (2018). Rethinking narrative: Leveraging storytelling for science learning. *Childhood Education*, 94(6), 4–12.

Fleming, L. (2013). Expanding learning opportunities with transmedia practices: Inanimate Alice as an exemplar. *Journal of Media Literacy Education*, 5(2). Retrieved from https://digitalcommons.uri.edu/jmle/vol5/iss2/3

Lee, K. M., Park, N., & Jin, S. (2006). Narrative and interactivity in computer games. In P. Vorderer & J. Bryant (Eds.), *Playing video games* (pp. 259–274). Mahwah, NJ: Erlbaum.
Marsh, T. (2010). Activity-based scenario design, development, and assessment in serious games. In R. van Eck (Ed.), *Gaming and cognition: Theories and practice from the learning sciences* (pp. 213–225). New York, NY: Information Science Reference.
Mawasi, A., Nagy, P., & Wylie, R. (2020). Systematic literature review on narrative-based learning in educational technology learning environments (2007–2017). In M. Gresalfi & I. S. Horn (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020* (Vol. 3; pp. 1213–1220). Nashville, TN: International Society of the Learning Sciences.
McCarthy, E., Tiu, M., & Li, L. (2018). Learning math with Curious George and Odd Squad: Transmedia in the classroom. *Technology, Knowledge and Learning*, 23(2), 223–246.
Pivec, M. (2007). Play and learn: Potentials of game-based learning [Editorial]. *British Journal of Educational Technology*, 38(3), 387–393.
Stansel, A., Tyler-Wood, T., & Austin, S. (2016). The development of a transmedia STEM curriculum: Implications for mathematics education. *Journal of Mathematics Education*, 9(2), 72–80.

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# 16. Africa Code Week: Raising Africa's Next-Generation Skilled Workforce

**JOHN T. OKEWOLE**

**Abstract:** The Africa Code Week (ACW) initiative has succeeded in less than half the time on its initial targets of introducing digital literacy to African children and youths. With an original 10-year vision (2015–2025) to introduce 5 million African youth to information and communication technology (ICT) and coding, it achieved the target in 2019, having trained a combined 7.95 million youth. This paper analyzes how the project has been able to achieve this lofty target, discussing how the project's core values were adapted across constituents. A closer look into some of the events and how it was organized serves as sample case study. The outlook of ACW and how it established various sustainable patterns of engagement form the 3rd part of the paper, which includes the public-private partnership in place that effectively helped to drive the project and the importance of accelerating 21st-century skill development in traditional school systems through effective collaboration. Also discussed is how the concept of mass education can help drive the skills ecosystem in Africa, taking a cue from the project, and the necessity of shifting unproductive education policies to accommodate innovation, creativity, and growth in the digital economy. The initiative was designed with educators and school leaders' inclusion, which partly helped lay the groundwork for sustenance. Finally, this paper recommends as a value proposition the pattern established to be used for other wide-ranging initiatives on the continent and elsewhere to build the much-needed skilled workforce of the future.

## Introduction

Africa Code Week (ACW; https://www.africacodeweek.org/) is the biggest digital literacy event of the African continent. Its aim is to raise awareness of information and communication technology (ICT) for a critical mass of participants (UNESCO, 2018). An initiative of the software company SAP, Africa Code Week has a long-term goal of widening access to coding workshops and resources for more than 5 million children and youth by 2025. According to its mission statement, it takes an empowered village to raise a child in the digital age, hence, Africa Code Week is instilling digital literacy and coding skills in the young generation, working closely with private, public, and nonprofit partners to drive sustainable learning impacts across Africa.

SAP is a software and services company that drives digital transformation of businesses, governments, and charities across 190 countries. Because of its global outreach and knowledge of various contexts, the organization through its leadership has learned that "innovation starts with people" (Pompeu-Pividal, 2016). This is what necessitated its spearheading such an initiative as Africa Code Week to drive sustainable digital literacy growth in Africa. Africa as a matter of urgency needs such an ambitious initiative if it will compete favorably in the digital economy (Sadovaya, 2018). It needs to be emphasized here that digital is the new literacy of the 21st century (Dahlman, Mealy, & Wermelinger, 2016). Arguably, every aspect of life on planet Earth revolves round digitization.

The world of work has changed forever with the impact of digitization, automation, robotics, and so forth. This has necessitated the need for 21st-century skills—critical thinking, collaboration, creativity, and communication—required to survive and thrive in the world of work (Kay & Greenhill, 2011). Most education systems are, however, not ready, aligned, and/or moving with the changing trends. Most African countries fall in this category. The attendant problem, commonly called the *digital divide*—a term that refers to the gaps in access to information and communication technology (ICT) and threatens the ICT "have-nots," whether individuals, groups, or entire countries—has hindered people from effectively taking advantage of the opportunities and affordances of the digital age (Lavery et al., 2018). The school system is a major point of challenge as it is where most skills are learned and acquired for the world of work. Invariably, with the schools still operating in a 20th-century mode, clearly for the industrial sector, they will continue to have issues in effectively preparing people for the new order. An example of what this leads to is *skills mismatch* (UNESCO-UNEVOC, n.d.), in which the skills a graduate has do not fit the job description available. An ambitious and wide-reaching action therefore is what can help to initiate a paradigm shift toward preparing a competent and agile workforce for the digital economy.

That is what Africa Code Week is pushing in its revolution and in the most impactful way. By introducing children and youth to ICT and coding, making available resources and professional development across a wide spectrum, the initiative is laying the appropriate foundation for digital literacy, which will lead to an increase in preparedness of the future workforce. Also, it sets out as a catalyst for a huge transformation of the education systems in Africa by bringing stakeholders (educators, policy makers, government, and the private sector) to the table in order to act for the needed change in policy and practice for massive digital-learning transformation. Several initiatives have taken place in Africa before now but none has sustainably impacted more people and reached more countries in a short time. The driving force is well-defined and executed strong partnerships with the public, private, and nonprofit sectors, helping to build a community capacity in ICT education across the entire continent.

Africa has the highest number of youth per population (UNDESA, 2015) and it is growing. Youth are also the demographic transitioning after school into the labor force. Youth ages 8–24 are the target block of the initiative. This is the school age ranging from primary school to higher education institutions, which by direct implication serves as an orientation that encompasses the future workforce. This is also the age group that is now referenced as *digital natives* (*Techopedia*, 2015), since a large chunk of these youth were introduced early to digital gadgetry and are digital consumers already. Africa Code Week is offering the very important incentive of raising and nurturing digital creators, developers, and entrepreneurs from this block, which is indeed a push to advance the future development of the continent.

A striking complement to the design of the initiative is the toolkit being used—Scratch (https://scratch.mit.edu/)—which is a project of the Lifelong Kindergarten Group at the MIT Media Lab. It is a programming language and tool of engagement especially designed for ages 8 to 16 but with a variety of extensions that makes it valuable for use beyond that age.

In this paper, we take an in-depth look at the results of the initiative since inception and how it was achieved. Then a case study of the process of organizing a Code Week is presented. The prospects for Africa Code Week are bright and we will look at probable projections based on present results. Recommendations are then offered to learn from the patterns established for future initiatives.

## Analyses of Africa Code Week

The inaugural edition of Africa Code Week was held in 2015. Seventeen (17) countries participated from all the African regions. Figure 1 shows participation by regions. The total number of youth trained was 88,763, which represents an average of 5,200 children per country. The gender split for the first edition was almost even, that is, 50/50. Teachers' development has always been a priority for Africa Code Week. In the first edition 2,088 teachers were recorded trained. The event also started with a host of partners, the count of which was more than 100 partners.

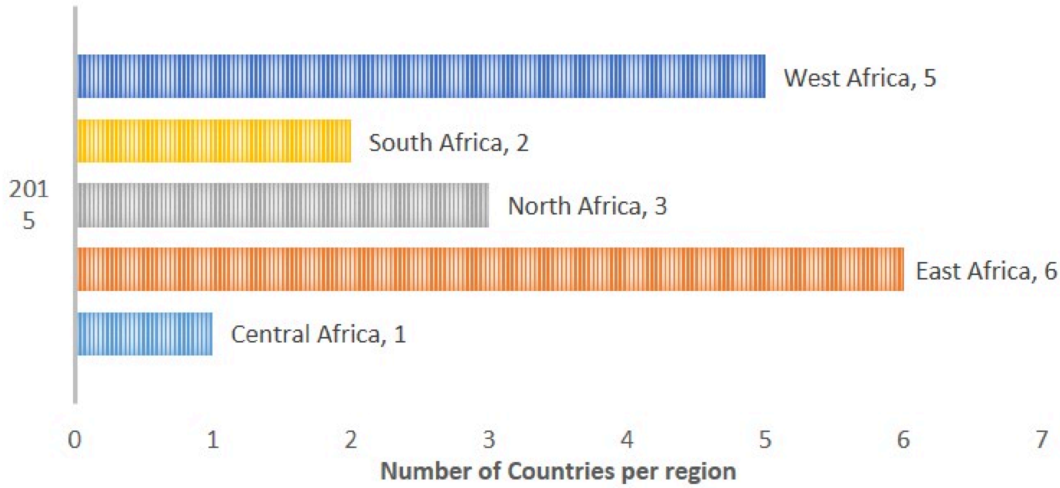


*Figure 1. Maiden edition of Africa Code Week participation by African regions.*

The initiative has experienced an astronomical increase in virtually all aspects since the maiden edition in 2015. After five editions of Africa Code Week, a combined more than 7.95 million youth have been trained (see Figure 2). The number of participating countries has increased year to year from 2015 to 2019 (see Figure 3). The numbers are 17, 30, 35, and 37 respectively. A comparative analysis of teachers-to-youth participation was carried out. Figure 4 shows the trend in the growth as a ratio of teachers trained to youth. Year 2018 shows a remarkable reduction in the number of teachers to youth trained compared with other years. While there was improvement in 2019 on the ratio of teachers trained, it fell short considering the increment experienced in the number of youth who participated. It is now well established that the more popular the program becomes across Africa, the more youth get enrolled and the more there is the support of parents for their wards to take part. School leaders and education ministries will obviously have to do more in coming years to encourage and allow participation of more teachers in the program as this participation is linked to the impact on sustaining and expanding the momentum in the classroom (Hague & Payton, 2011).

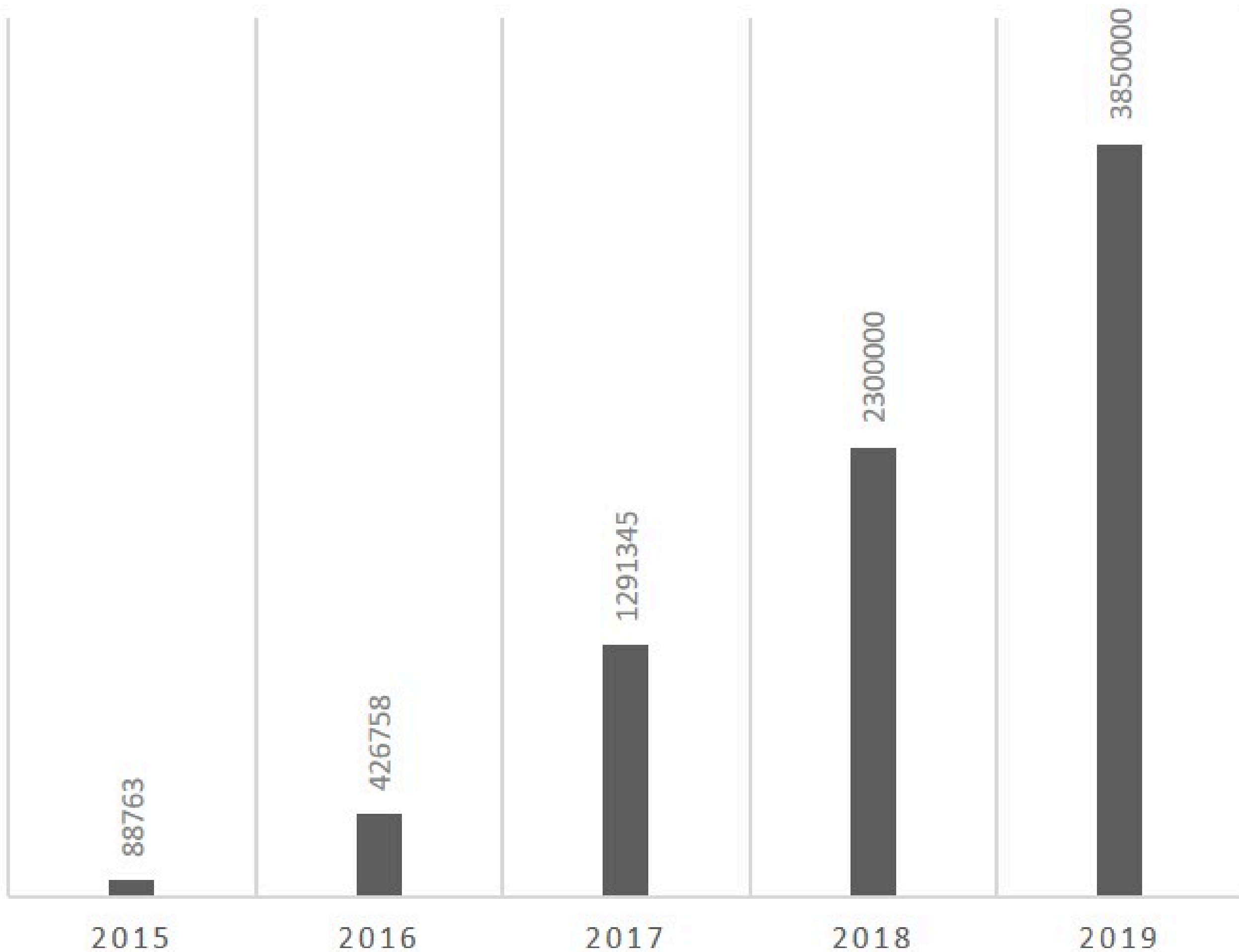


*Figure 2. Population of trained youth per year 2015–2019.*

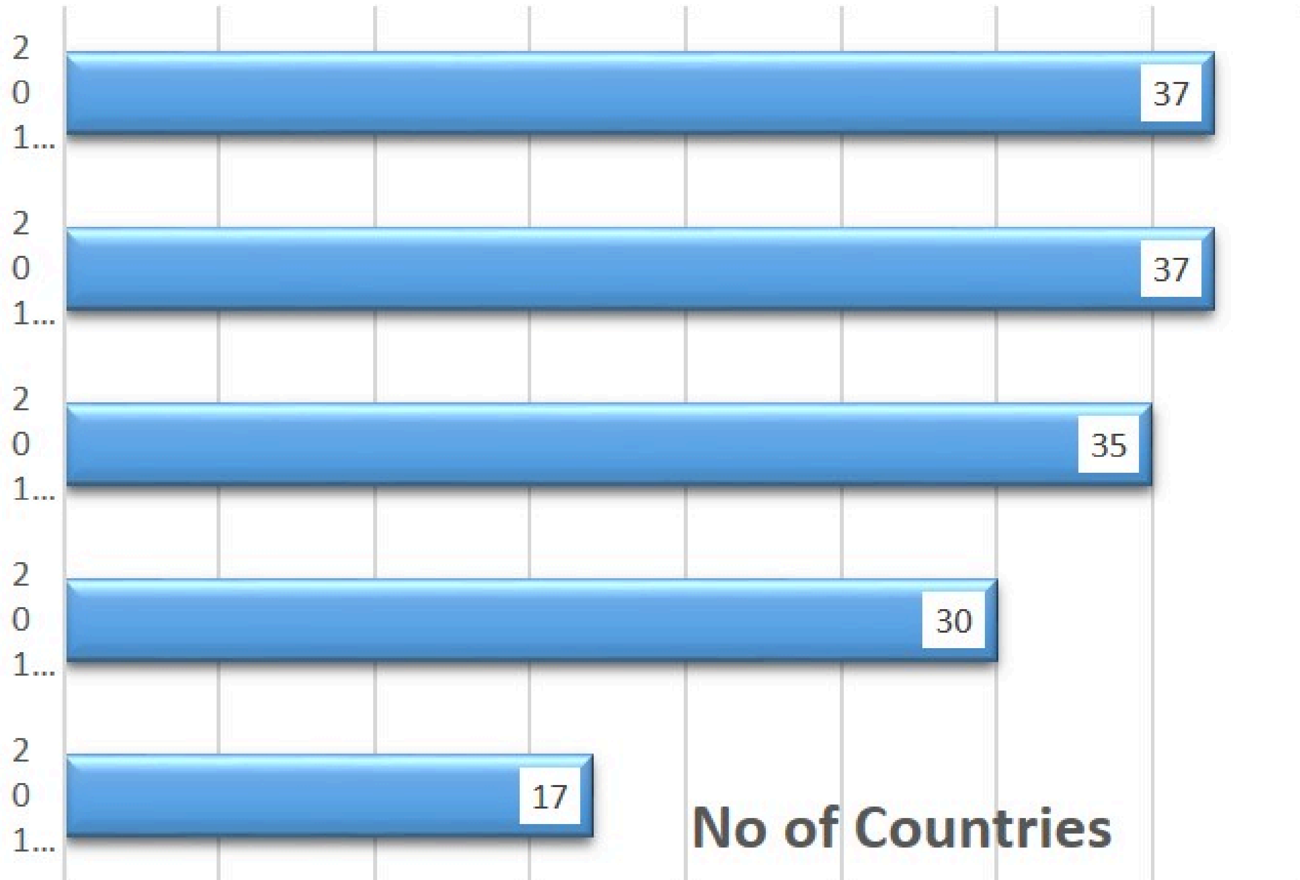


*Figure 3. Chart of Africa Code Week countries' participation 2015–2019.*

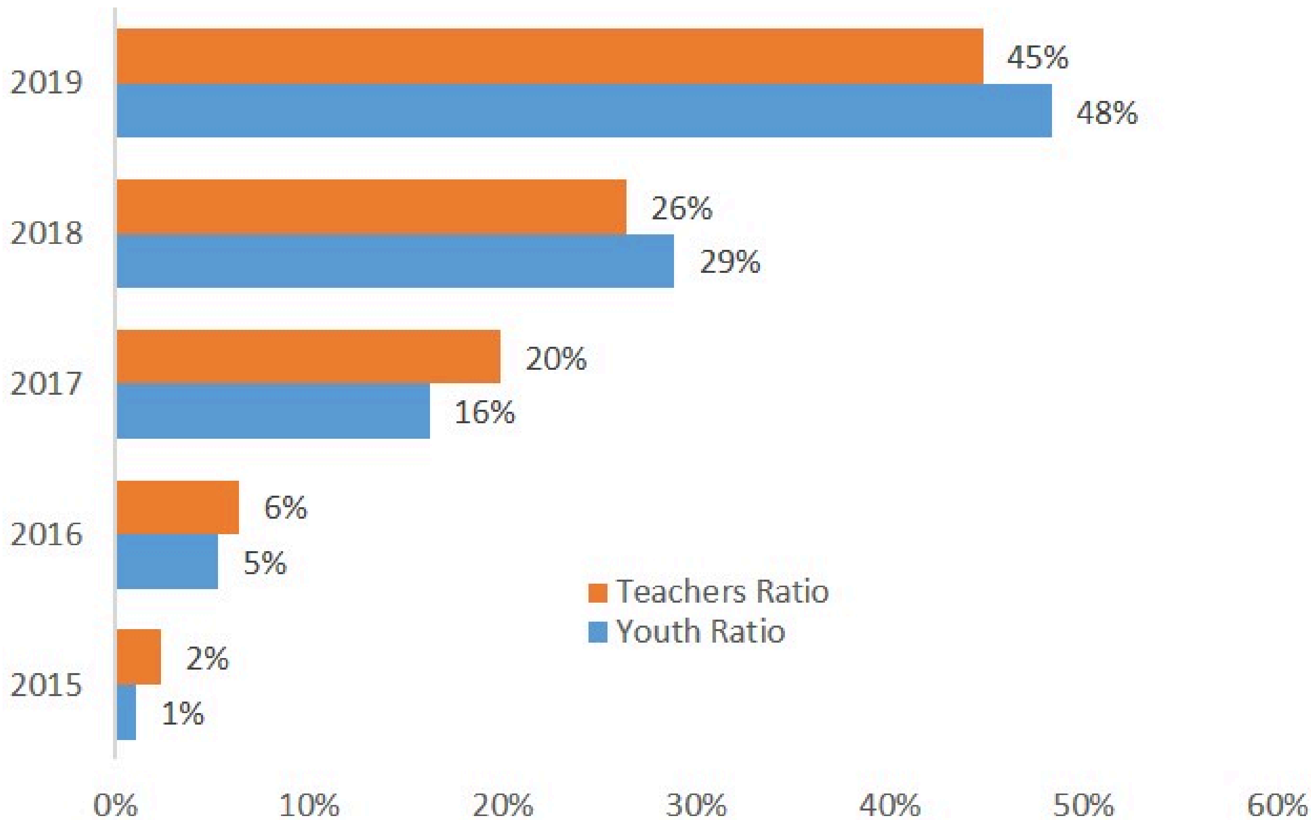


*Figure 4. Comparative analysis of teacher-to-youth participation 2015–2019.*

ACW has been well heralded as seen in Figure 5, which shows an increase in country participation instigating a direct increase in youth participation. At the same time, the gender representation (see Figure 6) is balanced, which is welcome progress toward achieving the United Nations' sustainable development goal 5 (SDG 5; United Nations, 2017).

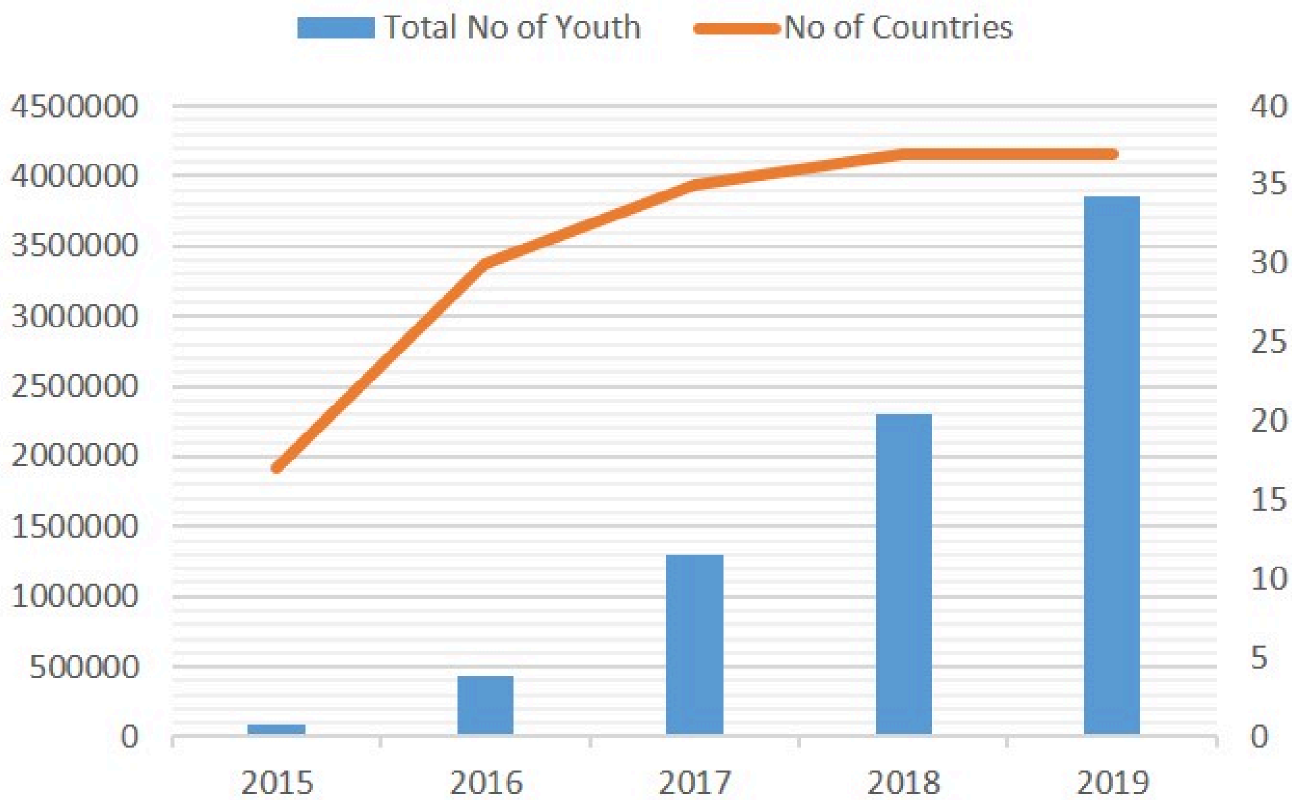


*Figure 5. Combined chart showing country and youth participation 2015–2019.*

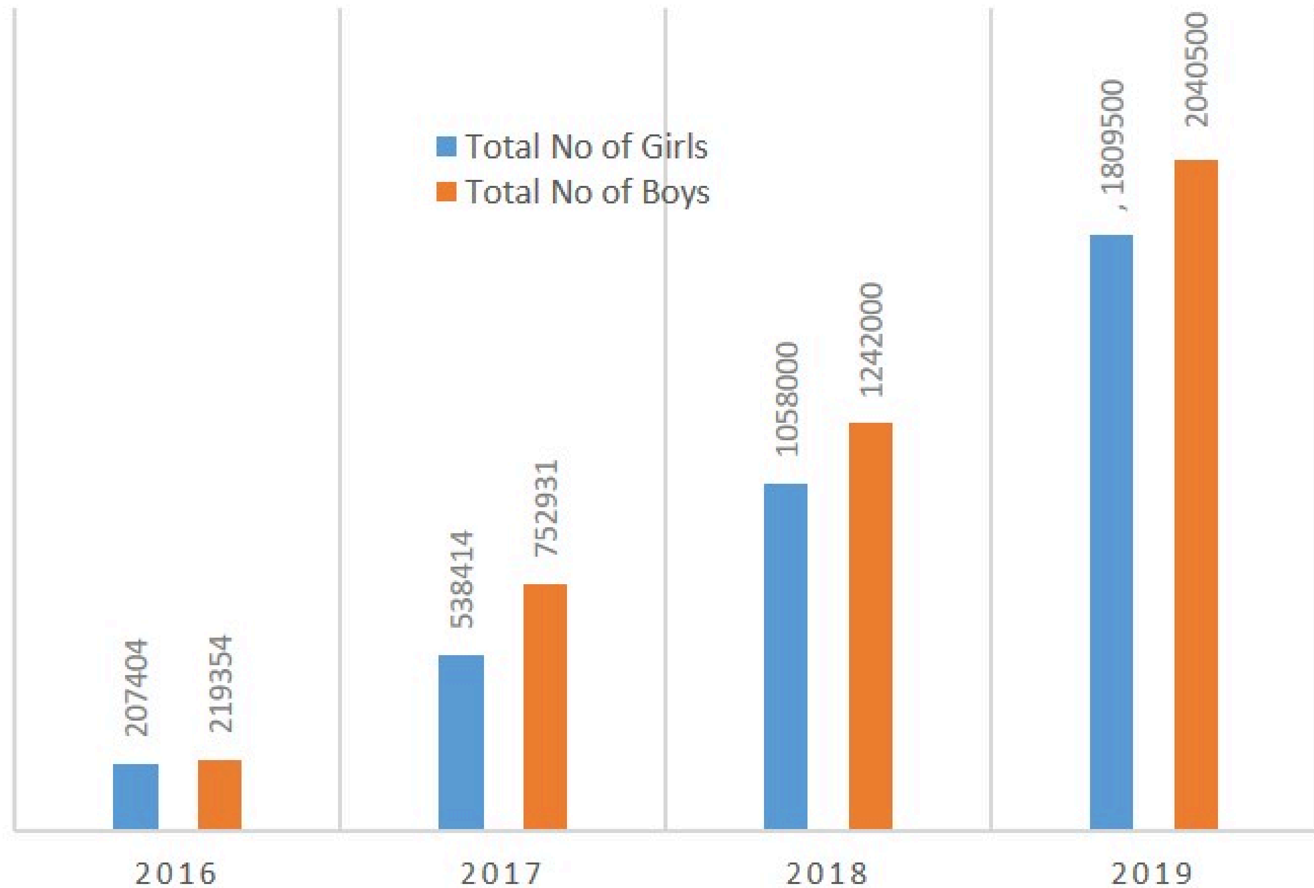


*Figure 6. Gender ratio of youth participation 2016–2019.*

## Case Study of Africa Code Week Organization

The process of organizing Africa Code Week is straightforward. There is a contact designated for the program per country who is responsible for information flow in terms of dates, partnerships, volunteers, relationships, and so forth. Two important dates are set: the date for the train-the-trainer and the Code Week date. There are partners and volunteers (ambassadors). Partners include grant givers, event organizers, and government ministries and agencies. Examples of grant givers include the Google CS initiative and the German Federal Ministry for Economic Cooperation and Development (BMZ) under the #eSkills4Girls initiative. Event-organizing partners include UNESCO Country Offices. Government partnership has also helped Africa Code Week to thrive. Volunteers assist in implementing the training. Volunteers are organizations that access micrograants to organize the event. Volunteers also work with designated schools to train both teachers and students.

The Africa Code Week 2018 edition took place at Yaba College of Technology Secondary School through a volunteer. He received a communication from the country contact person that included a letter requesting the school to participate. The volunteer worked with the school to ensure modalities and preparations were made. The school's computer lab was used. Prior training was scheduled for teachers and about 20 teachers were digitally empowered. The Code Week in the school started with an inaugural edition that was recorded by BBC Africa. Three periods were scheduled per day during the course of the Code Week to carry out training for all the class distributions of the school, which made it possible to cover the entire school population. More than 500 youth were trained and the ratio was 44:56 girls to boys. The training started to yield results immediately, as record numbers of the students returned to the computer lab to learn further and try out what they had learned. Since Scratch was installed in all 35 computers in the school's lab, students returned and took turns during break periods and after school hours to do more individual projects.

Another case study of the Code Week is the event organized by the UNESCO Abuja office (PrimePost, 2018). A train-the-trainer event was carried out after which schools were adopted by the trainers and the students were trained during the course of the week. The event also complemented the UNESCO YouthMobile project, hence it has additional trainings that include website design and mobile application development.

## Africa Code Week Projections

ACW is setting a pattern of engagement that has been critical to its success thus far. Public-private partnership is not new across the world; several programs in the world already run with it. Howbeit, in the case of ACW, an organization from the private sector understood the required investment that needed to be made for the upcoming generation and that it must be a concerted effort for it to work. SAP's (Welz & Rosenberg, 2018) reaching out and engaging partners that might even be competitors speaks volumes about its desire to make a needed impact for the good of the continent. As it is now, ACW increases collaborators year to year from the private sector, public sector, governments, and even individuals. The focus area is also a very important point of discourse. The traditional education systems are mostly inflexible and change is always difficult to make in schools, especially public schools. Taking a major initiative into that territory really needed so much courage, which SAP has exerted. Invariably, we need to understand that the more we avoid stepping into seemingly difficult terrain such as the school system, the more we debar progress and transformation for the future workforce, because that is where people are trained to enter the labor force.

Additionally, to effect a major change in the education system or achieve widespread impact, innovative ideas must be scaled. In the case of ACW, the principle of mass education was employed. There have been similar initiatives that have either been "one-off" or not scaled for effective impact. In that regard, ACW has become a transformational force in the education systems across Africa because of its scale and multiyear approach.

In the digital economy, keeping with the norm or tradition as it is known will only set people back. Innovation, creativity, and growth do not happen without a paradigm shift or a holistic change. While ACW has laid the way, the momentum cannot be sustained without education systems' yielding unproductive policy grounds. In fact, most of the participating countries need to make a quick readjustment for the Code Week to take place. Most countries lack policies, frameworks, and effective monitoring mechanisms for digital literacy, unlike the way core subjects such as mathematics and language are treated. For instance, some schools do not carry out schoolwide professional development, and some do not have periods for ICT subjects. For those that have, they lack competent teachers to train students in ICT. Implementing ACW has revealed and necessitated the need for a deeper look and accommodation of digital literacy as a core area in schools because of its utmost importance in developing skills for the world of work. A hallmark of this initiative is cultural inclusiveness, demonstrated in persistent bilingual (English and French) content development for the project; they are the most widely spoken languages in Africa.

A check of International Telecommunications Union statistics (ITU, n.d.) reveals how telephony has grown and accelerated Internet connectivity in Africa. The ages that have peaked in this are the 15–24-year-olds—the youth population. Hence, the swift progression of ACW is also due to the orientation of this primary age range targeted by the program. Noteworthy also is the fact that the primary audience are referenced as digital natives, that is, a generation of people already conversant and comfortable with digital technology outside the conventional school system. So, the initiative just tipped off their innate capability and as long as it exists and expands, the program will attract willing and ready learners. That ought to be an insight for education systems across the board to drive the necessary impact in the 21st century.

The design of the ACW did not leave educators and school leaders behind. In Africa, running an initiative with the existing system will help it to thrive more than going a separate way. The largest collection of youth come from the school system and the community is more comfortable with what comes through that channel than from a different place.

## Recommendations

As a value proposition, this paper proposes that the pattern established in the ACW project be used for other wide-ranging initiatives on the continent and elsewhere to build the much needed skilled workforce of the future. Some of the suggestions include: Education stakeholders should trade on the momentum to bring up policies and frameworks for digital literacy; initiatives should think and act for the long term; more priority should be given to teacher professional development; more collaboration should be encouraged and engendered for growth in the 21st century.

- Trade on the momentum—All stakeholders on the African continent need to take advantage of this initiative by learning and changing their disposition to education in the 21st century. The jobs of the future are going to be different from most.
- Think long term—There have been several initiatives like this that still exist but the challenge has always been that they were mostly one-off programs that could not make the widespread mark they should. Initially ACW was set to run for 10 years and with the success already achieved, we hope this will extend beyond then. Stakeholders and funders should take a cue from this.
- Upgrade education policies—There is no better time than this that Ministries of Education should upgrade and update their education policies to include digital literacy as a core subject with full practical complements like physics and so on.
- Prioritize professional development of teachers—This should be continual to help prepare the classroom leaders as it is essential for sustenance and continuity of the movement even after the initiative span is done.

## Conclusion

Africa Code Week, an initiative setting youth across Africa on the platform for digital literacy and for becoming digital creators, has succeeded in less than half of its projected time. This paper provided analysis of how it was done, dwelling on its core values, especially in effective collaboration and public-private partnerships. Recommendations were made for extending such a successful project, including impacts on policies and continued teacher professional development.

## References


Dahlman, C., Mealy, S., & Wermelinger, M. (2016). Harnessing the digital economy for developing countries. *OECD Development Centre Working Papers*. https://doi.org/10.1787/4adffb24-en

Hague, C., & Payton, S. (2011). Digital literacy across the curriculum. *Curriculum Leadership*, 9(10). Retrieved from http://www.curriculum.edu.au/leader/default.asp?id=33211&issueID=12380

International Telecommunications Union. (n.d.). *Statistics*. Retrieved from https://www.itu.int/en/ITU-D/Statistics/

Pages/stat/default.aspx
Kay, K., & Greenhill, V. (2011). Twenty-first century students need 21st century skills. In G. Wan & D. M. Gut (Eds.), *Bringing schools into the 21st century* (pp. 41–65). Dordrecht, The Netherlands: Springer.
Lavery, M. P., Abadi, M. M., Bauer, R., Brambilla, G., Cheng, L., Cox, M. A., … Marquardt, C. (2018). Tackling Africa's digital divide. *Nature Photonics*, 12(5), 249–252. https://doi.org/10.1038/s41566-018-0162-z
Pompeu-Pividal, R. (2016). *SAP steps up: Working with government to make the world a better place*. Retrieved from https://news.sap.com/2016/10/sap-ceo-bill-mcdermott-meets-with-world-leaders/
PrimePost. (2018). *Africa Code Week: UNESCO urges FG to take digital literacy seriously*. Retrieved from https://www.primepost.ng/2018/10/22/africa-code-week-unesco-urges-fg-to-take-digital-literacy-seriously/
Sadovaya, E. (2018). Digital economy and a new paradigm of the labor market. *Mirovaya ekonomika i mezhdunarodnye otnosheniya*, *62*(12), 35–45. https://doi.org/10.20542/0131-2227-2018-62-12-35-45
*Techopedia*. (2019). Digital native. Retrieved from https://www.techopedia.com/definition/28094/digital-native
UNDESA. (2015). *Youth population trends and sustainable development*. Retrieved from https://www.un.org/esa/socdev/documents/youth/fact-sheets/YouthPOP.pdf
UNESCO. (2018). Africa Code Week 2018 – Launch event. Retrieved from https://en.unesco.org/events/africa-code-week-2018-launch-event
UNESCO-UNEVOC TVET*pedia*. (n.d.). Skills mismatch. Retrieved from https://unevoc.unesco.org/go.php?q=TVETipedia+glossary+A-Z&filt=all&id=568
Welz, B., & Rosenberg, A. (2018). SAP next-gen matchmaking. In SAP *next-gen: Innovation with purpose* (pp. 45-55). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-72574-1_5
United Nations. (2017). SDG 5: Achieve gender equality and empower all women and girls. *17 goals to transform our world*. New York, NY: United Nations. Retrieved from https://www.un.org/sustainabledevelopment/gender-equality/

# 17. Improving Wearable Mindfulness App Through Participatory Design

ANNIKA PERSA, CRAIG G. ANDERSON, RICHARD MARTINEZ, MAX COLLINS, MARIA J. ANDERSON-COTO, AND KURT D. SQUIRE

**Abstract:** Educators embracing technology to promote social-emotional learning (SEL) are rising in discourse. Successful SEL programs struggle to scale. Such technologies seek to broaden reach and improve quality through feedback, tracking, and guided practice. Despite generating behavioral and neurological changes, previous interventions have been based on practicing skills in a thin social context and are disliked by youth. Using participatory design, we redeveloped an SEL into a wearable technology. In collaborative workshops, youth revealed their interests in and models of self-regulation that we incorporated into a smartwatch app. Redesigning the application resulted in higher levels of satisfaction and more frequent use. A tension emerged around youth's desire for tools to increase self-regulation without adding stress. While youth valued breath counting, they reported development of self-regulation through pursuits such as gaming. An interest-driven approach may leverage breath counting as attention-focus practice but competes with activities (sports, hobbies, academics) for youth time.

## Introduction

Noncognitive skills such as grit, tenacity, and perseverance have captured public imagination, as evidenced by Duckworth's (2016) *Grit: The Power of Passion and Perseverance*. Noncognitive skills predict general success across domains and are referenced in academic achievement (Farley & Kim-Spoon, 2014). Grit, tenacity, and perseverance are associated with the umbrella term *self-regulation* (*SR*), which is the enactment of behavior to monitor and regulate one's activities (Dweck, Walton, Cohen, Paunesku, & Yeager, 2011). Self-regulation represents (a) a host of skills that can be developed, (b) strategies that may be deployed in variable contexts, and (c) a resource that can be drawn upon (or depleted) through use. On a conscious level, for example, SR may be recognizing an angry feeling and diffusing it by enacting a calming strategy. The capacity to regulate one's self (social, emotional, and behavioral) has crucially been demonstrated to support academic and social development (Bodrova & Leong, 2007; Diamond & Lee, 2011; Raver et al., 2011). Diminished SR capacity creates difficulties directing attention, managing social problems, and learning.

### Educational Methods for Improving Self-Regulation

SR can be trained to affect the capacity of one's self-regulatory behavior. Targeted activities have been shown to train executive functions (EF) and improve EF and SR assessment (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). However, isolating and training EF to promote overall SR is limited by context; transfer of learning from single EF often fails to transfer to untrained tasks (Rossignoli, 2018). Transfer of EF training onto untrained tasks has involved extended activities situated in complex environments (Diamond, Barnett, Thomas, & Munro, 2007). Interest-driven activities that emphasize planning and reflection, such as fitness or academic planning, have provided examples of EF transfer for untrained tasks (Oaten & Cheng, 2006). Successful EF programs include connected learning; they introduce EF explicitly, address EF across activities, occur over extended time, repeat throughout the day, provide progression through increasing challenges, and often include mentorship (Diamond & Lee, 2011; Lakes & Hoyt, 2004).

## Game-Based Models of Self-Regulation

Game-based interventions offer models for managing self-regulation (Owen et al., 2010). *Luminosity* and *Elevate* show gains across cognitive tasks (Garcia, 2004; Nakano, 2015). Trainers such as *CogMed* employ game-based metaphors and SR training programs based on commercial games (such as *Super Monkey Ball* and *Brain Age*) demonstrate nearly half of a standard deviation improvement on IQ tests (Hardy et al., 2015). Commonly, SR cognitive training tools are based on clinical cognitive tests, making the intervention a form of "test taking" training (Mallan, Singh, & Giardina, 2010). *Breath counting* games can improve self-regulation (Kral et al., 2017). A two-week period breath-counting intervention improved attentional self-regulation as measured by behavioral tasks and neurological imaging (Patsenko et al., 2019). Evidence for physical brain changes over two weeks suggests breath counting may be a high-leverage psycho-sociological intervention (Yeager & Walton, 2011). Situating the above game within a robust social context could increase appeal and promote social or metacognitive practices associated with transfer (Rossignoli, 2018).

## Personalized Tracking for Self-Regulation

Personalized tracking can improve the regulation of attention (Michie et al., 2011). Through personalized trackers, users can collect, visualize, and share data (Kim, Jeon, Lee, Choe, & Seo, 2017). Trackers can detect behavioral markers, opportune moments for intervention, and context-sensitive interventions (Epstein, Kang, Pina, Fogarty, & Munson, 2016; Gouveia, Karapanos, &. Hassenzahl, 2015). Trackers may be improved by designing for levels of readiness, goal setting, and sustained engagement. Tracker users rarely consult past data, and in one study, only 30% of users set daily step goals; fewer updated their goals (Epstein et al., 2016; Gouveia, Karapanos, & Hassenzahl, 2015). Trackers may work best for intermediary behavior change; those in other stages such as pre-contemplation, action, or maintenance use them less. Trackers benefit by being designed for specific populations doing specific tasks along a trajectory of activity.

## Participatory Design With Youth

Participatory design represents a sustained engagement between designers and stakeholders that seeks to create more usable products while understanding the context of use and leveraging participants' tacit knowledge. Participatory design includes: (a) *explorations* (interviews, discussions, and observations), (b) *envisioning* (storyboarding, role-playing), and (c) *prototyping* (Spinuzzi, 2005). The most compelling situation for successful participatory design involves sustained collaboration through time (Brandt, Binder, & Sanders, 2012). During design activity, youth may require remediating skill gaps and explaining design context (Druin, 2014).

# Methodology

The design-based study included three phases: (a) a participatory design workshop in which youth redesigned a breathing app for wearable technology, (b) a design enactment that leveraged features and practices youth routinely engaged in, and (c) a naturalistic study of how youth used the collaboratively designed devices.

## Research Questions

1. How do youth conceptualize self-regulation into designs, explanations, and artifacts?
2. What features do youth desire in wearable self-regulation technologies?
3. How do youth use wearable technologies for self-regulation?

## Participatory Design Workshop

**Participants**. Twenty-seven youth from a low socioeconomic status middle school participated in seven 90-minute afterschool workshops in which they designed technologies for self-regulation. Youth were between ages 11 and 14 years old and compensated with lunch and a $30 gift card. A participant-researcher led each session with one to three participant-observers to take notes and lead small-group activities (see Figure 1). Small group activities were recorded with a video camera and audio recorder. Workshops began with a short 10-minute self-regulation training exercise (Patsenko et al., 2019).

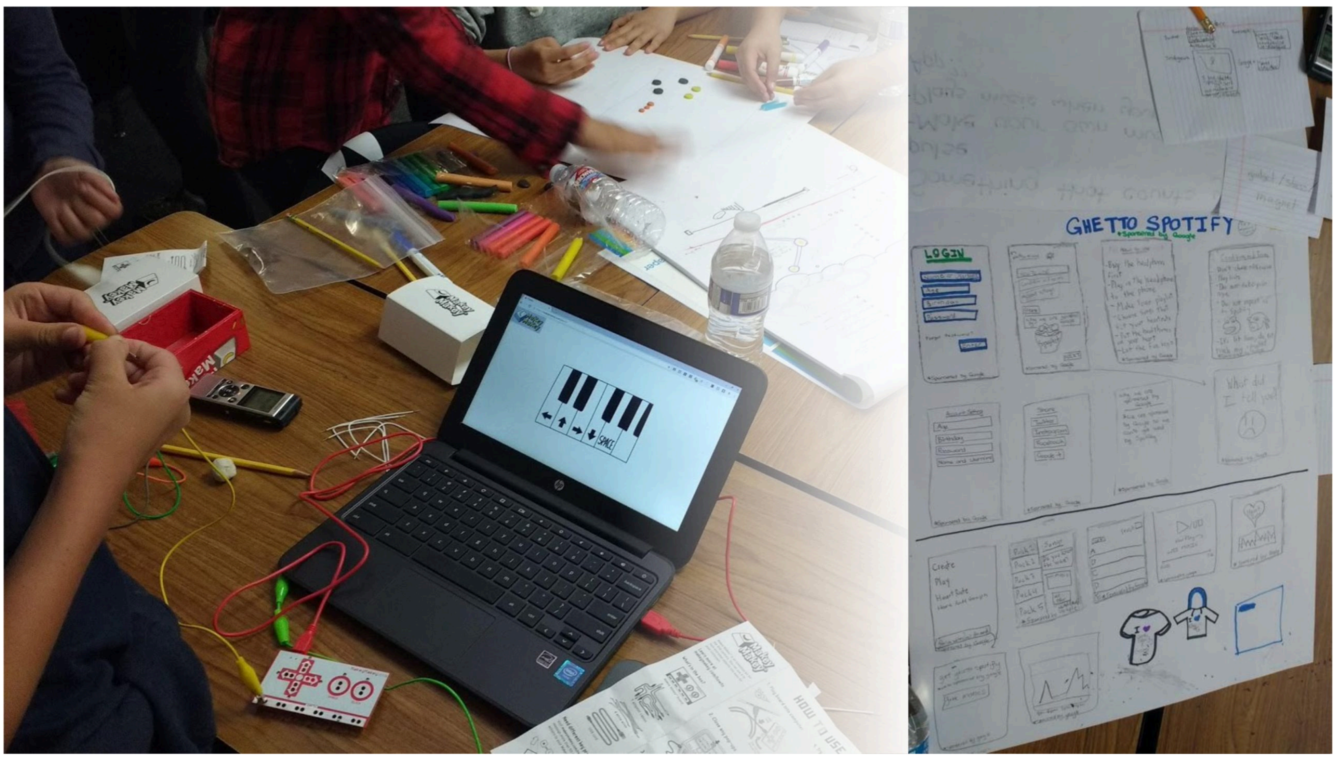


*Figure 1. Student prototypes integrated biofeedback data, customized lists and goals, and the ability to share playlists of music useful for concentration, as well as rhythm games for concentration.*

**Youth design activities.** Our design activities built upon previous participatory design workshops for LatinX youth and were presented as challenges intended to guide participants' activity (Vacca, 2017). A few challenges were to *Make a Game Prototype*, *Merge Multiple Ideas Together*, and *Storyboard an Idea*. Challenges guided activity and were not intended to formally teach or instruct about design. Youth produced the following designs: (a) a *space exploration* game that used mini-games to train focus, (b) an employment scenario game in which players managed distractions, (c) a fidget device that integrated multiple user inputs and outputs (toggles, clickers, sound), and (d) a music game in which players matched tones to follow a displayed pattern. A second design round focused on wearable devices and produced: (a) a heart-rate tracker that responded during moments of stress, (b) physical finger puppets to manage stress with a supplementary software application, (c) a white-noise device with music and rhythm elements, and (d) a support tool that assists in scheduling activity, logging achievements, and organizing competitions.

**Analysis.** Researchers convened after each session to identify themes and adapt workshop activities. Themes were recorded in a shared data repository with accompanying notes on groups or data sources to facilitate later analysis. After the workshop, researchers reviewed audio recordings and design artifacts and chose key events to examine in depth and transcribe. We present our findings as warranted assertions to answer our research questions (Stake, 1995).

## Results: Youth Designs, Artifacts, and Explanations

Youth (a) valued designing SR apps and (b) discussed strategies for managing stress and focus with sophistication. Youth reported enjoyment in exploring new friendships and experiencing others' points of view throughout the design activities. Youth, however, did not thoroughly enact social mechanics in their designs and largely focused on the immediate actions relevant to a single player or user (see Figure 2).

**Youth explicitly referenced self-regulatory behaviors in response to their homework.** Jasmine used music to induce a "hard working" mood, which was common. Wyatt shared that stress motivated him to work hard and focus– a view similar to the Yerkes-Dodson (1908) law. Wyatt connected stress to biological markers and wanted data on such markers: "if you're stressing out and your heart is racing, then a metronome may help you realize you're stressed and calm down to refocus."

**Youth used music to augment SR.** Music was cited as a motivational tool, mood setter, and ally for channeling stress, although it has not been thoroughly studied in the SR literature. Music does not train SR but counteracts depletion effects (Baumeister & Vohs, 2003). In addition to *training* SR, researchers might give youth tools to *improve* SR capacities; youth were more interested in augmenting performance than training SR. Youth described SR primarily as motivation or energy and sought tools that augmented their current functioning and performance.

**Proficiency in SR design activities.** Youth design demonstrated a readiness to engage in difficult challenges and sophistication in enacting higher-order collaboration. They reviewed games, proposed ideas, created artifacts, and iterated plans while managing group cohesion. Teams made storyboards and interface mockups with little instruction or prompting. They demonstrated tacit knowledge of user interfaces (UI) and onboarding experiences (e.g., email, profile setup, user details). Teams implemented roles without our instruction and included note takers, illustrators, constructors, and voice leaders.

*Figure 2. User interface mockups for a rhythm game. Student designers are playing with musical notation-based interface systems, similar to popular rhythm music action games.*

**Gameplay, mechanics, and transfer.** Youth wrestled with the context-dependent nature of self-regulation and transfer into untrained scenarios. Youth entertained grand ideas during initial brainstorming (e.g., Spotify clone; see Figure 1) but pruned them for designs achievable given our limited number of workshops. The designs resembled communities with abstract support around SR topics, instead of directly targeting SR improvement through specific activities. To use a martial arts metaphor, youth were more interested in creating dojos than training specific moves. While youth demonstrated an eagerness to approach complex software design, they often did not have the experience to guide themselves through the process to obtain a focused and specific SR trainer.

**Social interaction design.** Another design gamified the quantified self on a community level. Players would compete against other *teams* similar to FitBit "step count" challenges by monitoring their application usage. For example, *Team 1* would win if their total time spent watching YouTube was lower than *Team 2*'s. Competitions within this design included time on homework or player-defined contests (e.g., physical activity). Caspar said, "The competition makes you want to use it more, but there should be a beginning with a time limit that everyone needs to follow."

**Youth value social investigations about themselves and design.** Youth worked past the time allotted and expressed an interest in additional design sessions. The level of engagement suggests: (a) youth valued reflection on mind, body, and being, and (b) design-based programs are an engaging format of learning and experience alternative to traditional curriculum activities. *Situating users as designers of their own emotional regulation routine may be a guiding metaphor for the domain.*

## Findings and Design Guidelines

1. **Youth understand SR, value its development, and expressed interest in tools to improve it.** *Recommendation*: Explore design metaphors using emotional regulation routines that explicitly focus on improving and strengthening SR.
2. **Youth identified personal SR challenges and described strategies for improving performance.** *Recommendation*: Incorporate timers, scheduling features, and consider integrations of commonly used applications (e.g., music).
3. **Youth connected physiological responses to SR experiences.** *Recommendation*: Integrate physiological sensors as appropriate and provide tools for self-monitoring.
4. **Youth expected gaming conventions to be employed in SR tools.** *Recommendation*: Games are strongly associated with opposing reactions to calm and meditative breath counting but provide a strong motivation for youth and should be considered in the design of their SR tools.
5. **Youth demonstrated interest in discussing SR challenges with peers but hesitated to share data.** *Recommendation*: While protecting individual privacy and desires to share, opportunities to help students feel comfortable sharing their information may be needed to facilitate communal behaviors.

## Study 2: Redesign

*Tenacity* evolved to be a breath-counting community (Lakes & Hoyt, 2004) centered around *Tenacity* for the Apple Watch, which included a breath-counting application (*Breathe*), a pattern-matching game (*Lotus*), and a rhythm-music action game (*Rhythm Tap*) integrated through the iPhone (see Figure 3). We also included *Breathe Infinite*, in which youth breathe without session limitations and goals. This study follows a field-deployment schedule from convenience sample, to semicontrolled study, to in-the-wild study. The later studies contained a battery of cognitive measurements (Siek, Hayes, Newman, & Tang, 2014).


*Figure 3. Tenacity Apple Watch interface: Apple Watch selection menu, Lotus pattern-matching game, Breathe game, and iPhone companion app.*

## Participants

We recruited 35 participants between the ages of 11 and 15 across three events in two states. Participants were selected to round out the target demographic (at-risk middle school youth) rather than randomly sample a population (Rubin & Chisnell, 2014). The second out-of-state site broadened the user pool beyond our local at-risk selection.

## Procedure

Each participant was given an Apple Watch and an iPhone, introduction to the software, and overview of the study. They were asked to naturally use *Tenacity* for two weeks. Whereas previous studies *required* use, we desired to observe how youth used *Tenacity* outside of compulsion or strong financial incentives. At the end of the two weeks, they completed a questionnaire and one-hour semistructured interview. Sample questions included: How often did you use *Tenacity*? When and where did you use *Tenacity*? What was using *Tenacity* like?

## Findings

One third of the participants used the app at least once per day (12), some even multiple times in a day (9). Students' self-report claims matched analyses of log files (see Figure 4). Eighty percent of participants (29) used the app after school hours while in transit, idle, bored, after exercise, before bed, and while doing homework. Only three participants used the app in school. Forty-five percent of participants (16) reported using *Tenacity* to calm down. One participant stated, "I use *Breathe* … because I had to help my dad outside a lot and I got really [stressed out]. … Sometimes I use it like three times a day. Mostly because I get really [mad]." No participant mentioned using *Breathe* as an exercise application. Youth desired to strengthen attention but did not set out time for it explicitly.

Eight participants reported sharing the app with others. Participants did not report meeting each other in person to play. We released *Tenacity* with cohort groups, hoping to seed competition or cooperation, but such events were uncommon. A few reported competitions with *Lotus*, as one youth commented, "When we use *Lotus* we would be competing to see who can get like the fastest time to swipe." Only two suggested social-interaction improvements, compared to 33 app-centered improvements such as customization or rewards.

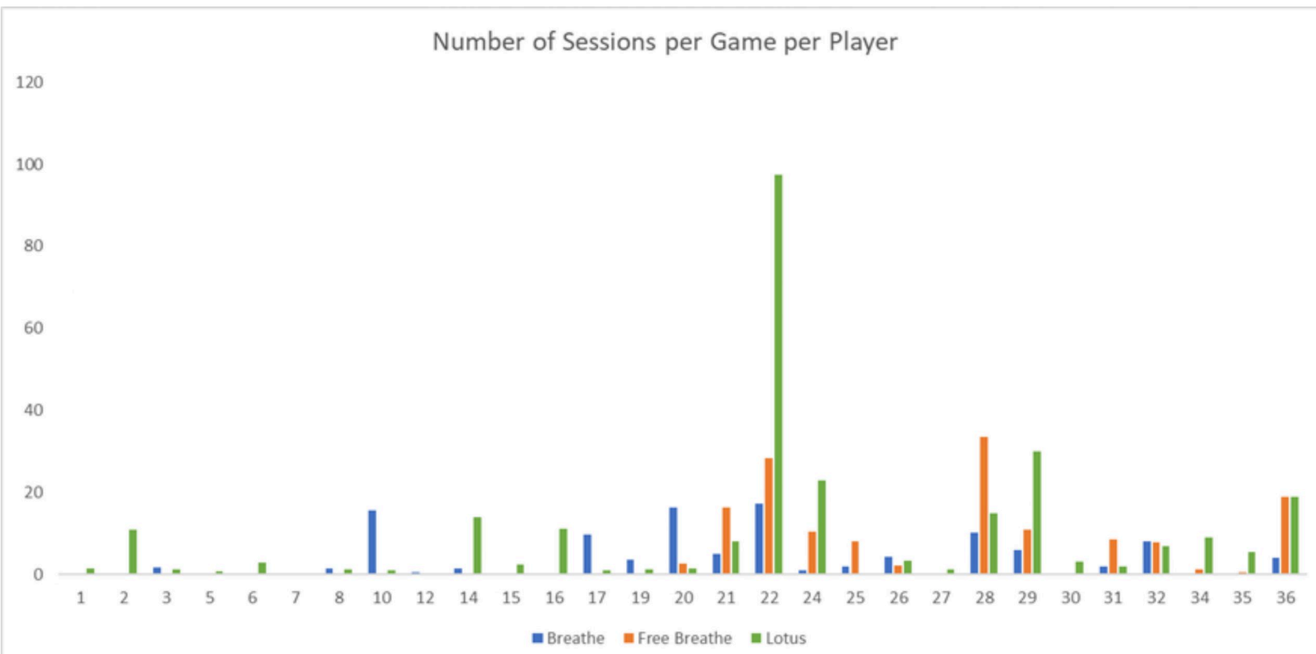


*Figure 4. Number of sessions per game per player. Individual users are displayed on the x-axis (n = 36). Total number of sessions for each game played by user is on the y-axis (n = 120).*

## Redesign Results

**Youth responded positively to the redesigned wearable version of *Tenacity*.** Comments were positive (whereas previous responses suggest non-use outside of the study). A subset of participants particularly valued the application as a daily tool. *The primary interest was in using* Tenacity *to relax and calm down.* Youth reported that *Tenacity Breathe* was useful for relaxing and focusing attention before homework. It was used in the mornings, between classes, and before sleep (or waking up during the night). After school was the most popular time to use the application, with another spike is usage seen before bedtime.

**Being able to organically train SR is a high priority.** Youth were interested in training SR in the service of other activities but *less* interested in SR training as the activity itself. Youth *already* have engaging and fulfilling digital experiences, *some of which are likely training SR as a byproduct of challenging scenarios*. As Apolonia said, "You can't tell it's a game made for something, it's a game made for fun. I don't have to play this game to practice my focusing skills." Awareness of research may create indigenous critiques on why youth need more interventions.

**Youth demonstrated interest in collaborative play.** Youth reported occasionally racing during the *Lotus* pattern-matching game and handing off devices to friends to watch them play. There was not, however, a strong desire to complete joint achievements; youth were reluctant to collaboratively play the *Breathe* game. We caution against overgeneralizing, but for this audience, breath counting was seen as a private experience and a method of relaxing.

**Youth want their personal information kept private.** Using *Breathe* was a distinctly *private* act. Privacy was mentioned in interviews as an obstacle to collaborative play. This suggests a need for a system in which players selectively share play behaviors yet keep control on what information others can access.

## Discussion

### Increasing Engagement Through Wearable Technologies

SR training has followed a medical science paradigm in which a static, uniform intervention is compared to a control to support research findings. These foundational studies, which have found positive effects, also report alienating students because of the disengaging focus on the "training" aspect of SR development. Youth shared concerns about stress and anxiety and an openness to approaches that build on their own mind-focusing techniques. They reported nontrivial amounts of stress (which is echoed in popular media) and are eager to discuss these issues with peers. Wearable tools that help are largely appealing.

### Future Directions: Biological Markers, Tracking, and Sociability

Youth valued opportunities to monitor and view biological markers or the allocation of their time throughout the weeks. Youth also advocated for competing among friends toward targeted behaviors. Yet youth did not readily form SR training communities (Epstein et al., 2016). *Tenacity Breathe* focused its design on a *private meditative experience*. There were isolated incidents of youth coordinating their breath counting, and a few turned it into a cooperative experience, but these were exceptions. Given that executive functions are robustly trained within rich sociocultural activity, finding ways to develop and nurture communities of some sort (SR training, Breath Counting, Meditation) may lead to organic and more easily supported SR development.

### Scaffolding Youth Performance Versus Training Underlying Skills

*The primary interest has been to use* Tenacity *to relax and calm down rather than train mindfulness as an underlying skill.*

Emphasis on increasing performance rather than training faculties suggests a paradox for designers; on the one hand, youth want to increase their attentional faculties, specifically, capacity to remain calm in the face of social and school stresses. On the other hand, students have resistance to targeted training and desire a low-stress experience. Social and academic stresses deplete SR and will require users to prepare to expend additional resources in order to improve. Youth want, and are willing to use a relaxation device, but they do not want another thing to stress about.

## Conclusions

We should reflect on the design assumptions of youth mindfulness tools. While youth are eager for tools and interventions that reveal their physical and emotional states, they are like every other member of society. Youth must approach and overcome daily challenges and stresses in a hypercompetitive environment. Are our efforts best placed in developing SR training apps? Should we instead make structural changes to achieve equitable and supportive systems that better prepare students for success? The rise of attention on individually psychologized paradigms such as grit and tenacity, rather than on the underlying social structures that contribute to them, may lead to a scenario in which those who are struggling continue to fall behind. One possible interpretation is that breath counting and mindfulness training are components to a necessary and larger systematic overhaul. SR trainers can be presented as tools to reduce stress and improve executive functioning, so long as they are implemented in a way that fosters understanding and remedying the social conditions that produce discrepancies between SR and achievement. One such use may be ongoing assessment and evaluation in order to identify and provide support to individuals in need.

## References


Baumeister, R. F., & Vohs, K. D. (2003). Self-regulation and the executive function of the self. In M. R. Leary & J. P. Tangney (Eds.), *Handbook of self and identity* (pp. 197–217). New York, NY: The Guilford Press.

Bodrova, E., & Leong, D. (2007). *Tools of the mind: The Vygotskian approach to early childhood education.* Upper Saddle River, NJ: Pearson Education.

Brandt, E., Binder, T., & Sanders, E.B. (2012). Tools and techniques: Ways to engage telling, making and enacting. In J. Simonsen & T. Robertson (Eds.), *International handbook of participatory design* (pp.145–181). New York, NY: Routledge.

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences*, 104(27), 11483–11488.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, 318(5855), 1387.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, 333(6045), 959–964.

Druin, A. (2014). Inclusive ownership of participatory learning. *Instructional Science*, 42(1), 123–126.

Duckworth, A. (2016). Grit: The power of passion and perseverance. New York, NY: Scribner.

Dweck, C., Walton, G. M., Cohen, G. L., Paunesku, D., & Yeager, D. (2011). *Academic tenacity: Mindset and skills that promote long-term learning.* Seattle, WA: Bill & Melinda Gates Foundation.

Epstein, D. A., Kang, J. H., Pina, L. R., Fogarty, J., & Munson, S. A. (2016). Reconsidering the device in the drawer: Lapses as a design opportunity in personal informatics. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (pp. 829–840). https://doi.org/10.1145/2971648.2971656

Farley, J. P., & Kim-Spoon, J. (2014). The development of adolescent self-regulation: Reviewing the role of parent, peer, friend, and romantic relationships. *Journal of Adolescence*, 37(4), 433–440.

Garcia, E. (2014). *The need to address noncognitive skills in the education policy agenda.* Washington, DC: Economic

Policy Institute. Retrieved from https://www.epi.org/publication/the-need-to-address-noncognitive-skills-in-the-education-policy-agenda/

Gouveia, R., Karapanos, E., &. Hassenzahl, M. (2015). How do we engage with activity trackers?: A longitudinal study of habito. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (pp. 1305–1316). https://doi.org/10.1145/2750858.2804290

Hardy, J. L., Nelson, R. A., Thomason, M. E., Sternberg, D. A., Katovich, D., Farzin, F., & Scanlon, M. (2015). Enhancing cognitive abilities with comprehensive training: A large, online, randomized, active-controlled trial. *PLoS ONE*, *10*(9): e0134467. https://doi.org/10.1371/journal.pone.0134467

Kim, Y-H., Jeon, J. H., Lee, B., Choe, E. K., & Seo, J. (2017). OmniTrack: A flexible self-tracking approach leveraging semi-automated tracking. In *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *1*(3), Article 67. https://doi.org/10.1145/3130930

Kral, T. R., Solis, E., Mumford, J. A., Schuyler, B. S., Flook, L., Rifken, K., & Davidson, R. J. (2017). Neural correlates of empathic accuracy in adolescence. *Social Cognitive and Affective Neuroscience*, *12*(11), 1701–1710.

Lakes, K. D., & Hoyt, W. T. (2004). Promoting self-regulation through school-based martial arts training. *Journal of Applied Developmental Psychology*, *25*(3), 283–302.

Mallan, K. M., Singh, P., & Giardina, N. (2010) The challenges of participatory research with 'tech-savvy' youth. *Journal of Youth Studies*, *13*(2), 255–272.

Michie, S., Ashford, S., Sniehotta, F. F., Dombrowski, S. U., Bishop, A., & French, D. P. (2011). A refined taxonomy of behaviour change techniques to help people change their physical activity and healthy eating behaviours: The CALO-RE taxonomy. *Psychology & Health*, 26(11), 1479–1498. http://doi.org/fdg8jr

Nakano, D. (2015). *Elevate effectiveness study*. Retrieved from https://www.elevateapp.com/assets/docs/elevate_effectiveness_october2015.pdf

Oaten, M., & Cheng, K. (2006). Longitudinal gains in self-regulation from regular physical exercise. *British Journal of Health Psychology*, *11*(4), 717–733.

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., … Ballard, C. G. (2010). Putting brain training to the test. *Nature*, 465, 775–778.

Patsenko, E. G., Adluru, N., Birn, R. M., Stodola, D. E., Kral, T. R., Farajian, R., … Davidson, R. J. (2019). Mindfulness video game improves connectivity of the fronto-parietal attentional network in adolescents: A multi-modal imaging study. *Scientific Reports*, 9(1). https://doi.org/10.1038/s41598-019-53393-x

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low-income preschoolers' preacademic skills: Self-regulation as a mediating mechanism. *Child Development*, *82*(1), 362–378.

Rossignoli, T. (2018). Brain training in children and adolescents: Is it scientifically valid? *Frontiers in Psychology*, *9*, 565.

Rubin, J., & Chisnell, D. (2014). *Handbook of usability testing: How to plan, design, and conduct effective tests*. New York, NY: John Wiley & Sons.

Siek, K. A., Hayes, G. R., Newman, M. W., & Tang, J. C. (2014). Field deployments: Knowing from using in context. In J. S. Olson & W. A. Kellogg (Eds.), *Ways of knowing in HCI* (pp. 119–142). New York, NY: Springer.

Spinuzzi, C. (2005). The method of participatory design. *Technical Communications*, 52(2). 163–174

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Vacca, R. (2017). Bicultural: Examining teenage Latinas' perspectives on technologies for emotional support. In *Proceedings of the 2017 Conference on Interaction Design and Children* (pp. 117–126). https://doi.org/10.1145/3078072.3079742

Yeager, D. S., & Walton, G. M. (2011). Social-psychological interventions in education: They're not magic. *Review of Educational Research*, 81(2), 267–301.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, 18(5), 459–482. doi:10.1002/cne.920180503

# 18. Academic and Social-Emotional Learning in High School Esports

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**Abstract:** Multiple high school esports leagues are expanding across North America, claiming learning benefits for participation. The popularity of esports among high school students presents opportunities to foster connected learning environments. Little is empirically known, however, about actual outcomes of school-affiliated esports clubs, and reservations about the social and cultural influence of esports abound. We examine the impact of a high school esports league on teens using national academic and social-emotional standards. Findings reveal important benefits in science, math, English language arts, social-emotional learning, and school affiliation. The most dramatic benefits were social-emotional. Odds-ratio analysis reveals the significant ($p < 0.10$) role of mentorship and student leadership in such outcomes, supporting the connected learning model. Group comparison of outcomes for students in low-income versus high-income schools reveals significant differences ($p < 0.10$) on 6 of 18 variables total, with students from low-income schools benefiting more from participation than students from high-income schools. This work provides early evidence of the positive academic and social-emotional outcomes esports may foster, for whom, and how.

## Introduction

Recent expansion of high school esports programs is predicated on arguments that such programs can benefit participating students by promoting engagement in school and creating an environment in which students learn scholastic, professional, and social skills. To date, however, such claims have not been tested empirically. Studies of connected learning (CL; Ito et al., 2013) investigating video game communities have emphasized the role of players' community leadership and the necessity of "families and educators invested in creating and supporting daily structures of participation of young people" (Kow, Young, & Salen-Tekinbaş, 2014, p. 44). The goal of this research, though, is to empirically examine the existing and potential impacts of student participation in high school esports clubs specifically. This work builds on a qualitative investigation of the North America Scholastic Esports Federation (NASEF; Cho, Tsaasan, & Steinkuehler, 2019) that identified organic learning opportunities that arose during league play. We interrogate these qualitative observations through the application of a structured coding scheme and statistical analysis of the patterns found.

How does participation in an afterschool esports club align with academic and social-emotional learning (SEL) standards? We conducted a quantitative analysis of qualitative interview data using a structured coding scheme based on select national academic (NGSS; National Science Teaching Association, 2014) and social-emotional learning standards (CASEL; Collaborative for Academic, Social, and Emotional Learning, 2019) to discern (a) what students participating in esports learned from the program, (b) what moderating variables shape those learning outcomes, and (c) whether the outcomes were equitable. The results of this investigation provide evidence that high school esports programs can indeed have positive impacts on academic and social-emotional outcomes as predicted based on U.S. program rhetoric. This work contributes to our understanding of the substance of structured esports participation. It provides early evidence of which positive academic and social-emotional outcomes esports may foster, for whom, and how.

## Related Work

The academic study of esports has developed rapidly during the last decade (Reitman, Anderson-Coto, Wu, Lee, & Steinkuehler, 2019), and at the confluence of research and practice are esports programs in schools. There are promising arguments for scholastic and extracurricular esports programs, such as NASEF, leveraging students' interests to help them engage with their schools, communities, peers, and classroom subjects. Evidence for those benefits is lacking, however. The present study contributes data to this conversation.

### Games and Learning

While there is little data on the benefits of esports leagues specifically, researchers have examined the kinds of learning that can happen in and around video games. From fostering scientific reasoning (Clark, Nelson, Sengupta, & D'Angelo, 2009; Steinkuehler & Duncan, 2008) to improving literacy (Gee, 2003) to strong associations with technology expertise (Hayes, 2008), playing video games and participating in the communities around them correlates with certain kinds of learning. Clark et al. (2009) highlight science learning in particular. Their argument is explicitly not that games are superior learning tools to textbooks. Rather Clark et al. (2009) walk through how games can be a part of an educational approach that integrates "people's tacit spontaneous concepts with instructed concepts, thus preparing people for future learning through a flexible and powerful foundation of conceptual understanding and skills" (p. 3). The forum discussions Steinkuehler and Duncan (2008) studied contained systems- and model-based reasoning, social knowledge construction, and an understanding of knowledge to be "an open-ended process of evaluation and argument." These are all examples of the tacit learning that Clark et al. (2009) say games are capable of fostering.

Esports clubs are attractive to students for reasons beyond the desire to play and compete. From designing to organizing to commentating (Kempe-Cook, Sher, & Su, 2019), esports clubs can give students a space to practice skills in a context that interests them. Anderson et al. (2018) identify "myriad ways to participate in esports that go beyond just competing on a team: event organizing, legal protections, web development, shoutcasting, game analysis, and many other integral activities. These roles are paramount to the growth of the tournaments and surrounding community" (para. 1). The esports ecosystem supports competition, participatory community, and social interactions in pursuit of common endeavors.

## Quantifying Qualitative Data

### Context of Study

This investigation was conducted during the North America Scholastic Esports Federation's (NASEF) first year of competition. NASEF consisted of a competitive league in one county with a network of school-affiliated clubs with teacher-organizers (GMs), coaches—provided by Connected Camps (2019), —and student-players. *League of Legends* (*LoL*; Riot Games, 2009) was the game selected for competition. Swiss-style tournament brackets were played over eight weeks, culminating in a full day of live-streamed matches. The championship event was emceed by a combination of local university undergraduates and participating high school students.

## Participants

Six local school sites were selected for maximum variation in schoolwide geographic, income, and racial/ethnic demographics, prioritizing variation in percentage of students receiving free or reduced-cost lunch. Percentages of students receiving free or reduced-cost lunch across these sites range from 10% to 73%, with a mean of 35%. From those six sites, 55 students participated in five student focus groups, 10 GMs participated in six GM focus groups, and five coaches participated in three coach focus groups.

## Procedure

Data were collected through semistructured focus-group interviews, conducted in-person or online via a private Discord server. Two researchers conducted the interviews using a protocol that standardized the topics covered but allowed for conversational variation on the actual form of questions used. Interview topics for both students and staff, interviewed separately, were attitudes toward the league; changes to gameplay and teamsmanship; impact on schoolwork, attitudes toward school, and relationships; and what was learned from participation.

## Data Corpus

The resulting interview data corpus was transcribed and cleaned by removing staff discussion that was not related to student activities. Data were segmented into turns of talk with one unit of analysis equaling one speaker turn. Table 1 details the resulting corpus.

| Participant Role | Number of Turns of Talk | Number of Words |
|---|---|---|
| Students | 449 | 45999 |
| Coaches | 24 | 42979 |
| General Managers | 53 | 48118 |
| Total | 526 | 137096 |

*Table 1. Data corpus.*

## Data Analysis

A coding scheme (see Table 2) based on the work of Stage, Asturias, Cheuk, Daro, and Hampton (2013) was developed to capture key interconnected science, math, and English language arts (ELA) standards developed by the National Science Teachers Association (see Figure 1; Stage et al., 2013). We then supplemented these academic standards with codes representing the SEL standards recommended by the Collaborative for Academic, Social, and Emotional Learning (CASEL, 2019) and three additional codes based on the CL model (Ito et al., 2013): (a) *school affiliation*, defined as students' increased positive attachment or affinity toward their school; (b) *mentorship*, defined as the positive modeling or enculturation of students by a teacher GM, a coach, or another student; and (c) *student leadership*, defined as students' decision making or community organizing to positively affect the team or club.

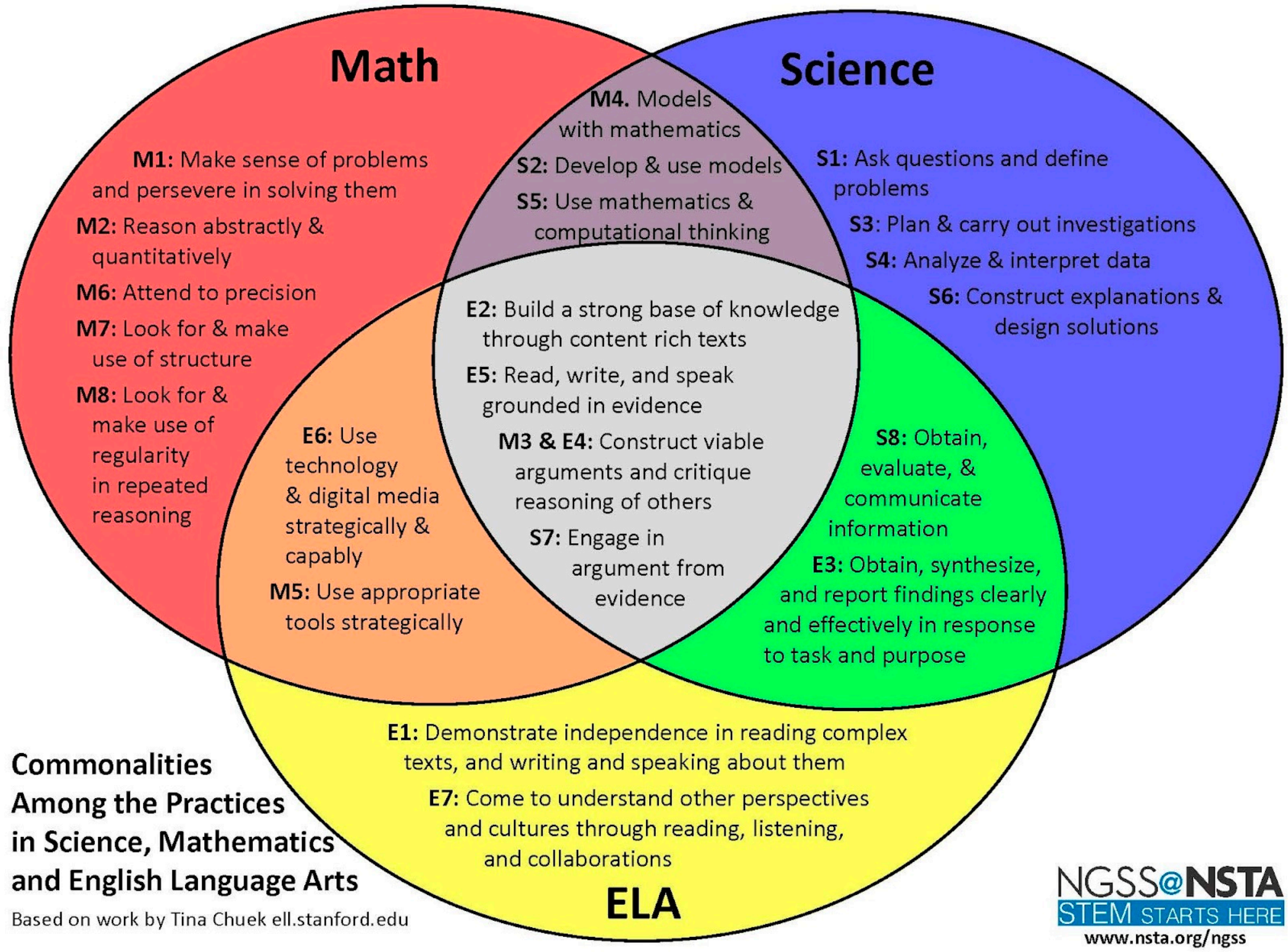


*Figure 1. Academic content standards (Stage et al., 2013).*

Four researchers coded the entire data corpus with four-way interrater reliability; 10% of the corpus was selected at random and coded by the four researchers independently. Agreement was defined as a four-way match on each turn of talk, yielding an interrater reliability of 92.31%. Codes are not mutually exclusive, which allowed us to test for significant relationships among learning outcome codes (science, math, English language arts, social-emotional skills) and possible mediating variable codes (mentorship, student leadership, school income).

Next, mediating codes and standards codes were assessed on a one-to-one basis to see if they were dependent. This was done by tabulating the codes' presence in a turn of talk with 2×2 contingency tables. Typically, Pearson's chi square or Fisher's exact are used to assess independence. However, the data did not meet the requirements of fixed margins for Fisher's exact or the expected cell counts for Pearson's chi square. Boschloo's exact test (Boschloo, 1970), with a null hypothesis of independence between codes, was therefore chosen in their stead. Odds ratios and their 95% confidence intervals were calculated to measure the effect of a mediating variable on a standard's code appearing in talk and should be interpreted as the change in odds of a standard appearing if a mediating variable was present. Odds ratios with values less than one indicated a drop in odds of a standard's appearance, while values greater than one represented the opposite.

| |
|---|
| **Science** |
| Ask questions & define problems (NGSS S1) |
| Plan & carry out investigations (NGSS S3) |
| Analyze & interpret data (NGSS S4) |
| Scientific explanations (NGSS S6) |
| Design solutions (NGSS S6) |
| **Math** |
| Reason quantitatively (NGSS M2) |
| Attend to structure (NGSS M7) |
| Attend to regularity (NGSS M8) |
| Problem-solving (NGSS M1/S5) |
| **English Language Arts** |
| Communicate info/findings (NGSS E3/S8) |
| Use evidence (NGSS E5) |
| Construct/critique argument (NGSS E4/M3) |
| **Social-Emotional Learning** |
| Self-awareness (CASEL) |
| Self-management (CASEL) |
| Social awareness (CASEL) |
| Relationship skills (CASEL) |
| Responsible decision-making (CASEL) |
| Affiliation (CL) |
| **Mediating Variables** |
| Mentorship (CL) |
| Student Leadership (CL) |

*Table 2. Coding scheme (with source in parentheses).*

To test for differences by school income level, we categorized each of the six school sites by income level based on their percentage of students receiving free or reduced-cost lunch. Schools with less than 40% free or reduced-cost lunch were categorized as high income and schools with 40% or higher were categorized as low income following Title 1 definitions (U.S. Department of Education, 2018). Using these data, we then categorized student and staff interviews by the income level of their school and compared the overall percentage of learning indicators in talk from high-income schools to talk from low-income schools. Participants were then grouped by school income and we again used Boschloo's (1970) Exact test to assess whether each standard's odds of appearing in a turn of talk depended on the income level of the school the participant attends or works at. Odds ratios were again calculated to determine the strength and direction of dependence.

## Results

### Overall Student Outcomes

The highest individual outcome variables are Social Awareness ($n$ = 191), Relationship Skills ($n$ = 163), and Self-Awareness ($n$ = 153). The lowest two counts fell under Science: Scientific Explanations & Design Solutions ($n$ = 3) and Plan & Carry Out Investigations ($n$ = 5).

### Mentorship and Student Leadership

Mentorship yielded four significant results across science, math, and ELA domains (see Table 3). "Ask Questions & Define Problems" had the largest odds ratio (4.60), with a confidence interval well above 1. It is followed by "Problem Solving" (2.43), "Communicate Info/Findings" (2.37), and finally "Use Evidence" (2.16). Nonsignificant results include "Analyze and Interpret Data" (2.34) and "Social Awareness" (1.67). While their $p$ values are not considered significant, they are small. Additionally, their confidence intervals do not straddle 1 and are skewed toward higher values. Note: Codes "Plan and Carry Out Investigations" and "Scientific Explanations & Design Solutions" did not meet the sample size requirement for statistical analysis and have been omitted.

| | Mentorship | | | Student Leadership | | |
|---|---|---|---|---|---|---|
| **Code** | **Boschloo's** | **OR** | **95% CI** | **Boschloo's** | **OR** | **95% CI** |
| **Science:** Ask Questions & Define Problems | ~0* | 4.60 | 2.36 - 8.95 | 0.4378 | 0.57 | 0.17 - 1.9 |
| **Science:** Analyze & Interpret Data | 0.0731+ | 2.34 | 0.95 - 5.78 | 0.7278 | 1.13 | 0.33 - 3.9 |
| **Math:** Problem-Solving | 0.0334* | 2.43 | 1.08 - 5.46 | 0.0003* | 4.75 | 2.17 - 10.4 |
| **Math:** Reason Quantitatively | 0.7007 | 0.42 | 0.05 - 3.24 | 0.211 | 2.07 | 0.57 - 7.56 |
| **Math:** Attend to Structure | 0.2211 | 1.48 | 0.81 - 2.72 | 0.1767 | 1.56 | 0.8 - 3.04 |
| **Math:** Attend to Regularity | 1 | 0.96 | 0.47 - 1.97 | 0.0117* | 0.20 | 0.05 - 0.84 |
| **Math:** Appropriate (Math/Digital) Tool Use | 0.1508 | 1.79 | 0.82 - 3.92 | 1 | 0.86 | 0.3 - 2.51 |
| **ELA:** Communicate Info/Findings | 0.013* | 2.37 | 1.24 - 4.53 | 0.2556 | 1.57 | 0.73 - 3.39 |
| **ELA:** Construct/Critique argument | 1 | 0.95 | 0.48 - 1.89 | 0.5508 | 0.74 | 0.32 - 1.69 |
| **ELA:** Use Evidence | 0.0334* | 2.16 | 1.09 - 4.27 | 0.0583+ | 2.06 | 0.97 - 4.36 |
| **SEL:** Self-Awareness | 0.7603 | 1.09 | 0.63 - 1.9 | 0.2586 | 0.66 | 0.33 - 1.31 |
| **SEL:** Self-Management | 0.7374 | 1.09 | 0.6 - 1.98 | 0.5809 | 1.16 | 0.6 - 2.24 |
| **SEL:** Social Awareness | 0.0548+ | 1.67 | 1.01 - 2.76 | 0.8734 | 1.07 | 0.6 - 1.92 |
| **SEL:** Relationship Skills | 0.1187 | 1.50 | 0.89 - 2.52 | 0.0001* | 3.07 | 1.76 - 5.35 |
| **SEL:** Responsible Decision-Making | 0.0761+ | 1.73 | 0.94 - 3.2 | 0.1632 | 1.62 | 0.81 - 3.22 |
| **SEL:** Affiliation | 0.8138 | 1.05 | 0.47 - 2.32 | 0.7936 | 0.81 | 0.31 - 2.12 |

* $p < 0.05$
\+ $p < 0.10$

Table 3. Learning standards' dependence on Mentorship & Student Leadership.Student Leadership had three significant results within the math and SEL domains. "Problem-Solving" had the highest odds ratio (4.75), followed by "Relationship Skills" (3.07). Both indicate positive relationships with Student Leadership. However, "Attend to Regularity" (0.20), while significant, yielded an odds ratio below 1, suggesting the opposite. "Use Evidence" has an odds ratio greater than 1 (2.06) and a confidence interval that is skewed above 1, along with a smaller, but nonsignificant *p* value.

## Equity

We investigated whether outcomes were the same for students in low- and high-income schools; Figure 2 illustrates the percentage of talk coded by our learning indicators for each school income level and Table 4 lists odds ratios and other analyses. Odds ratios are interpreted shifting from high income to low income. The science standard of "Analyzing & Interpreting Data" showed the greatest gain for low-income students (odds ratio = 11.61), followed by "Appropriate (Math/Digital) Tool Use" in math (odds ratio = 3.34), "Self-Management" in SEL (odds ratio = 3.20), and "Responsible Decision-Making" in ELA.

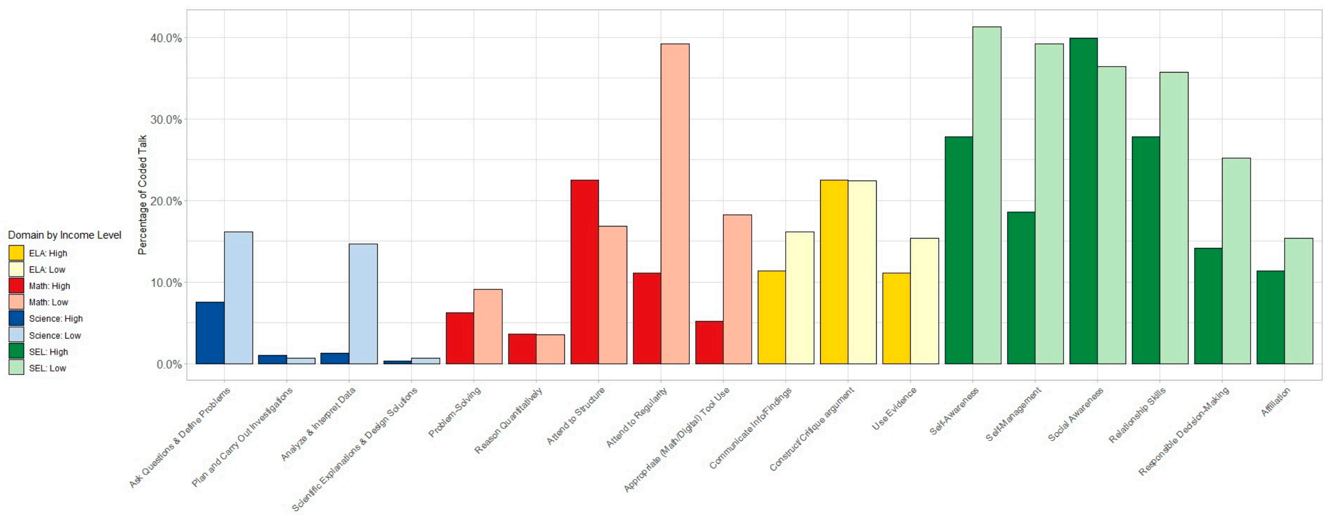


*Figure 2. Student learning indicators across four domains (science, math, English language arts, SEL) by school income level.*

| Code | Boschloo's | OR | 95% CI |
|---|---|---|---|
| **Science:** Ask Questions & Define Problems | 0.447 | 1.33 | 0.66 - 2.67 |
| **Science:** Analyze & Interpret Data | ~0 | 11.61 | 3.87 - 34.82 |
| **Math:** Problem-Solving | 0.3922 | 1.42 | 0.65 - 3.12 |
| **Math:** Reason Quantitatively | 0.7614 | 1.19 | 0.39 - 3.62 |
| **Math:** Attend to Structure | 0.1082 | 0.64 | 0.37 - 1.11 |
| **Math:** Attend to Regularity | 0.0009* | 2.5 | 1.48 - 4.23 |
| **Math:** Appropriate (Math/Digital) Tool Use | 0.0006* | 3.34 | 1.67 - 6.7 |
| **ELA:** Communicate Info/Findings | 0.3192 | 1.36 | 0.74 - 2.5 |
| **ELA:** Construct/Critique argument | 0.8798 | 0.94 | 0.55 - 1.61 |
| **ELA:** Use Evidence | 0.2244 | 1.49 | 0.79 - 2.8 |
| **SEL:** Self-Awareness | 0.0062* | 1.82 | 1.18 - 2.8 |
| **SEL:** Self-Management | <0.0001* | 3.2 | 2 - 5.12 |
| **SEL:** Social Awareness | 0.6532 | 0.89 | 0.58 - 1.36 |
| **SEL:** Relationship Skills | 0.1287 | 1.41 | 0.91 - 2.19 |
| **SEL:** Responsible Decision-Making | 0.0003* | 2.76 | 1.61 - 4.74 |
| **SEL:** Affiliation | 0.6009 | 0.81 | 0.4 - 1.63 |

*Table 4. Dependence of learning standards on school income level.*

## Discussion

The coding scheme used in this study represents a detailed set of specific learning goals across domains in which high school esports aspire to effect change. The patterns found as a result of this analysis are in keeping with a previous qualitative evaluation (Cho et al., 2019), while providing a more detailed window into the natural outcomes of students' participation in a school-affiliated high school esports league.

### Science and Math

Science and math appear to be a natural part of students' NASEF activities. Mathematizing esports content seems more naturally aligned with competitive play, with both game and league structures providing a rich context for quantitative and analytical thinking. Particularly fruitful were activities in which students analyzed their own performance (35% of such cases), the performance of their team (50%), or the performance of their opponent (17%). Scientific forms of reasoning, in contrast, appear to be more potential than actualized outcomes, with greater evidence of the early phases of scientific inquiry—such as defining problems (S1)—than the latter phases of the scientific process—such as developing scientific explanations (S6).

### English Language Arts

Communication and argumentation were also core parts of students' naturally occurring activities during league participation. Students engaged in both expository and persuasive oral and written texts as a natural part of their preparation for competitive play. In more than half of such arguments presented, students used evidence as a means to support their claims. Communication skills were improved not only from face-to-face afterschool interactions but also from their in-game interactions as well. The following interview with a teacher GM illustrates:

> I don't have any of my team as students, but I did notice that their levels of communication did improve as the coaching sessions went on, and in terms of their gameplaying and their skills, definitely there was a huge improvement. … I think they're becoming more thoughtful in what they're saying, in what they need to say, and what they need not to say. (School 3, GM 1)

## Social-Emotional Learning

There is a striking emphasis on SEL gains across the interviews. Both students and staff spoke at length about the ways in which the league was transformative in terms of both self-awareness and self-management, on the one hand, and social awareness and relationships skills, on the other. Students frequently told stories about transformation in their understanding and skills of emotional regulation. As one student commented:

> I get tilted very easily, and whenever I play with them, I would start getting upset, and they would start joking, and it would take me *off* tilt, and then I would sit down and focus and be like, okay, I know what I've been doing wrong. I know how to improve it for the next games. So, I haven't been getting as tilted as often, because I have gotten better to where if someone does do really horrible, I don't care. I just focus on myself playing. (School 4, Student 3)

Students also remarked on the role the league had in increasing their affiliation with school. Acknowledging students' interests and making a space for their game-related accomplishments made students feel more meaningfully connected to both the institution of schooling and the adults participating in it. As another student commented:

> I was really excited to hear about it [NASEF] too because I have been playing this game since 2012. I thought, yeah, this is something I want to do. This is what I've always wanted in school. I've always avoided actual sports and everything because I hated the crowd. This is where I felt like I could truly fit in. (School 1, Student 3)

## Equity

Students from lower-income schools showed greater gains than students from higher-income schools (see Figure 2), contrary to initial concerns about the equity of esports-based programming for high schoolers based on prior research. Cho et al.'s (2019) initial qualitative evaluation of the NASEF league found barriers to participation for some students based on limited access to gaming computers and lack of representation in certain game communities. While the increased learning outcomes for students from low-income schools allow us to infer that economic inequities do not interfere with interest-driven learning in this context, they do not assess these other forms of equity that create barriers to entry for many. Such findings are therefore encouraging but require further investigation to assess differences based on gender, ethnicity, sexual orientation, and level of gameplay skill.

### Mentorship and Student Leadership

Mentorship and student leadership both seem to mediate the relationship between league participation and many of the benefits found in this study. Teacher GMs and coaches appear to play a key role in modeling behavior and fostering environments in which students learned to focus on improving their social and analytical skills. Having experts model best practices for team play and success gave students tangible actions to take to each game. Over the course of the season, both students and staff reported changes in the way students spoke to each other. The mentorship and opportunities for student leadership that coaches and teachers provided appear to play a vital role in enabling the learning outcomes discussed in this work. In these results and those of Cho et al. (2019), the presence of near-peer coaches helped encourage self-reflection and positive communication skills. Adopting this mindset, student learning can be bolstered by the presence of peers and mentors, not because of the esports context itself. While esports can certainly be a rich context for learning opportunities, we infer that students are benefiting more because of the relationships they build.

## Future Work

As high school esports gains broad popularity, so too do our opportunities for authentically engaging young people in crucial academic and social-emotional skills by connecting students' interests to core ideas and practices valued beyond the game. Since these data were collected, NASEF has evolved its afterschool programming from a mentored competitive league to a full-service afterschool enriched esports club structure supporting not only in-game competitors but also strategists, content creators, organizers, and entrepreneurs (Anderson et al., 2018). Digital toolkits, content curricula, and weekend workshops are now available to supplement and enrich student activity. Most recently, a four-year high school English Language Arts curriculum, based on this preliminary research and developed by local master teachers, was approved by the State of California and was to be made available for schools in Fall 2019. The next step is to assess the impact of high school esports when enriched by carefully designed and standards-aligned materials. The research question driving this next phase of investigation will be: How does participation in an *enriched* esports club foster academic and social-emotional skills?

## Conclusion

Our findings provide preliminary support for the popular claim made by high school esports organizers in the United States: For students passionate about esports, school-affiliated competitive gaming can foster environments for interest-driven learning. Most noteworthy are the SEL gains reported by both students and staff. Both qualitative (Cho et al., 2019) and quantitative findings highlight how the esports league fostered self- and social awareness and regulatory skills. For many teens, the competitive frame that esports provides around video gameplay is the first real experience they have had of authentic, extended "in situ" mentorship in how to behave online. Enriching esports programming here may well be a means for rehumanizing online gaming generally.

Contrary to initial concerns about equity by income, overall positive outcomes tend to favor lower-income schools. This finding is consistent with the general pattern of findings across games for learning research: Video games, when integrated into formal or informal educational environments, tend to show the greatest gains among students who are otherwise most at risk (Steinkuehler & King, 2009). These results suggest not only *that* positive academic and social-emotional outcomes are possible from esports programming but also *how* they are made possible—through relationships with adults and near-peers and opportunities for students themselves to lead (Ito et al., 2013). Thus, this study might in part be considered a validation of the CL model itself, demonstrating that programming based on student interests, tied to academic and social opportunities, and *enabled by positive relationships* is a potent vehicle for student learning. In this context, esports becomes a veritable Trojan horse for academic and social-emotional development.

## References


Anderson, C. G., Tsaasan, A. M., Reitman, J. G., Lee, J. S., Wu, M., Steel, H., … Steinkuehler, C. (2018). Understanding esports as a STEM career ready curriculum in the wild. In 2018 *10th International Conference on Virtual Worlds and Games for Serious Applications* (VS-Games). IEEE. https://doi.org/10.1109/VS-Games.2018.8493445

Boschloo, R. (1970). Raised conditional level of significance for the 2 × 2-table when testing the equality of two probabilities. *Statistica Neerlandica*, 24(1), 1–9. https://doi.org/10.1111/j.1467-9574.1970.tb00104.x

Cho, A., Tsaasan, A. M., & Steinkuehler, C. (2019). The building blocks of an educational esports league: Lessons from year one in Orange County high schools. In *Proceedings of the 14th International Conference on the Foundations of Digital Games*. ACM. https://doi.org/10.1145/3337722.3337738

Clark, D., Nelson, B., Sengupta, P., & D'Angelo, C. (2009). Rethinking science learning through digital games and simulations: Genres, examples, and evidence. Presented at the Learning Science: Computer Games, Simulations, and Education Workshop sponsored by the National Academy of Sciences, Washington, DC.

Collaborative for Academic, Social, and Emotional Learning. (2019). Core SEL competencies. Retrieved from https://casel.org/core-competencies/

Connected Camps. (2019). About us. Retrieved from https://connectedcamps.com/about

Gee, J. P. (2003). What video games have to teach us about literacy and learning. *Computers in Entertainment*, 1(1), 1–4.

Hayes, E. (2008). Girls, gaming and trajectories of IT expertise. In Y. B. Kafai, C. Heeter, J. Denner, & J Y. Sun (Eds.), *Beyond Barbie and Mortal Kombat: New perspectives on gender and computer games* (pp. 138–194). Cambridge, MA: The MIT Press.

Ito, M., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., … Watkins, S.C. (2013). *Connected learning: An agenda for research and design.* Irvine, CA: Digital Media and Learning Research Hub.

Kempe-Cook, L., Sher, S. T., & Su, N. M. (2019). Behind the voices: The practice and challenges of esports casters. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems.* ACM. https://doi.org/10.1145/3290605.3300795

Kow, Y.M., Young, T., & Salen-Tekinbaş, K. (2014). *Crafting the metagame: Connected learning in the Starcraft II community.* Irvine, CA: Digital Media and Learning Research Hub. Retrieved from https://dmlhub.net/wp-content/uploads/files/craftingthemetagame.pdf

National Science Teaching Association. (2014). NGSS hub. Retrieved from https://www.nsta.org/ngss

Reitman, J. G., Anderson-Coto, M. J., Wu, M., Lee, J. S., & Steinkuehler, C. (2019). Esports research: A literature review. *Games and Culture*, 15(1), 32–50. https://doi.org/10.1177/1555412019840892

Riot Games. (2009). *League of legends* [Computer game]. Los Angeles, CA: Riot Games.

Stage, E. K., Asturias, H., Cheuk, T., Daro, P. A., & Hampton, S. B. (2013). Opportunities and challenges in next generation standards. *Science*, 340(6130), 276–277. https://doi.org/10.1126/science.1234011

Steinkuehler, C., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology*, 17(6), 530–543. https://doi.org/10.1007/s10956-008-9120-8

Steinkuehler, C., & King, E. (2009). Digital literacies for the disengaged: Creating after school contexts to support boys' game-based literacy skills. *On the Horizon*, 17(1), 47–59. https://doi.org/10.1108/10748120910936144

U.S. Department of Education. (2018). *Improving basic programs operated by local educational agencies (Title I, Part A).* Retrieved from https://www2.ed.gov/programs/titleiparta/index.html

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# 19. A Framework for Researching Sound Within Educational Games

JASON ROSENBLUM

**Abstract:** Using an ecological, player-interactivity approach to game sound, this paper describes a research framework for sound in educational games. This analysis describes the prior attempts to create research frameworks for sound for educational multimedia and presents perspectives from game studies, film theory, and sound perception to ground a phenomenological discussion of sound in educational games. In discussing this framework, the shared essential meanings from a phenomenological study of sound in educational games are applied within a phenomenological sound listening framework. I use this framework to reflect how participants' experiences were affected by the ways they used game interfaces, interacted with game characters, experienced game narrative, and described the game's environment. This framework further illustrates the possibility space for potential experiences of sound in gameplay as determined by the choices players make, the game's state of play, and the degree of synchresis present between what players hear and what they see as they play.

## Literature Review

How do educational researchers study sound within educational games? The scope of the available research in this area is extraordinarily limited, and few direct studies of sound within educational games offer a coherent process to examine this aspect of the game experience. One approach used by Petri and Gresse von Wangenheim (2017) examined sound as a component of the user experience (UX) of games. Researchers employed a survey measurement system to evaluate the overall UX of the game experience and concluded that inclusion of sound effects and sound design elements were important components in gameplay, and that "sound UX can therefore be considered an important determinant of user learning" (p. 142). In addition, they concluded that decisions that lead to appropriate *media matching* are important to game design. The notion of media matching is similar to the notion of appropriate pairing of audiovisual interactions, known in film theory literature as *synchresis* (Chion, 1994). However, little direction is given beyond this analysis to direct future researchers on how to best design for sound overall in an educational game. In their discussion of digital game design, Kostolny and Bohacik (2017) also discuss the potential application of sound design, together with narrative and visual components important to enhance a game's "Catchiness" (p. 2). Authors then illustrate the use of sound within an analysis of varying states of gameplay within an educational game. It is notable that sound is described as an integral component of game design; however, no direction is provided to inform future research, and no conceptual models are discussed on which to base the analysis of the sound discussed.

### Educational Multimedia

Although frameworks for studying game sound within educational games are lacking, frameworks for studying sound within educational software and multimedia do exist. Bruce Mann proposed one such framework to design sound for multimedia in 2008. Mann's structured sound function (SSF) model for multimedia sound was intended to help designers "control attention to visual events" (Mann, 2008). This model outlines a number of categories to describe a range of uses of sound to support temporal, point of view, location, and character-based sound functions. Mann's notion that sound should be paired with visuals is novel. The model is predicated on the design of sound to manage cognitive load, and it proposes five functions and three structures for sound to "help learners to focus their attention on visual events in multimedia" (Mann, 2008, p. 1165). However, a convincing rationale is not presented for the decisions that led to the five sound function categories or to the structures that outline how sound should affect visual events in his model. In addition, the research to codify this model cannot be found, and no theoretical grounding is provided to explain how sound and visuals work together in immersive environments in ways that support ludic engagement. In 2001, Bishop and Cates also proposed a framework for sound in multimedia and based the framework on a model of an instructional communication system. This model assumes that learners move through a process to select and analyze information before finally constructing new knowledge with the information presented (Bishop & Cates, 2001). Bishop and Cates's sound model expands on this communication system and seeks to address problems introduced by noise in the system that occurs when learners work through problems to acquire, process, and retrieve information. According to Bishop and Cates, sound is able to direct attention, communicate information, and "elaborate on visual stimuli by providing information about invisible structures, dynamic change, and abstract concepts almost impossible to communicate visually" (p. 11). Moreover, sound can help connect learners to content while "creat[ing] a systematic auditory syntax for categorizing main ideas" in addition to focusing learner attention by "employ[ing] novel, bizarre, and humorous auditory stimuli" (p. 15). Bishop and Cates (2001) illustrate how to apply this framework to design sound by describing a potential multimedia module to teach the concept of information processing, as a way to describe aspects of their framework. On the surface, this framework is promising; however, it is limited to describing how auditory cues can be used to grab learner attention and provide a cue for future presentation of content. No discussion of auditory cues and visuals is provided, and no review of sound design within either multimedia or game environments is presented. In addition, no research model is made available to ground this investigation from a sound-listening perspective. In a follow-up study, Bishop, Amankwatia and Cates (2008) examined sound events present in lessons from four software applications and investigated how these learning tools used sound to support information processing. They studied the frequency of sound events in 12 lessons from these programs and used content analysis to analyze applications for sounds present. Sound was predominantly used to manage attention and support organization of information. However, learner perspectives of sound were not incorporated in their research. Neither Mann (2008), Bishop and Cates (2001), nor Bishop et al. (2008) explain how sound and visuals relate to communicate information or create immersive experiences. None of the frameworks reviewed provide a comprehensive strategy by which to guide the design of sound for educational games or address how sound and visuals work together to affect how people experience gameplay. Scant research is available within educational technology to examine participant experiences of gameplay, and no suitable frameworks can be found for conducting research into sound and educational games.

## Sound and Games

The use of sound in computer games (and arcade video games) is ubiquitous. The use of sound to draw attention and provide interactive cues can be traced to interactive entertainment of the 19th century (e.g., penny arcades) and can be found throughout popular video game titles from the 1980s through currently available titles (Collins, 2008). Sound has been used to "reward" successful game interactions and to reflect choices people make in games. For instance, the game *The Legend of Zelda: Ocarina of Time* (Nintendo EAD, 1998) used "melodic foreshadowing" to integrate music with in-game puzzles, while melodic passages were used as environmental cues through a subtle blending of "danger music" and "attack music" as the player approaches an enemy (Belinkie, 1999; Gibbons, 2009; Whalen, 2004). Sound and music in games can also regulate player affective responses. Straightforward sound-design techniques such as modulating volume levels and adjusting the timing of effects have been shown to increase anxiety, fear, and suspense in games, and giving players choices over the music they hear has been shown to reduce anxiety (Toprac & Abdel-Meguid, 2011; Wharton & Collins, 2011).

## Game Audio and Player Interactions

Karen Collins (2008) offers a compelling analysis of game audio from the perspective of player interactivity, and she provides a framework that explains how sound and visuals work together in games to provide players with immersive gameplay experiences. In Collins's framework, games use sound in ways that provide players with cues for action and feedback for choices. In addition, game design can also use sound to respond to player decisions as well as to changes that occur during gameplay. Collins's framework organizes a discussion of game audio from the perspective of diegesis and "degrees of player interactivity" (p. 125). Collins (2008) draws from film sound theory to describe diegesis as the way in which a game player perceives the source of the sound being played at different points during gameplay. Sounds that both the player and game characters can hear are diegetic sounds. However, sounds that can be heard only by the player are nondiegetic. Within Collins's (2008) framework, game sound can be interactive and designed to respond to player actions. Game sound can also be adaptive and change in response to a state within the game. Alternatively, game sound can also be nondynamic. Interactive, adaptive, or nondynamic audio can either be diegetic or nondiegetic. Game sound provides a crucial connection to the audiovisual illusion provided by the interaction of game visuals with sound, and at times it is mediated by player choices and changes in the game. This illusion enables players to create semantic meaning from play and helps to establish a realistic game setting. Notably, Jorgensen (2008) and other game sound theorists describe the role of game sound from the ecological perspective of the events conveyed by sound instead of from the technical perspective of the sounds themselves. An ecological, everyday listening approach to describing the role of game audio is crucial if, as Bishop et al. (2008) suggest, designers of educational software hope to use sound to "represent content … depict a context … or illustrate a construct" (p. 481). A synchretic, ecological approach to examining sound as paired with visuals can also help to derive a framework by which to understand learner perspectives of their sound-listening experiences while playing educational games. Such a context-driven, learner-centered, and synchretic perspective is missing from current scholarship, and thus it presents an opportunity to examine game sound from a phenomenological perspective.

## Study Overview Phenomenology

I took an interpretive, phenomenological approach to examine what it was like to experience sound while playing educational games. This phenomenological approach enabled me to address this question and explore participants' lived experiences of playing educational games while listening to sound. The study of experience is central to phenomenology, and the method has been applied within educational technology research to examine student experiences within learning environments (Cilesiz, 2009; Miller, Veletsianos, & Doering, 2008). I applied phenomenology to address the central question, "What is it like to experience sound while playing educational games?" I incorporated participant perspectives that arose out of their immediate descriptions of sound in games, their reflections of past experiences, and their description of personal significance of their experiences participating in this research. I applied these perspectives when searching for essential meanings, and as I structured the reductive, analytical process (Dahlberg, Dahlberg & Nystrom, 2008; Giorgi, 1997; Giorgi & Giorgi, 2003; Moustakas, 1994; Rosenblum & Hughes, 2017), I used these phenomenological approaches to learn about the structure and essential meanings of my participants' experience of sound as they played educational games. According to Merleau-Ponty (2002), "The structure of actual perception alone can teach us what perception is" (p. 4, Kindle ed.). I derived this structure by gaining access to the "totality of lived experiences" (p. 2) of sound in games as described by my participants.

## Data Collection and Analysis

I selected and interviewed six participants for this study. I asked each participant to play three games and participate in interviews over three temporally separated interview sessions (Cilesiz, 2010). I preselected educational game titles based on an analysis of game sound from the perspectives of acoustic ecology and player interactivity (Collins, 2008; Gaver, 1993; Schafer, 1993). The games selected included a 2D strategy game, an interactive story game, and a 3D problem-based learning game. During each session, I asked people to play games while I digitally recorded their gameplay and audio/video recorded the interview session. I applied a stimulated recall and think-aloud protocol to play back their gameplay and to ask questions about their experiences. I subsequently coded interview transcripts, reduced data, and derived essential meanings in this research (Rosenblum, 2014; Rosenblum & Hughes, 2017). The eight shared essential meanings derived in this study represent various ways in which sound affects participant experience of playing three educational games. These meanings indicate that sound: conveyed a sense of the game's interface in addition to the environment in which play was situated, supported the presentation of characters in the game, and worked to communicate the game's narrative to the player. Music in the games studied helped to provoke thought and also conveyed an emotional context for play. Sound was essential for players to remain engaged with their gameplay. People noticed when sounds heard and visuals seen did not match.

## Sound and Silence

One of the challenges in this investigation was to design a phenomenological investigation to enable an "opening up" of the phenomenon of sound. From an ontological perspective, the experience of sound may be thought of in what Don Ihde terms as "auditory horizons." Ihde's (2007) auditory horizons are an extension of Husserl's idea of phenomenological horizons, which connote the background of understanding within which one explores a given phenomenon (Ricoeur, Ballard, Embree, & Carr, 2007). One way to demarcate horizons is to identify their boundaries. For auditory horizons, one such boundary that Ihde describes is silence. As Ihde observes, unless one is bereft of hearing, one does not really lose the ability to hear sound: Even in perfect silence one hears the sounds that characterize one's physical being, such as breathing and heartbeat. However, an interesting aspect of silence is that is even if one does not passively receive auditory input through one's ears, one exercises what Ihde and others have described as an "auditory imagination." That is, one hears "inside" one's own head even in the absence of sound. Such a distinction becomes critical to note, especially given the role that auditory imagination plays in asking people to explore horizons related to their experiences of sound.

It is difficult for people to describe what they hear (Jorgensen, 2008). As Jorgensen (and others) point out, humans have no "earlids" with which to filter (and therefore evaluate) perception of sound. As Don Ihde (2007) points out, it is difficult to describe sound because the listener is situated in a horizonal field while experiencing sound. Ihde describes phenomenological horizons as the descriptions and perspectives that shape how one perceives an experience. Ihde characterizes and illustrates this horizonal field as a "Focus Field Horizon Structure" (p. 106). Moreover, the boundary of this horizonal field is a point where the phenomenon is not relevant to our experience. In the case of sound, this boundary is delimited by what Ihde (2007) calls a "horizon of silence" (p. 52). Taking Ihde's Focus Field Horizon Structure, I interpret his notion of a horizonal field to describe all possible sound horizons, and his notion of focus within this field to describe the immediate focus on sound. I pair this interpretation of sound horizons with Ihde's notion of silence as a horizonal boundary to illustrate the placement of the listener's focus on sound within a space of potential sound horizons. In his model, a large circle represents a possibility space for events that comprise one's possible experiences of sound at any given time; in other words, it encompasses what someone might say about sound. A smaller, concentric circle in the middle of Ihde's field represents the immediate focus on sound as it is experienced. A horizon, therefore, is a point within these circles that represents one of many facets of experience. However, herein lies a paradox. According to Ihde, one cannot turn off the perception of sound. Sound is what Merleau-Ponty would describe as an embodied experience (Merleau-Ponty, 2002). If one is physiologically capable of hearing—and even if one were to completely muffle sounds that can arise as a result of sound waves impacting the ears—one would still have the experience of hearing the physical self—that is, the heartbeat. From a philosophical perspective, Ihde (2007) maintains that instead of silence, one experiences "auditory imagination" in which one fills in the perceptual blanks in the absence of sound. This perspective on auditory imagination is in turn borne out in neurological studies by researchers such as Kraemer, Macrae, Green, and Kelley (2005) and Zatorre and Halpern (2005), who conducted brain imaging studies on people who listened to music and who experienced "gaps" of silence in the music. Interestingly, the auditory cortex of study participants continued to remain active throughout the experiment, a phenomenon described by Voisin, Bidet-Caulet, Bertrand, and Fonlupt (2006) as "listening in silence." Therefore, asking players to play a game silently would naturally lead them to "listen in silence" to the game as they played, even as they missed the cues and information normally provided through sound. People bring with them the sum total of their individual expectations and perspectives for what they think (consciously or not) they should hear (Neuhoff, 2011). These neurological perspectives are crucial to understanding phenomenological perspectives of sound, silence, and gameplay.

### Silence Within Study Design

I incorporated silence into my current study by asking that people play games with the sound turned on and interviewing them, while allowing for the natural silences present in the game to form the horizons that they experience. The advantage of this approach is that the horizons that they identify are derived from the game's individual design strategies for sound use. Descriptions therefore are less likely to be affected by large gaps of silence and participants are less likely to describe or compare their experiences based on what they imagine. Another (perhaps equally important) advantage of this approach is that they can climb the learning curve of the game more readily with sound (Jorgensen, 2008). Because of the difficulty faced when concentrating on our experiences of sound (Ihde, 2007; Jorgensen, 2008), I let people play games with sound but used silence in ways that helped people to cleanse their perceptual palate. Thus, I bracketed my experience as a sound designer and sound researcher and periodically turned off sound when participants indicated difficulty in describing their experiences with sound. In this way, I purposefully activated their process to listen in silence and in doing so used the contrasting experience as a perceptual prompt to enliven their descriptions of sound in educational games. Such an approach has the phenomenological effect of shifting the focus of their perception of sound in their experiential field (Ihde, 2007). In doing so I moved their focus from the "middle" of the horizontal field to its boundary (i.e., silence) and back again. This process of purposefully shifting the phenomenological focus thereby helps ensure that people experience multiple possible horizons for sound during their play of educational games. A key goal of phenomenology research (Giorgi, 1997) is to identify as many possible horizons of an experience as possible. This strategy can be critically useful in helping to open up the phenomenon of sound in educational games while also having the intangible benefit of helping to make people more aware about the ways in which they perceive sound. In practice, I asked people to play games with sound. However, I also periodically turned off sound during play when I encountered areas in the game that either raised additional interview questions or were otherwise difficult for people to describe what they were hearing. In this way, I could use silence as a fine-tuned tool to help people to clear their perceptual palate and attend to what they heard.

## An Applied Phenomenological Framework

It is critical that designers of games in general, and of educational games in particular, have a framework by which to consider how sound affects player experiences of games. Educational environments offer fertile ground for such investigations. Gershon (2017) makes the case for attention to sound as a strategy to inform the design of educational curriculum and draws upon ecological approaches to sound listening in this discussion. According to Gershon, educators should reconceptualize learning environments from an aural point of view and use it to shape design of curriculum, what Gershon describes as a "sound curriculum" to "brea[k] frames and ope[n] ears" (Gershon, 2017, p. 2). This investigation frames an investigation of sound through a phenomenological lens. This study's philosophical design draws upon Don Ihde's (2007) phenomenological perspective of sound and relies upon his Field Focus Horizon Structure to explain the phenomena of sound listening and silence. I therefore propose an applied phenomenological framework to research sound that incorporates Ihde's framework for sound and silence, that draws upon perspectives on player interactivity by Karen Collins (2008), and that also incorporates the findings from this investigation (see Figure 1).

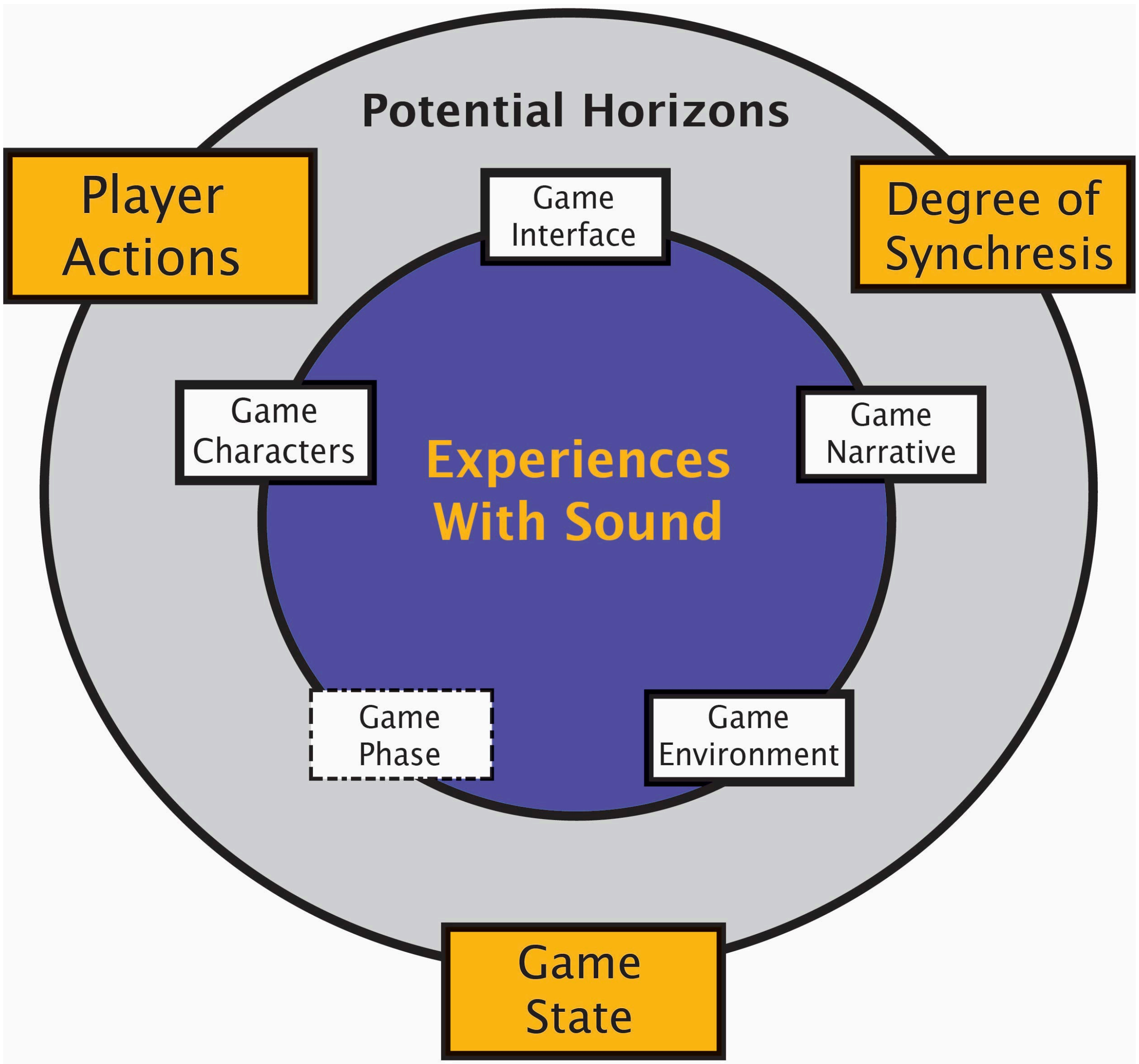


*Figure 1. Applied phenomenological framework for sound in educational games.*

In this applied phenomenological framework, the inner circle, Experiences With Sound, represents the player experience of sound heard in games. The outer circle, Potential Horizons, represents the possibility space for all of the potential horizons of meaning that could exist for the player based on what is heard. The outer boundary of this framework represents the absence of sound heard. Potential horizons are dependent on three critical factors, represented in boxes placed on the border of the outer circle: the actions taken by the player in the game (Player Actions), the game's state at the time of the experience (Game State), and the degree of synchretic pairing of sound and image that is embedded in the game's design (Degree of Synchresis). The notion of player actions is analogous to Collins's (2008) discussion of interactive sound that is triggered as a result of the game players' interaction with the game. The idea of game state is also taken from Collins's framework, since it is important in describing changing conditions that mark different aspects of gameplay, and thus results in what she describes as adaptive audio. I do not include Collins's description of nondynamic audio for sound that is not impacted by player actions, since the experiences from these sounds are included both in the explanation of synchretic pairing and are also reflected in other areas of the framework. The third factor in the outer circle, Degree of Synchresis, is also included in this area because of the importance that the participants placed on audiovisual pairing across all three games studied. Degree of Synchresis reflects the extent to which there is a plausible pairing of sound and visuals within the game's design. The three factors, Player Actions, Game State, and Degree of Synchresis, mediate participant experiences of sound as they play games and are dependent upon the players' actions, their progress through game states, and the degree to which players interpret synchretic pairing of sound and visuals. Although these three factors may vary based on an individual's own experience and perspective, it is important to note that removing the ability for players to hear sounds when they interact with a game, failing to provide sound to denote game state, or having minimal synchresis present in a game can dramatically reduce the number of potential horizons of meaning that can be derived as a result of experiences of sound.

While the outer circle of this framework represents the potential horizons of meaning that could emerge from play, the inner circle represents components that were presented using embedded game sound. These components are represented as boxes placed on the border of the inner circle: Game Interface, Game Characters, Game Narrative, Game Environment, and Game Phase. All of these components, except Game Phase, were extracted from the shared essential meanings found in common across all three games in this study. The fifth component, Game Phase, was added because it was an essential meaning derived specifically from the analysis of the strategy game. This game contained a structure that organized play through a series of phases within a given round. This box has a dotted outline since this component did not emerge as a shared essential meaning. All five components of gameplay thus reflect the ways in which sound is embedded in each of the games' designs in this study. The inner circle represents player experiences with sound as played games, and as such is situated within the overall possibility space of the potential horizons of meaning. This framework is designed to visually summarize the relationship of game components and mediating factors that defined the possible horizonal space for this study and which, through play, ultimately led to these participants' thick descriptions of sound in educational games. As researchers are able to study sound, more may be learned about how sound and visuals convey information, and in what ways can people find value in the use of sound in educational games. Such understandings will enable the educational game community to explore how to design immersive game-based learning environments that are both engaging and motivating.

## References

Belinkie, M. (1999). *Video game music: Not just kid stuff.* Retrieved from http://www.vgmusic.com/vgpaper.shtml

Bishop, M. J., & Cates, W. M. (2001). Theoretical foundations for sound's use in multimedia instruction to enhance learning. *Educational Technology Research and Development*, 49(3), 5–22. doi:10.1007/bf02504912

Bishop, M. J., Amankwatia, T. B., & Cates, W. M. (2008). Sound's use in instructional software to enhance learning: A theory-to-practice content analysis. *Educational Technology Research and Development*, *56*, 467–486. doi: 10.1007/s11423-006-9032-3

Chion, M. (1994). *Sound on screen* (C. Gorbman, Trans.). New York, NY: Columbia University Press.

Cilesiz, S. (2009). Educational computer use in leisure contexts: A phenomenological study of adolescents' experiences

at Internet cafés. *American Educational Research Journal*, 46(1), 232–274.
Cilesiz, S. (2010). A phenomenological approach to experiences with technology: Current state, promise, and future directions for research. *Educational Technology Research and Development*, 59(4), 487–510. doi:10.1007/s11423-010-9173-2
Collins, K. (2008). *Game sound: An introduction to the history, theory, and practice of video game music and sound design*. Cambridge, MA: The MIT Press.
Dahlberg, K., Dahlberg, H., & Nystrom, M. (2008). *Reflective lifeworld research* (2nd ed.). Lund, Sweden: Studentlitteratur AB.
Gaver, W. (1993). What in the world do we hear? An ecological approach to auditory event perception. *Ecological Psychology*, 5(1), 1–29.
Gershon, W. S. (2017). Sound curriculum: Sonic studies in educational theory, method, and practice. New York, NY: Routledge. doi:10.4324/9781315533131
Gibbons, W. (2009). Blip, bloop, Bach? Some uses of classical music on the Nintendo entertainment system. *Music and the Moving Image*, 2(1), 40–52.
Giorgi, A. (1997). The theory, practice, and evaluation of the phenomenological method as a qualitative research procedure. *Journal of Phenomenological Psychology*, 28(2), 235–260.
Giorgi, A. P., & Giorgi, B. M. (2003). The descriptive phenomenological psychological method. In P. M. Camic, J. E. Rhodes, & L. Yardley (Eds.), *Qualitative research in psychology: Expanding perspectives in methodology and design* (pp. 243–273. Washington, DC: American Psychological Association. https://doi.org/10.1037/10595-013
Ihde, D. (2007). *Listening and voice: Phenomenologies of sound*. Albany: State University of New York.
Jorgensen, K. (2008). Left in the dark: Playing computer games with the sound turned off. In K. Collins (Ed.), *From Pac-Man to pop music: Interactive audio in games and new media* (pp. 163–176). Burlington, VT: Ashgate.
Kostolny, J., & Bohacik, J. (2017, October). *Digital games in education and their development*. Presented at the 15th International Conference on Emerging eLearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia. doi:10.1109/ICETA.2017.8102494
Kraemer, D. J. M., Macrae, C. N., Green, A. E., & Kelley, W. M. (2005). Sound of silence activates auditory cortex. *Nature*, 434, 158.
Mann, B. (2008). The evolution of multimedia sound. *Computers & Education*, 50(4), 1157–1173.
Merleau-Ponty, M. (2002). *Phenomenology of perception* [Kindle ed.]. New York, NY: Routledge.
Miller, C., Veletsianos, G., & Doering, A. (2008). Curriculum at forty below: A phenomenological inquiry of an educator/explorer's experience with adventure learning in the Arctic. *Distance Education*, 29(3), 253–267. doi:10.1080/01587910802395789
Moustakas, C. (1994). *Phenomenological research methods*. Thousand Oaks, CA: Sage.
Neuhoff, J. G. (2011). Perception, cognition and action in auditory display. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 63–85). Berlin, Germany: Logos.
Nintendo EAD. (1998). *The legend of Zelda: Ocarina of time* [Video game]. Kyoto, Japan: Nintendo.
Petri, G., & Gresse von Wangenheim, C. (2017). How games for computing education are evaluated? A systematic literature review. *Computers & Education*, 107, 68–90. doi:10.1016/j.compedu.2017.01.004
Ricoeur, P., Ballard, E. G., Embree, L., & Carr, D. (2007). *Husserl: An analysis of his phenomenology*. Evanston, IL: Northwestern University Press. doi:10.5195/JFFP.2017.800
Rosenblum, J. (2014). *What is it like to experience sound, while playing educational games?* (Unpublished doctoral dissertation). University of Texas, Austin, TX.
Rosenblum, J., & Hughes, J. E. (2017). Digital recording technologies in phenomenological investigations. *Journal of Ethnographic & Qualitative Research*, 12(1), 29–49.
Schafer, R. M. (1993). *The soundscape: Our sonic environment and the tuning of the world* [Kindle ed]. Rochester, VT: Inner Traditions/Bear & Company.
Toprac, P., & Abdel-Meguid, A. (2011). Causing fear, suspense, and anxiety using sound design in computer games. In M. Grimshaw (Ed.), *Game sound technology and player interaction: Concepts and developments* (pp. 176–191). Hershey, PA: Information Science Reference.

Voisin, J., Bidet-Caulet, A. l., Bertrand, O., & Fonlupt, P. (2006). Listening in silence activates auditory areas: A functional magnetic resonance imaging study. *The Journal of Neuroscience*, 26(1), 273–278. doi:10.1523/JNEUROSCI.2967-05.2006

Whalen, Z. (2004). Play along – An approach to videogame music. *Game Studies: The International Journal of Computer Game Research*, 4(1). Retrieved from http://gamestudies.org/0401/whalen/

Wharton, A., & Collins, K. (2011). Subjective measures of the influence of music customization on the video gameplay experience: A pilot study. *Game Studies: The International Journal of Computer Game Research*, 11(2). Retrieved from http://gamestudies.org/1102/articles/wharton_collins

Zatorre, R., & Halpern, A. (2005). Mental concerts: Musical imagery and auditory cortex. *Neuron*, 47, 9–12.

# 20. StoryMode: An Exploratory Test of Teaching Coding Within ELA Projects

AMY STRACHMAN, JOE SHOCHET, AND GRANT HOSFORD

**Abstract:** Teachers and parents agree that computer science education is a necessary discipline to learn and want to see it in their schools and homes. Children who are exposed at an early age to computational thinking and STEM curricula are more likely to enter technical fields, hold fewer gender-based stereotypes about STEM, and show many other beneficial outcomes. However, teachers do not have the time, budget, or feel qualified to introduce a coding curriculum into their already overwhelming schedules. The current study explores an educational tool designed specifically to teach computational thinking and coding skills to young children ages 5 to 9 years old that may overcome these barriers. Using a game-based, block-based programming environment, StoryMode uses a visual environment that makes learning programming easy, fun, and engaging. Children create multiscene animated stories using code in StoryMode. The platform was created such that any teacher, with or without computer science knowledge, can easily and confidently use it in his or her classroom and integrate it with an English Language Arts (ELA) curriculum. The results of this exploratory study found that across 10 classrooms, StoryMode was interesting and engaging for young children, easy for teachers to implement, and a potentially useful teaching tool for computational thinking concepts. Teachers were especially excited for its future use and integration into lessons beyond ELA, including social studies and science. Overall, this research suggests that StoryMode may provide a way to overcome many of the time, resource, and implementation barriers to computer science education.

## The Importance of Children's Learning Coding and Computational Thinking

Computational thinking and its foundation in STEM are our children's future. Jobs in computing are increasing twice as fast as in other occupations, and 58% of new STEM jobs are coming from computer science (Bureau of Labor Statistics, 2019). The greatest advancements, innovations, new products, and new industries have been derived from STEM and the minds of those interested in its areas of research. It is therefore imperative that we encourage the interest, confidence, and knowledge of STEM skills in our children. The elements of computational thinking (e.g., sequencing, looping, events, conditional logic, variables, and algorithms) are particularly beneficial when introduced to children at a young age. Children who are exposed at an early age to coding and computational thinking demonstrate fewer obstacles entering technical fields (Madill et al., 2007) and fewer gender-based stereotypes regarding STEM careers (Metz, 2007). Increased knowledge of computational skills in early childhood is also associated with better problem solving, decision making, basic number sense, language skills, and visual memory (Clements, 1999; Flannery et al., 2013).

Despite the many benefits of studying and working in STEM, there are few educational technologies created for early childhood that focus on coding and computational thinking skills (i.e., under the age of 8 years old). Creating this type of educational technology for young children comes with numerous challenges. First and foremost, many 5- and 6-year-olds cannot yet read, and therefore, a strict syntax or text-based program would be frustrating and uninteresting. Second, young children learn more effectively when the skill is introduced with an appropriate level of complexity to support their reasoning and executive function skills (Clements & Sarama, 2011). Third, girls remain less interested in STEM careers and associated games (Valian, 2006). There unfortunately remains a gender stereotype for STEM subjects such that even as early as second grade, children believe that math is for boys both implicitly and explicitly (Cvencek, Meltzoff, & Greenwald, 2011). And researchers believe this gender stereotype persists because of lack of experience with

STEM-related activities (Master, Cheryan, Moscatelli, & Meltzoff, 2017). Overall, an effective educational technology that teaches coding and computational thinking for young children needs to consider their developmental and cognitive capabilities, while also still capturing the interest of both boys and girls and their many different views of what is fun to play.

## Barriers to Teaching Coding in the Classroom

In a survey of 504 K–12 teachers by YouGov in November 2018, 88% of teachers and educators agreed that computer science is critical for students to learn (Microsoft Education Team, 2018). However, many teachers do not include computer science instruction in their classrooms. The teachers surveyed explained the many reasons for not implementing coding, such as its not being a part of the current curriculum, insufficient funding, and a lack of trained and qualified computer science instructors. Moreover, only 20% felt confident in their own understanding of computer science education, and thus did not feel they could teach it themselves. In a Gallup study during 2014, principals and superintendents of schools and districts that do not offer computer science classes said it was because of limited time to devote to classes that are not tied to testing requirements and low availability/budget for computer science teachers (Busteed & Sorenson, 2015). In short, an effective technology for teaching coding also needs to overcome the sizable barriers to computer science instruction in early elementary years: Teachers do not have the time, money, or feel qualified to introduce a coding curriculum into their already overwhelming schedules.

## Using Story Lines in Games as a Teaching Tool

There has been positive evidence that instruction via games can affect young children's development of coding skills (Fessakis, Gouli, & Mavroudi, 2013; Strawhacker, Lee, & Bers, 2017). For example, Strawhacker and colleagues examined 222 K–2 students' performance on a series of assessments designed to measure computational thinking concepts after lessons on ScratchJr (Bers & Resnick, 2014) programming. Their results showed that K–2 students were able to perform well on areas of symbol decoding and sequence comprehension, as well as on areas of debugging and goal-oriented coding. The next step to getting young children to learn coding concepts with games is to find one that captures the interest of both boys and girls, and that can be implemented easily by teachers in the classroom.

Our study explores the idea that this can be done with pretend-play, story-creating games. Research suggests that young children are not only more interested in fantasy play and stories over realistic ones, but they also learn better from such content. For example, a study of preschoolers' knowledge of new vocabulary words showed greater gains when storybooks and play content were creative and fantastical versus realistic (Weisberg et al., 2015). Pretend play is also a useful form of behavior for learning in young children and has shown to be beneficial for cognitive skills, including symbolic thinking and counterfactual reasoning (Weisberg et al., 2015). This type of learning should benefit both girls and boys since they engage in sociodramatic play with equal frequency, but with varying topics (e.g., boys make use of tools and vehicles while girls tend more toward home and school; Edwards, Knoche, & Kumru, 2001). The game *Alice* (Pausch, 1999) is a 3D interactive graphics game and uses storytelling to teach coding; however, it is created for cognitive abilities at middle-school level and beyond. Despite using more advanced algorithms and techniques than would be applicable to young children, a study of the *Alice* game found a strong benefit in teaching these concepts through engaging and interesting storytelling content (Cooper, Dann, & Pausch, 2000). The use of stories is also a versatile teaching tool that can be applied to book reports, personal narratives, and opinion projects.

## StoryMode as a Coding Game Within ELA

Creating stories is an engaging and potentially effective way for young children to learn computational thinking and coding concepts and may also overcome the many implementation barriers for teachers. In order to test this idea, the current study used a new teaching tool called StoryMode. This patent-pending (Shochet, 2016) game-based, block-based programming environment was designed for children ages 5 to 9 years old to learn coding and computational thinking skills while using a story line. By using a block-based programming environment, the game enables students to code using icons rather than traditional text commands. The idea behind visual programming is to make learning easier by removing many of the challenges posed by traditional languages (e.g., syntax, variable initialization; Werntrop & Wilensky, 2015). Thus, the game can be played regardless of age, language, or country. It focuses on translating complex computer science concepts into a block-based or coding language format that maintains sufficient clarity and simplicity for young children to understand. The characters are controlled by the players through blocks that represent actions such as walk, jump, or throw an object. The players then drag commands from the library of actions to the code tray, the interface where events occur through touch. When they tap the character, the commands they have selected (walk, jump, etc.) allow them to reach their goal.

Within StoryMode, children can choose from multiple story templates with different setups to get started, and then each story can include several linked scenes. Students take on the role of "author" using design skills to set up the scene and coding skills to move and create interactions between characters and objects for each scene of the story. StoryMode provides a variety of characters, props, backgrounds, and emotions for children to add to each scene. Children are able to position and arrange objects in Edit mode and to program each object to follow certain commands. They can code a character to move or speak when tapped or as soon as the scene begins. A voice-over command allows the children to record their own voices and then to associate their speech with a character or object in their stories. Children can also use code to program their characters to trigger back-and-forth interactions and conversations. And it is important to note that the open-ended setup of StoryMode allows teachers to choose how best to use the tool. Any teacher, with or without computer science knowledge, can implement it into his or her classroom and integrate it with the current English Language Arts (ELA) curriculum (e.g., book reports, narratives).

## Research Study

The current study is a qualitative exploration of StoryMode and its potential as a feasible and versatile tool for bringing coding into early elementary classrooms. The following research questions were addressed:

1. Are first- and second-grade *students* able to progress through StoryMode, and do they find it easy to use and interesting/engaging?
2. Are *teachers* able to incorporate StoryMode into their classrooms, and are they interested in using it in the future in order to bring coding concepts into ELA lessons?

### Participants

The study involved teachers (N = 10) and students (N = 94) from eight classrooms across two elementary schools in the San Francisco Unified School District. At each school, there were four classroom teachers and one on-site coordinator who participated. The on-site coordinators had multigrade support roles at their schools with a focus on technology instruction. Only students with parental/guardian consent participated in the study (see Table 1). The two school sites varied in demographics: School A had 84% on free or reduced lunch, 70% English learners; School B had 34% on free or reduced lunch, 24% English learners. Both school sites had implemented coding instruction in their current and prior school years.

| Participant | School Site | Grade | # of Students |
|---|---|---|---|
| Teacher 1 | A | K | 12 |
| Teacher 2 | A | 1st | 13 |
| Teacher 3 | A | 1st | 10 |
| Teacher 4 | A | 2nd | 10 |
| On- Site Coordinator A | A | K-5 | n/a |
| Teacher 5 | B | 1st | 19 |
| Teacher 6 | B | 1st | 12 |
| Teacher 7 | B | 1st | 11 |
| Teacher 8 | B | 2nd | 7 |
| On- Site Coordinator B | B | K-5 | n/a |

*Table 1. Description of participants.*

## Method and Data Collection

Teachers first attended a 1.5-hour training session on the use of StoryMode. The following week, they used StoryMode on three consecutive days during their ELA lessons. Lessons lasted 35–60 minutes. Teachers were provided the three ELA lesson plans and curricular materials for each day that corresponded with the features of StoryMode (see details below).

Two research assistants observed each teacher's classroom during these lessons at least once to gather qualitative assessments. Field notes from classroom observations were reviewed for themes across the classrooms and lessons, as well as for evidence that stood out as significant for understanding how StoryMode was being used and received by the students. At the conclusion of the study, teachers participated in a one-hour focus group to discuss their reflections on the game and their experience using it in the classroom. A sample of students' stories created in StoryMode was also analyzed to see the tangible products of students' work. These stories were analyzed using a protocol covering six themes: Sequencing, Storytelling, Genre, Language Use, Use of StoryMode Features, and Other (anything of interest that did not fit in the above categories). In addition, students were asked at the end of the study about their emotional response to StoryMode on a 1–5-point Likert scale (using frowning and smiling faces): "How did using StoryMode make you feel?"

## Lesson Plans

A brief three-lesson companion curriculum was provided to teachers with StoryMode as an example of how this educational technology could be used with ELA instruction. The curriculum itself was not the focus of the study, but rather, allowed teachers to incorporate StoryMode into their day without having to develop their own lesson plans. These three lessons were developed based on common ELA writing programs in California.

- In Lesson 1, students are introduced to StoryMode by watching and listening to a version of "Goldilocks and the Three Bears" that includes StoryMode characters. They then discussed story structure, creative elements, and review how the coding in the example was done. Students then viewed a tutorial of StoryMode. After a discussion of this tutorial, students begin creating "Goldilocks and the Three Bears" using StoryMode and a worksheet that guided the creation of a story arc.
- Lesson 2 moved students into more advanced coding with StoryMode. A different popular children's story was read, and the teacher discussed how the story could be changed to be more funny or interesting. Students then accessed StoryMode, where they were provided with one complete scene and one scene with images only, along with a worksheet of challenges and ideas for coding their own version of the story.
- Lesson 3 tied the coding back into the story making. Students created a three-scene story in StoryMode with a few instructions to help them through the first scene (e.g., replace the characters on the screen with your own characters, replace one of the events with an event you haven't used before, add a new character that interacts with one of the old characters). Students then completed the rest of the story on their own.

## Results

### Are First- and Second-Grade *Students* Able to Progress Through StoryMode, and Do They Find It Easy to Use and Interesting/Engaging?

Classroom observers agreed that students were able to readily pick up the fundamentals of the game and were happy to share their stories at the end of class. Teachers noted that starting on the first day, students began using the game with little hesitation. As one teacher put it, "Once they see it, once they know what to do, they don't feel like they're afraid." The children loved picking their characters, adding items, using the different commands, and most wanted to continue working in StoryMode despite the lesson's coming to an end. They were very happy to share their stories at the end of class. Observers noted that all or nearly all the students raised their hands to volunteer sharing their story. Some students readily went to the front of the classroom to share their story even when they did not appear to have a full story created. In the focus groups, teachers noted how much students loved the accessible creativity of picking their characters, adding objects, and animating their characters (especially eating things). Overall, StoryMode appears to be easy to use by first- and second-grade students, while also an interesting game that kept children's interest throughout multiple lessons. The latter was also confirmed quantitatively: 71% of students felt "very happy" using StoryMode (see Figure 1).

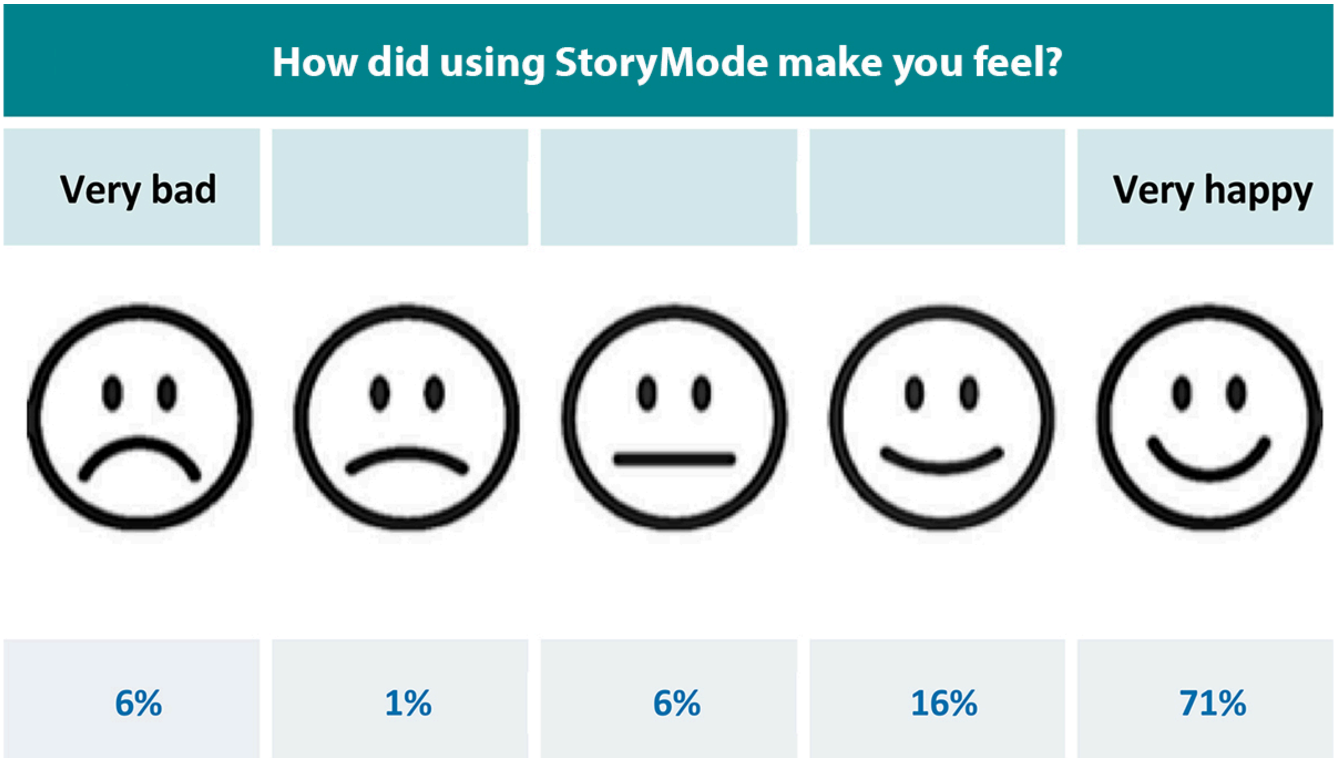


*Figure 1. Assessment of student Interest in StoryMode.*

## Are *Teachers* Able to Incorporate StoryMode Into Their Classrooms, and Are They Interested in Using It in the Future to Bring Coding Concepts Into ELA Lessons?

In the focus groups, teachers were complimentary of how StoryMode could be used to reinforce their teaching around the ELA curriculum of story building (i.e., the structure of beginning, middle, and end), and they wanted more time and more ways to incorporate StoryMode into their writing curriculum (e.g., "how to" books, science writing, book reports). One teacher said she would use StoryMode in the future as a spelling tool by having students program each character to say something related to particular words. Two additional teachers commented on how the basic format of the game's implementation had some helpful parallels to their existing writing instruction: "It is sort of like what we do during writing workshop and reading workshop: We modeled it, and then they went and did their own. It was really cute. They had the sequence down, but all of them created something a little unique and tweaked it to their own style." Teachers also commented on how they were pleased with how StoryMode could engage their students, particularly given children's various skill levels. One teacher said, "The challenging kids who always get in trouble, they were really engaged and focused, and they did not get in trouble during that time." Teachers liked how easy it was to play and experiment in the game. One teacher noted how quickly a user can undo certain actions by removing a character, object, or command. Another teacher commented that "there's no negative consequences. It is always positive. It's 'Oh, you made a mistake. Try something else.' It's OK if they make a mistake." They agreed that this freedom to experiment is important when implementing a new educational technology into the classroom. Altogether, teachers thought StoryMode is an interesting and exciting tool for incorporating coding concepts into many different types of lessons

## Story Analysis

After the third day of implementation, a set of seven students' work in StoryMode was randomly selected to be analyzed. From these seven students' work, 13 of their stories were analyzed. The stories presented a mix of progress, from nascent to refined. Many of the stories were well populated with objects and characters, suggesting that setting up their scenes is a relatively easy task for students. This aligns with observations in the classroom, in which students readily added multiple characters/objects to their stories. About half of the stories were very brief, with only a few commands added. A typical story in this category might have two characters, one or both of which would walk somewhere and then eat an object or another character. Six of the 13 stories included extra elements that hinted at an early progression toward storytelling. This included responsive dialogue (e.g., Character 1: "hi my name is claire'" Character 2: "hi my name is arad") or evidence that the student had a setting in mind for the characters. The results of this story analysis suggest that students were able to navigate StoryMode and use coding skills to create stories.

# Discussion

Telling stories is an engaging and fun way for young children to learn computational thinking and coding concepts that can overcome the many barriers of bringing coding into the classroom. The current study examined the idea of using a storytelling coding game (StoryMode) as a teaching tool for children to learn ELA along with coding concepts. The platform was created such that any teacher, with or without computer science knowledge, can implement it into his or her classroom and integrate it with ELA curriculum. Students can tell their own stories and let their imaginations flourish through coding or follow a predesigned curriculum that corresponds with an ELA lesson. Teachers found StoryMode exciting and useful, and they could see it extended into other subjects, such as science and social studies. Showing high teacher interest, student engagement, and ability to cross into ELA curriculum are critical first steps toward finding a tool that introduces students to computer science concepts. Future research will quantitatively test the game's efficacy in teaching specific computational thinking skills, such as sequencing, events, loops, and algorithms.

# References

Bers, M., & Resnick, M. (2014). ScratchJr [Educational programming language]. Cambridge, MA: MIT Media Lab.

Bureau of Labor Statistics. (2019, March 12). *Computer and information technology occupations.* Retrieved from https://www.bls.gov/emp/tables/emp-by-major-occupational-group.htm

Busteed, B., & Sorenson, S. (2015). *Many students lack access to computer science learning.* Gallup Education. Retrieved from https://www.gallup.com/education/243416/students- lack-access-computer-science-learning.aspx

Clements, D. H. (1999). The future of educational computing research: The case of computer programming. *Information Technology in Childhood Educational Annual*, 1, 147–179.

Clements, D. H., & Sarama, J. (2011). Early childhood mathematics intervention. *Science*, 333(6045), 968–970.

Cooper, S., Dann, W., & Pausch, R. (2000). Alice: A 3-D tool for introductory programming concepts. *Journal of Computing Sciences in Colleges*, 15, 107–116.

Cvencek, D., Meltzoff, A.N., & Greenwald, A.G. (2011). Math-gender stereotypes in elementary school children. *Child Development*, 82, 766–779.

Edwards, C. P., Knoche, L., & Kumru, A. (2001). Play patterns and gender. In J. Worrel (Ed.), *Encyclopedia of women and gender* (pp. 809–815). San Diego, CA: Academic Press.

Fessakis, G., Gouli, E., & Mavroudi, E. (2013). Problem solving by 5–6 years old kindergarten children in a computer programming environment: A case study. *Computers & Education*, 63, 87–97.

Flannery, L. P., Silverman, B., Kazakoff, E. R., Bers, M. U., Bontá, P., & Resnick, M. (2013). Designing ScratchJr: Support for early childhood learning through computer programming. In *Proceedings of the 12th International Conference on Interaction Design and Children* (pp. 1–10). New York, NY: ACM.

Madill, H., Campbell, R. G., Cullen, D. M., Armour, M. A., Einsiedel, A. A., Ciccocioppo, A. L., & Coffin, W. L. (2007). Developing career commitment in STEM-related fields: Myth vs. reality. In R. Burke & E. Elgar (Eds.), *Women and minorities in science, technology, engineering and mathematics: Upping the numbers* (pp. 210–244). Northampton, MA: Edward Elgar.

Master, A., Cheryan, S., Moscatelli, A., & Meltzoff, A. N. (2017). Programming experience promotes higher STEM motivation among first grade girls. *Journal of Experimental Child Psychology*, 160, 92–106.

Metz, S. S. (2007). Attracting the engineering of 2020 today. In R. Burke & M. Mattis (Eds.), *Women and minorities in science, technology, engineering and mathematics: Upping the numbers* (pp. 184–209). Northampton, MA: Edward Elgar.

Microsoft Education Team. (2018, December 3). *It's Computer Science Education Week, and we're here to help you make it great!* [Blog post]. Retrieved from https://educationblog.microsoft.com/en-us/2018/12/computer-science-education-week-tips-courses/

Pausch, R. (1999). *Alice* [Educational video game]. Pittsburgh, PA: Carnegie Mellon University.

Shochet, J. (2016). U.S. Patent No. 15346494. Washington, DC: U.S. Patent & Trademark Office.

Strawhacker, A., Lee, M., & Bers, M. U. (2017). Teaching tools, teachers' rules: Exploring the impact of teaching styles on young children's programming knowledge in ScratchJr. *International Journal of Technology and Design Education*, 28, 347–376.

Valian, V. (2006). Women at the top in science—and elsewhere. In S. J. Ceci and W. M. Williams (Eds.), *Why aren't more women in science?* (pp. 27–37). Washington, DC: American Psychological Association Press.

Weisberg, D. S., Ilgaz, H., Hirsh-Pasek, K., Golinkoff, R. M., Nocolopouou, A., & Dickinson, D. K. (2015). Shovels and swords: How realistic and fantastical themes affect children's word learning. *Cognitive Development*, 35, 1–14.

Werntrop, D., & Wilensky, U. (2015). The challenges of studying blocks-based programming environments. In *Proceedings of the IEEE Blocks and Beyond Workshop* (pp. 5–7). New York, NY: ACM.

# 21. Bridging Theory to Practice: Conducting Culturally Responsive Interviews With Historically Marginalized Youth in STEM

TIERA TANKSLEY

**Abstract:** The goal of this paper is to move beyond theoretical explorations of culturally responsive research to instead offer researchers concrete examples and effective strategies for designing culturally responsive instruments and protocols in STEM educational research. As a Black female researcher from a multiply marginalized background, I intentionally leverage minoritized funds of knowledge, cultural intuition, and experiential insight to offer a validated model of culturally responsive interview methods. In doing so, I propose tangible means of enacting critical theories of race, gender, and cultural responsiveness into research practice. This practice-based articulation of culturally responsive research stems from a rigorous analysis of 1 large-scale, multisite study on race, education, and STEM equity. Data from the study include protocols and subsequent revisions, sample interview questions, participant quotes, and research memos.

## Introduction

> I think it's important for [researchers] to give students this platform to speak and formalize our thoughts … make it real, make it research, put it on paper, document it. [Underrepresented students] talk about these issues in a lot of informal spaces, but then we just go back and deal with it. Nothing ever changes. (Evelyn, Black female college student)

This opening quote by a former study participant beautifully summarizes the purpose and promise of culturally responsive interview methods in studies of race, identity, and educational inequity. As a young Black woman attending a predominantly White institution (PWI), Evelyn regularly experienced interlocking systems of oppression that not only created harsh and inequitable learning experiences, but that also left her feeling overlooked, undervalued, and unheard. At the close of her interview, Evelyn shared that she was grateful to not only have a chance to share her experiences with intersectional inequality on campus, but also an opportunity to draw upon her personal, communal, and cultural knowledge to offer potential solutions to the problems she regularly experienced in college. For Evelyn, there was something powerful and transformative about being positioned as a co-constructor of knowledge rather than a subject to be studied or a problem to fix. Ultimately, her willingness to speak candidly about her uncomfortable experiences with race and racism on campus stemmed from a desire to leverage cultural knowledge and personal experience into transformative change for students like her. As she puts it, a researcher can transform her story into "something researchable, a real article, something that people are really going to read for information."

I believe that Evelyn's empowering interview experience was the product of carefully devised, critically informed research protocols that worked to make her feel safe and heard. Several leading theories note the transformative potential of centering students' voices and cultural identities in the research process, particularly when the goal is to eradicate institutional inequity. The organizing logic behind many of these culturally situated frameworks is that in order to disrupt oppressive systems that continually create inequitable learning conditions, more research methods must be developed and deployed that can uncloak the obscure ways that systematic subjugation manifests in schools and classrooms. By uplifting the cultural, communal, and personal knowledge of minoritized students, these methods work to disrupt deficit assumptions about students' lived experiences with inequity that re-create oppressive systems of silence and erasure.

Innumerable theories work to center students' voices and dismantle White supremacist power structures that pervade educational spaces, but one particular framework gaining popularity in STEM educational research is culturally responsive praxis. Culturally responsive praxis (CRP) is an epistemological standpoint that aims to create a more socially just education system by centering the voices, cultures, and lived experiences of minoritized students as indispensable sources of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992). As such, culturally responsive methods work to leverage students' personal interests, community connections, and cultural knowledge to foster more empowering reciprocal relationships between researchers and participants. It is important to note that culturally responsive research positions students as stakeholders in their education, and in doing so requires the use of research methods that can amplify students' voices, identities, and experiences with oppression in safe, meaningful, and transformative ways.

Although there is an extensive body of research on culturally responsive praxis and its theoretical underpinnings, there remains a critical dearth in practice-oriented research that provides concrete examples of data-collection instruments and protocols that can be leveraged in everyday educational research settings. Thus the goal of this paper is to move beyond theoretical explorations of culturally responsive research and its epistemological tenets to instead offer researchers practice-oriented and tested strategies to develop culturally responsive instruments and protocols.

## Conceptual Framework

By positioning minoritized youth as community experts capable of analyzing the roots of their own educational oppression, culturally responsive research collaboratively leverages both minoritized and majoritarian funds of knowledge to produce transformational change in both formal and informal learning spaces. Although culturally responsive theory explicitly requires students to collaboratively analyze systems of power and subjugation to work toward greater social justice (Gay, 2002; Ladson-Billings, 2014), this particular tenet often gets overlooked in praxis. Unfortunately, critical examinations of power and oppression in the experiences of underrepresented students are most often deployed in the theoretical and analytical phases of research, wherein researchers use critical theory to create initial research questions or construct coding schemas. In these instances, researchers are neither centering nor amplifying student voices but are rather speaking for them. It is not enough to submerge participant narratives into bodies of critical scholarship after the data-collection phase has commenced; in order to strive toward authentic social justice, researchers must collaborate with youth participants to coanalyze how race, power, and oppression shape their everyday experiences during the interviews.

While existing scholarship detailing CRP's theoretical tenets are helpful in thinking broadly about what culturally responsive research is, a question still remains about how to construct research protocols that ensure these tenets are practically enacted with student participants. How exactly do we, as culturally responsive researchers, design instruments and protocols that effectively connect theory to praxis? Despite the growing use and popularity of CRP in the field of STEM equity research, few studies have empirically investigated CRP methodologies to assess if implementation is aligned with theory, and even fewer provide concrete examples of how to design and develop protocols that bridge theory to praxis in meaningful and transformative ways. In order to ensure that culturally responsive research is indeed happening, we need more practice-oriented resources that can bridge this important theoretical framework to everyday research practices in meaningful and accessible ways. Thus, the primary goal of this paper is to move beyond theoretical explorations of culturally responsive research and its epistemological tenets to instead offer practice-oriented and empirically tested examples of culturally responsive instruments that can begin to answer this question.

## Methods

This study uses critical reflexive praxis to analyze one large-scale, qualitative research study focusing on issues of race, education, and STEM equity for minoritized students. The study, Advancing Informal STEM Learning (AISL), which received funding from the National Science Foundation, focused on youth mentorship in informal STEM learning spaces. Data analyzed in this paper include interview protocols, research team notes, field notes, and participant interviews.

## Findings

Using a grounded theory approach, I reviewed analytical memos, participant transcripts, and field notes for instances in which I was able to foster a sense of trust and safety that enabled participants to speak openly and honestly about identity and educational inequality. Broadly, strategies that explicitly disrupted oppressive power structures—both in the research and in the school context—were the most successful at fostering students' sense of trust. Thus, three subthemes for conducting critical, culturally responsive research with students of color emerged from the data: (a) establish meaningful and reciprocal relationships with the students via culturally responsive rapport building; (b) disrupt power hierarchies between researcher and participant; and (c) identify and challenge systems of power and oppression that affect students' learning experiences in STEM.

### Critical Reflections on Power and Positionality

At the onset of the AISL study, the research team employed strategies that were aimed at building relationships with students. These strategies, however, were more typical of "cultural rapport building" than culturally responsive praxis, which has an explicit commitment to disrupting systems of power and oppression. For instance, before employing CRP, we began our semistructured interviews with broad, open-ended questions that simply asked students to "tell me about yourself." The implicit assumption in this protocol design was that trust and safety could be fostered during the interview by using everyday, race-neutral conversational etiquette. We hoped that asking them to "tell us about themselves" would be an opening to share relevant background, including issues of race and identity. Moreover, when it got to tough questions about persistence and inequality in STEM, we hoped that if we asked students "are there barriers to your participation in STEM?" students would describe racial, gender, or class inequalities that they regularly experience. We learned, however, that in order for students to feel safe talking about systems of power, we had to explicitly and unapologetically challenge these invisible systems—even if it made us uncomfortable. Thus, an important revision to our interview protocol was using explicit language to talk about race, racism, and oppression in STEM. A comparison analysis between our race-neutral pilot protocol and our race-conscious culturally responsive protocol revealed that using explicit language about discrimination and racial inequality signaled to youth that it was "OK" to identify and resist hegemony.

Reviewing weekly research team memos made it clear how power and positionality play a crucial role in determining the depth of relationships we built with students and the richness of the stories they decided to share with us. Over and over again, I found that my willingness to speak candidly about my positionality—as a researcher, as a Black woman, and as a person pushed out of STEM—helped foster feelings of trust and support that enabled students to do the same. It is important that sharing my own stories of "life on the margins" disrupted power in two invaluable ways. On the one hand, it disrupted traditional power structures that exist between researcher and participants in which the interview is unidirectional and the student learns little to nothing about the person conducting the study. On the other hand, it invites students to identify and challenge systems of power that affect their learning experiences in hopes of generating transformative change.

## Strategies for Designing CRP Protocols

The goal of this paper was to offer researchers practice-oriented and tested strategies to develop culturally responsive instruments and protocols (see Tables 1, 2, and 3).

| **Strategy** | **Example** |
|---|---|
| Give more specific information about your positionality - your racial identity, why you're involved in this research. | A quote from a NSF AISL interview reads:<br><br>"I'm just going to start with like a general question, and it's going to be, tell me about yourself. I'll open up by telling you a little bit about me so that it's probably a little less awkward." |
| Build in instructions about trust and rapport building into the protocols | Instructions at the top of the interview protocol state:<br><br>"Open the interview telling the student about yourself. Then invite them to share about themselves. For the follow up questions, work to build a sense of trust and openness by providing your own answers. Tell them what you're "into" nowadays, what you do in your free time, etc." |
| Share stories about you that build trust, show shared experience and show some degree of vulnerability. | Interviewer: Mine too. Mine too. We have like, the same goal. Like, I keep saying I want to save up money so I can get a house so that my parents can live there when they retire so that they don't have to like, work until they're 90.<br><br>Student:Yeah, because my parents work really hard, and sometimes they work really hard, and sometimes I don't see them. Sometimes they're sleepy, and then they're like, not there. |

*Table 1. Establish meaningful and reciprocal relationships with the students.*

| Strategy | Example |
|---|---|
| Position the Students as Experts & Co-Constructors of Knowledge.<br><br>Explicitly describe them as "research consultants" or "content experts." | A line from a recruitment script for the NSF AISL study reads:<br><br>"We are very interested in hearing from you about what works and isn't working to keep you interested in and persisting in STEM. Instead of trying to come up with suggestions and solutions from an outside perspective, we think it makes more sense to draw upon your expert opinion. No one knows how this STEM course/program works better than you and we want to hear what you think about it" |
| Prior to starting the interview, reiterate to the student that they are being asked to give their candid perspectives and insights on your research questions because they have experiential knowledge that adults don't have. | A quote from a youth interview from the NSF AISL study reads:<br><br>"No one knows more about the experiences of youth STEM than you and your peers. That's why we want to hear from you" |
| Share interview questions prior to conducting the interview (e.g. during the recruitment process) | An excerpt from a field note from the NSF AISL study reads:<br><br>"Some examples of the questions you'll be asked are: What types of STEM activities are you interested in doing here or at home? Who supports you when it comes to doing STEM? What keeps you coming back to this program? Are there any obstacles to you participating in this program? Have you ever considered dropping out of this program? How could we change this program so that all kids - kids of color, girls, kids that speak languages other than English - can be successful? |
| Reassure your participants that the interview is a conversation that goes both ways. You are asking them to be vulnerable about their experiences, and to show them respect and appreciate you must be willing to be vulnerable as well. | A note from an interview transcript reads:<br><br>"Any question I ask you about your experience, you can ask me. I'm happy to share more about me and I think it's important that this is a conversation - not an interview - where you feel comfortable probing for more information about me. If you have any questions or want to know more about something I said, feel free to ask!" |

*Table 2. Disrupt power hierarchies between researcher and participant.*

| Strategy | Example |
|---|---|
| Part of viewing students as experts is believing that they are fully capable of theorizing answers to your research questions. Rather than asking vague, tangential interview questions and then making your own postulations about the ways identity or power inform their experience, ask the students to theorize it themselves. | Instead of asking “tell me about your experiences in STEM,” and then waiting for issues of identity and power to originally emerge in the response, be direct. Explicitly tell the student that you’re interested in knowing more about their experiences with race, identity and power.<br><br>A quote from a student interview in the AISL study reads:<br><br>"How do you think your experience in STEM is shaped by your racial identity? Do you think your race or ethnicity impacts your experience in this STEM program?” |
| Ask explicit questions about persistence, race/gender stereotypes, and cultural relevance in the program. | “Okay, so something that we’re interested in, in the study is how kids persist through things that are challenging. Like, what makes you want to push through and not want to give up?”<br><br>“You’re really impressive. I’m wondering like, have you ever heard these stereotypes about like, girls can’t do robotics and stuff, like people believe that? “ |

*Table 3. Identify and challenge systems of power and oppression that affect students’ learning experiences in STEM.*

## Conclusion

Interviews can be a powerful tool to gain insights into issues of race, identity, and educational equity in STEM through understanding the perspectives of students who regularly navigate these oppressive and exclusionary spaces. Yet interviews can prove to be an ineffective and oppressive means of collecting data when issues of power, privilege, and positionality are not explicitly addressed. Minoritized students are less likely to open up about the pedagogies, practices, and policies that hinder their experiences in STEM to someone they perceive as a community outsider. Fully aware of the risks of speaking about power and suppression, students of color are necessarily wary about sharing stories from the margins with just anyone.

## References


Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education*, 53(2), 106–116.

Ladson-Billings, G. (2014). Culturally relevant pedagogy 2.0: Aka the remix. *Harvard Educational Review*, 84(1), 74–84.

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice*, 31(2), 132–141.

# 22. Understanding Youth's Personal Connection to Data in a Gamelike Assessment System Through Learning Analytics and Qualitative Analysis

SAWAROS THANAPORNSANGSUTH, YIPU ZHENG, AND NATHAN HOLBERT

**Abstract:** In this paper, we explore middle school students' understanding of data in a gamelike assessment system called "*Beats Empire*." *Beats Empire* situates students as music studio managers. Students use their data-analysis skills to sign artists, record songs, and determine song-release strategies to win the game. We examine how gameplay can engage students in playful construction tasks that elicit computational thinking about data. To this end, we draw qualitative data from students' play-aloud interviews and log data from classroom implementation of the game. The complementarity of learning analytics and qualitative analysis leads us to better understand how students make data-oriented gameplay decisions while actively connecting data from the insight screen with their personal experiences in music when recording new songs. The study provides methodological input on how qualitative analysis and log-data learning analytics can build upon each other to explore students' behaviors in an open-ended learning environment. It showcases the importance of integrating both quantitative and qualitative data. On the one hand, learning analytics is a useful tool for capturing insights from the students' gameplay experience. On the other hand, qualitative analysis provides space for students to explain their actions and what is meaningful to them.

## Introduction

*Beats Empire* (Holbert et al., 2019) is a playful gamelike assessment system designed for middle school students that puts players in the role of a music studio manager. The design of *Beats Empire* is influenced by the constructionist design paradigm and culturally relevant learning. Students examine data about listeners' music preferences and trends, which vary by mood, genre, and geography. Using the data set, they make decisions about which artists to sign, what songs to record, and where to target their song release. Ultimately, students choose what kind of studio they want to create and define their own goals of success. All students' actions are logged and data about how players are interacting with the game are analyzed to offer useful information about students' understanding of data.

This paper takes an initial step in exploring methodological input on how qualitative analysis and log-data learning analytics can build upon each other to explore students' behaviors in open-ended learning. We aim to understand how students use data and what data means to them. Through students' log data and their play-aloud interviews, we observe how students use the game's insight screen in making meaningful gameplay decisions and strategic choices. Students used the data informed by the insight screen to connect with their prior knowledge in pop culture to make rational and personal gameplay decisions. They also create in-game artifacts that reflect upon their personal tastes in music. We find that by investigating the gameplay solely through log data, we miss an opportunity to understand the challenges and complexities faced by the students when comprehending data. This paper reports that students' lack of line graph usage may hinder them from making long-term predictions and analyses on the music trends.

## Backgrounds

Born in the mid-1990s through the late 2010s, youth today are digital natives as they are immersed in data-driven technology since birth (Hicks, 2011; Prensky, 2001). Common Sense Media (2019) reported that youth today spend more than seven hours per day on-screen. Smartphone ownership among 13-year-olds has grown from 50% in 2015 to 72% in 2019. Youth are accustomed to advanced technology but do not necessarily have the ability to interpret or understand data. Despite the saturation of technology in youth's lives, standardized curricula, methods, and resources on data science that drives the technology we interact with every day rarely exist or are absent in schools throughout the United States (Chan & Ensari, 2019; Philip, Olivares-Pasillas, & Rocha, 2016). The ability to interpret data is a form of data literacy that has become increasingly important for youth to be able to navigate the world in the digital age (Philip et al., 2016). There is a need for educating and researching how youth make sense of data.

There are several initiatives designed to develop students' computational and statistical thinking skills so that they can access and analyze data. For instance, the Mobilize project (Phillips et al., 2016) aims to teach data science concepts across a large school district. Mobilize has received high interest from schools and students; however, it has encountered challenges in its assessment methods to capture what it had hoped to cultivate (Gould et al., 2016). *Beats Empire* seeks to assess middle school students' data knowledge in a playful, gamelike environment. In our pilot play tests, we found that assessing students' data knowledge in the gamelike environment can heighten their engagement. Students see the importance of data collection because they will later use the analysis to increase their artist's followers. In a conventional assessment, it is hard to engage students with the long-term arc of a set of related constructs (Pellicone et al., 2019).

In addition, there are limited studies on understanding how students make sense of data related to their real-life experience. Previous research on data comprehension mainly focused on students' cognitive capability in graph interpretation in formal math education. For example, Curcio (1987) defined three levels of graph reading: Read with the data, read between the data, and read beyond the data. Watson and Moritz (1999) examined students' statistical thinking under the setting of different sample sizes. Friel, Curcio, and Bright (2001) defined "graph sense" and identified factors influencing graph comprehension. Díaz-Levicoy, Batanero, Arteaga, and Gea (2019) compared the performance of Chilean children when reading different types of graphs included in the school curriculum. In this study, we hope to supplement the discussion by understanding students' concepts of data in the context of their daily life experience and reasoning.

## Methodology

Thirty-five seventh graders in an urban middle school in the northeastern United States engaged in one hour of gameplay. Students ranged in age from 12 to 14 years old. All names used in this paper are pseudonyms. We collected data through automatic log files of the gameplay of all 35 students. Seven students were randomly selected to participate in pre- and postinterviews and one-on-one "play-aloud" sessions with field researchers (in which students narrated their reasoning behind choices in the game). At the end of the gameplay on the same day, the entire class participated in a focus group. For this analysis, we used the automatic log data to investigate our guiding question and to understand general patterns in how participants approached the game. Interviews and think-aloud recordings were transcribed. Time-stamped log data were exported from the back end to JSON format and then converted to comma-separated files and imported into RStudio.

The seven interviewed students were asked questions about their (a) understanding of trends and how data are used in informing real-life decisions, (b) their familiarity with line graphs, and (c) the gameplay experience. These seven are not necessarily meant to be illustrative of the entire sample but do provide an interesting set of cases. Once the interviews were transcribed, we looked closely at segments of the interview related to the students' (a) definitions of trend, (b) usage of insight screens to inform their gameplay decisions, and (c) song-title generating habits. The data were coded "bottoms-up," in which themes and coding categories emerged from patterns in the data (Miles, Huberman, & Saldaña, 1994). For example, one code categorizes students' perceptions of themselves in relation to the understanding of trends. Example phrases from the interviews included: "What's the craze," "What is popular at the moment," and "The thing that is popular."

## Findings

### Phase 1: Students' Song-Title Generating Habits

We started our analysis by taking an expansive view of the data. We looked through interview transcripts, highlighting interesting gameplay behaviors or generating questions about potential gameplay patterns. We observed that the majority of students spent a lot of time in their gameplay cycling through auto-generated titles for their new song release. They would meticulously think about the song title even though it did not lead to any in-game rewards. We were interested in verifying the prevalence of this observation across subjects and exploring the reasons behind their actions. Thus, we processed and analyzed log data to help answer the question.

To our surprise, out of 35 students, 24 students generated more than 50 song titles per song release (see Figure 1). Two students even generated more than 175 song titles! What is even more surprising is that the auto-generated song title button is the second most-clicked button in the game (see Figure 2). It was used almost as much as the "back" button! (Note that a few students initially thought that the song titles they had previously seen would cycle back around so they kept going through the list.) It is clear that the auto-generated song title feature is still crucial in the students' engagement in the game. This phenomenon led us to question why the feature was so prominent in the students' gameplay experience. We also wondered if the feature would facilitate or hinder the students from exploring other meaningful features in the game that would better cultivate students' understanding and applications of data.

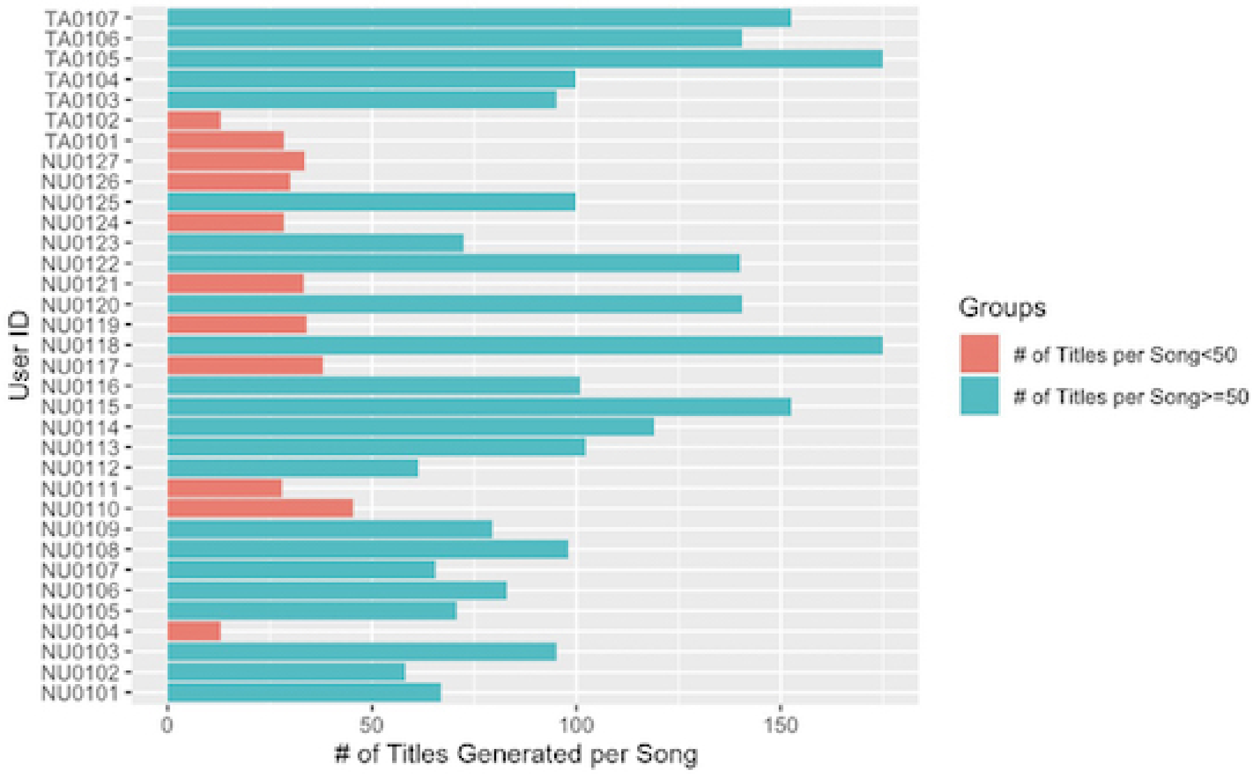


*Figure 1. Most students went through more than 50 song titles in order to record a song.*

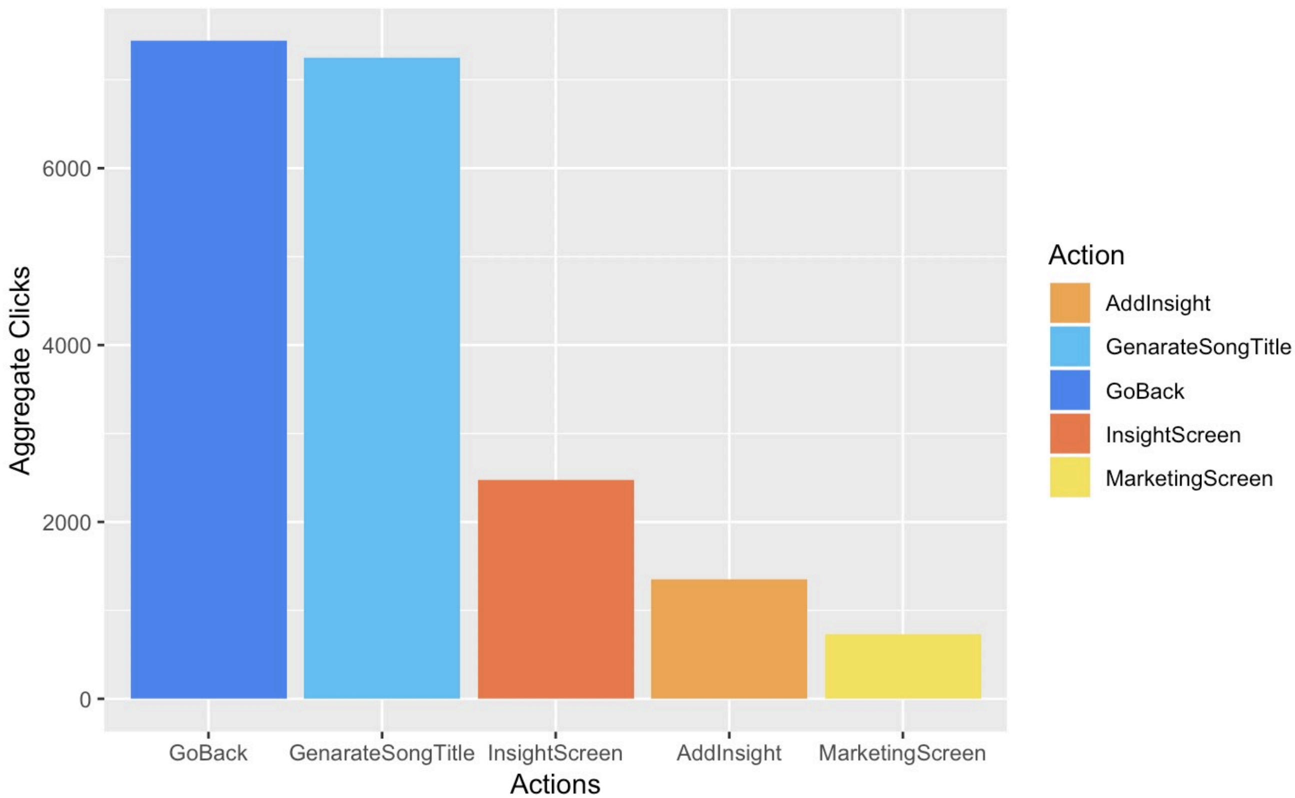


*Figure 2. Students' aggregated clicks ranked by functions. The auto-generated song title feature is ranked second in the whole gameplay.*

## Phase 2: Investigating Students' Song-Title Generation Habits Through Qualitative Analysis

In this study, we looked into how students make sense of data, which went beyond managing a music studio in the gameplay and instead focused on their broader experiences in music and pop culture. The qualitative findings in our study highlight how students not only used data from the insight screen to determine which song to release but also used their intuition and prior experiences in making choices in the gameplay.

In the second phase, we were interested in why the students spent a lot of time clicking through the auto-generated song titles when this action does not lead to any in-game reward. Out of 35 students, 24 generated more than 50 song titles per song. Note that we did not explicitly inform the students that their choices on song titles had no in-game reward. Our goal was to discover the implications behind the action as it is one of the indicators of high engagement in the gameplay. Across the play-aloud interview data, our findings suggest that students who spent a lot of time scrolling through the song titles were actually looking for song titles that were suitable for the most popular moods indicated by the bar graphs in the insight screen. In other words, an otherwise unnoticed aspect of gameplay (choosing song titles) ended up revealing a very meaningful pattern relating to students' experiences. Throughout all seven play-aloud interviews, the students used their intuition and personal experience to select the final title based on the mood. For instance, Derrick looked at the insight screen and learned that the song with a nostalgic mood was popular among his fans. He said, "I always go with the highest [bar graph]." When he was recording his song, he browsed through the song titles and chose "All-American." He reasoned that the title was nostalgic because "back in the '60s there were people who were considered all-Americans." Similarly, Alex checked his insight screen and learned that the borough of Morris enjoyed listening to the songs that signify hope. Alex spent a moment clicking through the song titles and chose "Uncrushable Joy." He said, "Because it sounds like hope." Joe commented on his song title selection habit that "I normally just pick a lot of the song titles, the one that speaks to me and that could relate to one of the topics."

## Phase 3: Investigating Students' Usage of the Data Insight Screen: Bar Graph Versus Line Graph

In the third phase of our data analysis, we were interested in how the students were using the "Insight screen" in making decisions in the gameplay. The insight screen is the data-analysis tool provided within the game to help students understand the trends within each borough so that they can release songs that satisfy their fans (see Figure 3). Students could look through the data by mood, topic, and genre. They could see the trends in bar graphs, line graphs, or with geographical locations. The students must identify and act on the data and trends that they can see forming within the data visualizations provided to them.

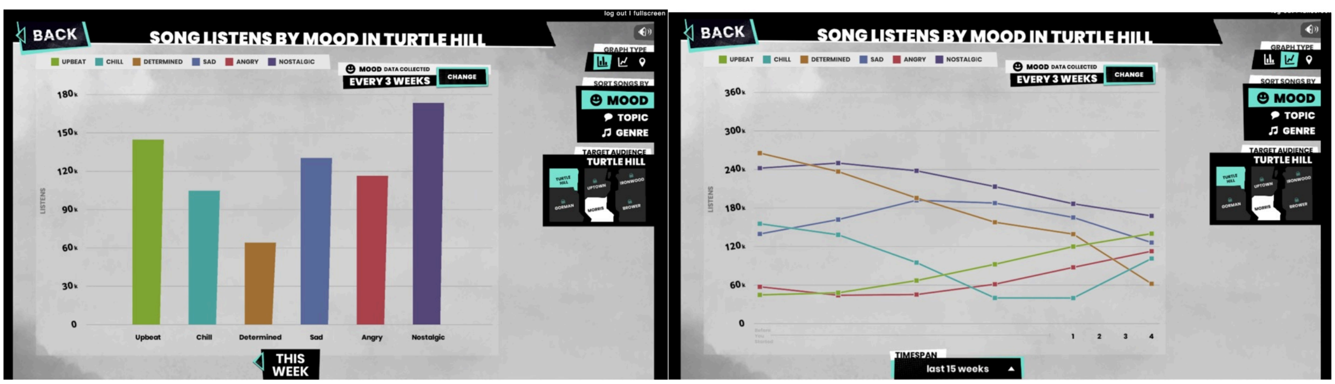


*Figure 3. The screen shots of the insight screen on Turtle Hill by mood in bar graph (left) and by mood in line graph (right).*

Through the log data, we found that students also extensively spent time on the insight screen (ranked eighth out of 233 unique gameplay interactions in total). Targeting each borough to release their songs, the students often employed the insight screen by looking at the borough's preference through mood and topic. From the log data, we saw how the students were frequently switching from sorting the data by mood and topic to make decisions of what to record. However, they rarely shifted from bar graph to line graph (see Figure 4). We found that when choosing what to record, the students identified a song to be "most popular" by using mainly the bar graph. The log data showed how students clicked onto the line graph but switched back to the bar graph throughout the gameplay. Less than half of the class self-reported that they were using the line graph during the post-gameplay focus group.

The play-aloud interviews revealed why they chose the bar graph over the line graph. For instance, Alex said that he would just use the bar graph because "it makes more sense." The bar graph provided sufficient data for the students to navigate the gameplay. It informed the students which mood, topic, or genre was the highest at the moment and that information was enough for them to excel. Moreover, we found that students may partially understand the benefits of the line graph. For example, Joe thought that line graphs offered better visualization. Sam said that the line graph gave her a better overview of the data while providing her more details on how they fluctuated: "Every week it went up and down, not just in summary." For her, the bar graph showed only a summary of the data, while the line graph showed how they increased and decreased. Students seemed to omit the key point of a line graph: analyzing data in relation to time. Using the line graph, the students could make a better long-term prediction and analysis of the music preference trends based on its past and future projections.

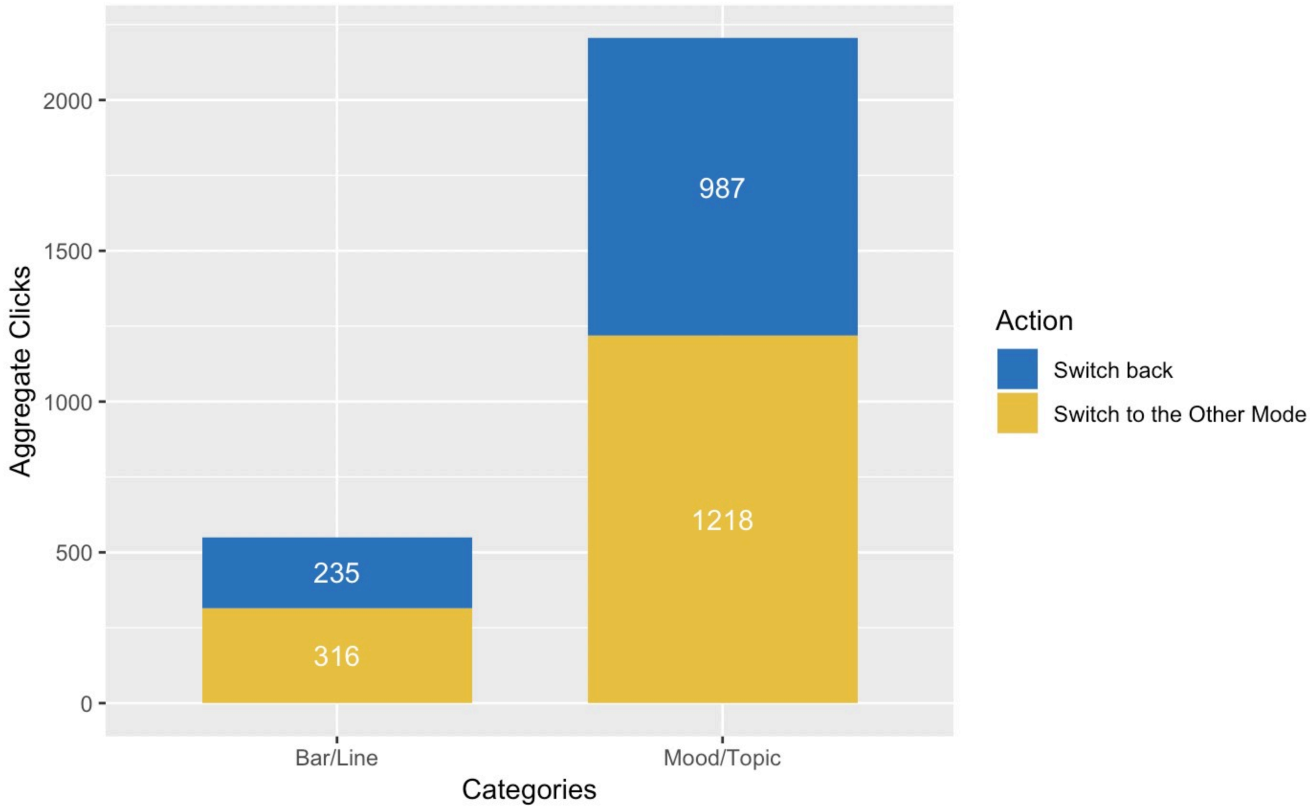


*Figure 4. Students often switched from mood and topic. They rarely switched from bar graph to line graph.*

## Phase 4: Understanding the Students' Meaning of Trends

In the third phase, we investigated the absence of line graph usage. We found that students may overlook the benefit of a line graph in tracking changes and making predictions over short and long periods. The final phase of the finding focuses on what students thought "trend" was. Our goal is to take a step back and look into students' fundamental understanding of trends. We aim to see if the students took the aspect of "time" into account.

We asked the students, "What do you think the trend means?" Six out of seven students we interviewed thought of trends as something that is currently popular. Kendrick answered, "Trend means that a lot of people do it and then it becomes that everybody else wants to do it, so it becomes a trend, and it's really popular." Alex referred to the trend as "What's the craze. What's the thing that you like right now." The students particularly situated their understanding about trends in the context of pop culture and fashion. For instance, Alex talked about trends as "top music and clothes." Eric also mentioned that trend was how a song became popular. Sam, one of the students who used the line graph, explained that trend was "a thing or video that a lot of people are viewing and sharing because they think it's funny, entertaining, or they just like it." All in all, the students were more inclined to the nonstatistical definition of trend. They thought of trends as popularity rather than a method for understanding how and why things have changed or will change through time.

## Implication and Conclusion

### Game Design Implication

The goal of *Beats Empire* is to create an environment where students' understanding could be formatively assessed in a playful environment (Holbert et al., 2019). In this paper, we investigate seven grade students' understanding of data through *Beats Empire* gameplay. We demonstrate how students make sense of data and the concept of *trend* in their daily context. Trend is a core concept in data science. Data scientists use the word to indicate the change or development in a general direction over a certain period of time. However, the students in this paper thought of trends as popularity at the current moment. The discrepancy in defining trends between the data scientists and the students allows us to reflect upon design suggestions on both assessment and learning games.

For assessment games such as *Beats Empire*, designers should consider closely when selecting the context of the game. Different contexts may significantly impact students' interpretations of certain concepts. In the case of *Beats Empire*, students' interpretation of trends may derive from *trendy*, a word that is commonly used in music or fashion. When they say "trendy," they often emphasize the fact that a lot of people know or like certain things at the current moment in such a context. However, if the assessment is situated in a different context, such as climate change, their interpretations might change accordingly. Thus, conclusions about the students' understanding should not be made without carefully examining the context of the assessment game itself.

For learning games, whose goal is to teach students about data, students' interpretation of "trendy" can be leveraged as an interesting entry point to understand the statically inclined concept of trend. In addition, designers need to pay attention to design features that help students discern "at the current moment" and "over a period of time." For example, the current design of *Beats Empire* does not intentionally push students to use the line graph, since the purpose of the game is not to instruct but to assess. However, an alternative design for a learning game (if *Beats Empire* were to be a learning game) could add a specific prompt to ask students to compare and contrast the bar graph and the line graph.

### Methods Implication

We showcase how integrating log-data learning analytics and qualitative interviews could strengthen our understanding of students' gameplay experience in ways that a single method could not. Throughout the analysis, we went back and forth between the log data and the play-aloud interviews. Combining both methods, the log data tell us "What happened?" while the interview data give us possible explanations of "How and why did it happen?" Qualitative data are useful in helping researchers relate naturally and holistically with students in the field. They also allow us to immerse in the students' interactions and matters that provide perspectives to others' ways of life (Emerson, Fretz, & Shaw, 2011). However, the proximity with students may engender subjectivity and biases when researchers analyze their data (Peshkin, 1988). Learning analytics methods fill this gap by supporting qualitative research in capturing transient actions and identifying overall trends in the sample population. Learning analytics also quantifies a qualitative phenomenon using combinations of log data attributes and verifies a qualitative phenomenon across a larger population (Berland, Baker, & Blikstein, 2014; Fields, Quirke, Amely, & Maughan, 2016; Zheng, Blikstein, & Holbert, 2020).

This paper uses the multimethod structure by taking an expansive view of qualitative data and spotted students' tendency to gravitate toward the auto-generated song titles function. Not only did the log data confirm our qualitative findings, but they also allowed us to further ask how students were using their personal experience to interpret the data in the game. This then led to another round of log data analysis in examining students' insight screen usage and possible explanations in the lack of line graph usage. Last, we pull in students' interview data to further investigate students' perceptions of trends in relation to data and time.

## References


Berland, M., Baker, R. S., & Blikstein, P. (2014). Educational data mining and learning analytics: Applications to constructionist research. *Technology, Knowledge and Learning*, *19*(1–2), 205–220.

Chan, M., & Ensari, I. (2019, September). *Using open-sourced data to nurture a civically engaged and computationally fluent generation.* Retrieved from https://cra.org/ccc/wp-content/uploads/sites/2/2019/09/Using-Data-to-Nurture.pdf

Common Sense Media. (2019, October). *The Common Sense census: Media use by tweens and teens*, 2019. Retrieved from https://www.commonsensemedia.org/research/the-common-sense-census-media-use-by-tweens-and-teens-2019

Curcio, F. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal for Research in Mathematics Education*, *18*(5), 382–393.

Díaz-Levicoy, D. A., Batanero, C., Arteaga, P., & Gea, M. M. (2019). Chilean children's reading levels of statistical graphs. *International Electronic Journal of Mathematics Education*, *14*(3), 689–700.

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (2011). *Writing ethnographic fieldnotes*. Chicago, IL: University of Chicago Press.

Fields, D. A., Quirke, L., Amely, J., & Maughan, J. (2016). Combining big data and thick data analyses for understanding youth learning trajectories in a summer coding camp. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education* (pp. 150–155). https://doi.org/10.1145/2839509.2844631

Friel, S., Curcio, F., & Bright, G. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education*, *32*(2), 124–158.

Gould, R., Machado, S., Ong, C., Johnson, T., Molyneux, J., Nolen, S., … Zanontian, L. (2016). *Teaching data science to secondary students: The Mobilize introduction to data science curriculum.* Presented at The International Association for Statistical Education (IASE) 2016 Conference, Berlin, Germany.

Hicks, S. D. (2011). Technology in today's classroom: Are you a tech-savvy teacher? *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(5), 188–191.

Holbert, N., Berland, M., Rutstein, D., Basu, S., Disalvo, E., Rochelle, J., … Kumar, V. (2019). *Designing constructionist formative assessment games.* Presented at the annual meeting of the American Educational Research (AERA) 2019, Toronto, Canada.

Miles, M., Huberman, A.,& Saldaña, J. (1994). *Qualitative data analysis: An expanded sourcebook.* Thousand Oaks, Ca: Sage.

Pellicone, A. J., Holbert, N. R., DiSalvo, B., Berland, M., Kumar, V., & Zhao, Y. (2019). Who played the game correctly? Data signatures of interaction in playful assessment. Presented at the Connected Learning Summit (CLS) 2019, Irvine, CA.

Peshkin, A. (1988). In search of subjectivity—one's own. *Educational Researcher*, *17*(7), 17–21.

Philip, T. M., Olivares-Pasillas, M. C., & Rocha, J. (2016). Becoming racially literate about data and data-literate about race: Data visualizations in the classroom as a site of racial-ideological micro-contestations. *Cognition and Instruction*, *34*(4), 361–388.

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon*, *9*(5), 1–6.

Watson, J., & Moritz, J. (1999). The beginning of statistical inference: Comparing two data sets. *Educational Studies in Mathematics*, *37*, 145–168.

Zheng, Y., Blikstein, P., & Holbert, N. (2020). *Combining learning analytics and qualitative analysis for the exploration of open-ended learning environments.* Presented at the Constructionism 2020 Conference, Dublin, Ireland.

# 23. The Effect of Virtual Stereoscopic Displays on Learning

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**Abstract:** Three-dimensional immersive visualizations may help students develop more expert ideas, as long as visualizations are properly scaffolded for learners. In this study, we examined how a dynamic virtual reality (VR) visualization influenced players' ability to understand the cellular environment and cellular processes by comparing learning from a virtual reality game on cellular biology between a stereoscopic (head-mounted display, or HMD) with a nonstereoscopic (non-HMD) alternative. Participants in both groups gained a better understanding of the cellular environment; however, participants who viewed the stereoscopic game had greater learning gains than the nonstereoscopic group. In addition to investigating the impact of VR in learning, we also explore how to scaffold educational VR games to optimize learning.

## Background

The relationship between structure, mechanism, and function is critical in understanding biology (Michael & McFarland, 2011), yet students often have a limited understanding of the connections between them. Research suggests that the realism of virtual reality (VR)-based stereoscopic visual representations may help novices develop more accurate mental models than nonstereoscopic displays (Ferdig, Blank, Kratcoski, & Clements, 2015). The increased accessibility and decreased cost of VR make VR more feasible for educational settings, and VR experiences have been developed to explore structural aspects of biology and biochemistry. However, existing studies of learning through VR show mixed results. Many studies of VR conflate the contributions of VR by varying both the viewpoint and the level of interactivity of the experience (slidedeck to interactive experience, e.g., Parong & Mayer, 2018). In order to isolate the effect of the VR-based display, we compare two similarly interactive stimuli (Gauthier & Jenkinson, 2017), varying only the viewpoint. This study is designed to focus on the effect of the stereoscopic view enabled by the head-mounted display (HMD) by having players play identical versions of a game with and without the HMD. Our research question is: "What effect does a stereoscopic view have on players' understanding of the complex cellular environment compared to a nonstereoscopic view?"

### Theory of Multimedia Learning

The theory of multimedia learning (Mayer & Fiorella, 2014) states that the brain processes text and images first separately (dual coding theory), that each channel has limited capacity (similar to cognitive load theory), and that learning is the process of bringing the information together and making sense of it. According to this theory, the goal of multimedia design is to limit extraneous processing that is not related to the learning objective, manage the essential processing, and foster generative processing (sense making). In the case of virtual reality, learners typically experience significantly higher cognitive load and learn less in comparison to those who do not use VR (Makransky, Terkildsen, & Mayer, 2019). The increased amount of sensory information in both the visual and verbal channels can cause learners to experience essential processing overload in VR compared to a less immersive counterpart (Richards & Taylor, 2015). In order to combat cognitive load, Mayer and Moreno propose a variety of solutions depending on the kind of load.

In previous studies, VR has been an overload on either or both of the visual and verbal channels. The suggested load-reducing methods are off-loading, segmenting, and pretraining (Mayer & Moreno, 2003).

## Stereoscopic Displays and Learning

Studies show that students prefer three-dimensional (3D) views of material over two-dimensional (2D) views (Ferdig et al., 2015; Huk, Steinke, & Floto, 2010; Loup-Escande, Jamet, Ragot, Erhel, & Michinov, 2017). Studies were mixed on the effects of the view of learning. Ferdig et al. (2015) found that 3D images were correlated with higher quiz scores on high school students' tests on the brain and the first anatomy unit, but not on a second anatomy unit. Huk et al. (2010) found that cues had a positive effect on students' recall and comprehension of ATP-synthase for both the 3D and 2D groups. The 3D group had a better understanding of how ATP-synthase worked in the laboratory condition, but not in the classroom setting, suggesting that distractions in the classroom setting may create additional cognitive load on the students. Loup-Escande et al. (2017) focused on stereoscopic versus nonstereoscopic views in educational virtual environments by having students play different versions of the game *VirtualKart2*. The participants who had the 3D view were more likely to complete the game successfully and experienced more immersion and flow during the game, but that there was no difference between 2D and 3D in learning outcomes.

Experience in an immersive 3D environment may also impact learners' gains from the game. In a study of the effect of nonstereoscopic 3D and stereoscopic 3D images on immediate, delayed, productive, and receptive recall of foreign language vocabulary, Kaplan-Rakwoski (2019) found no significant difference between the effect of stereoscopic 3D and nonstereoscopic 3D images on foreign language recall for both immediate and delayed test scores; however, there was a significant difference in receptive recall for learners who reported not having played a stereoscopic 3D video game before the study. The level of interaction with the material may also impact learning. Remmele, Weiers, and Martens (2015) compared the effect of 2D and stereoscopic 3D visualizations on students' understanding of the nasal cavity. Students who used the 3D visualizations were more likely to represent details in their clay-based models. When both 2D and 3D groups were asked to interact with the model by turning the virtual model, they found the 2D model also helped students understand spatial depth.  The number of studies focusing on learning outcomes is still relatively small (Loup-Escande et al., 2017); thus additional research is needed to best understand the different views.

### *Cellverse*

This study investigates an educational game designed to help students learn cellular biology called *Cellverse*. The goal of the game is to explore, diagnose, and select a therapy for a virtual cell. The diseases they investigate have a genetic component, leading players to interrogate cell processes, especially the central dogma (DNA to RNA to proteins). When players first enter the virtual cell, they are in a projection of the cell, which is a simpler environment with fewer organelles. Players are introduced to FR3ND, a nonplayer character (NPC) who accompanies the player during the game. FR3ND shows players features of the hand controllers, including how to move forward, how to select organelles, and how to call up a virtual clipboard to learn about and collect samples of the organelles, as shown in Figure 1 (left), and how to bring up a dashboard guide, as shown in Figure 1 (right). Once players complete the tutorial, they start the inquiry and are given a checklist at the bottom of the dashboard: first to look for clues, gather evidence based on those clues, and verify that evidence. In addition to traversing across the cell at microscale, players can also launch a nanobot and see a view of the process of translation from messenger RNA (mRNA) to amino acid chains through ribosomes at the rough endoplasmic reticulum (RER). As in microscale, players can look for clues and gather evidence. The evidence they gather appears in the right-hand column of the dashboard, as shown in Figure 1 (right). After players verify their evidence, they can then use the evidence to make a diagnosis of one of the five types of cystic fibrosis in the cell.

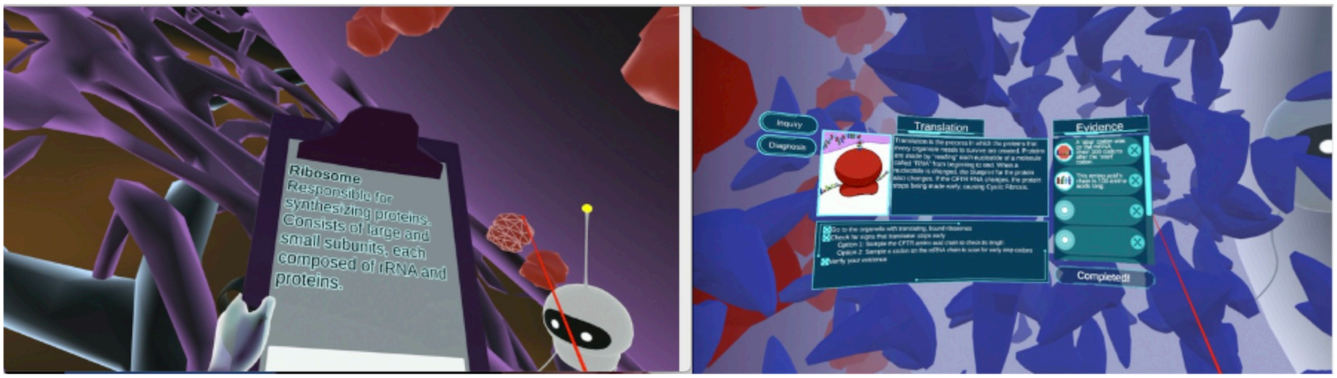


*Figure 1. The microscale view in Cellverse shows the nonplayer character FR3ND and the clipboard (on left). The nanoscale view in Cellverse shows dashboard (on right).*

Initial studies of an open-ended version of the game show that students gain more accurate overall mental models of the cell but did not improve in their understanding of size and scale or in their factual knowledge of cell organelles (Thompson et al., under review). This inquiry focuses on the role of the stereoscopic view in learning about the cellular environment.

## Method

Data collection for the study occurred between February and March of 2020. Our initial plan was to recruit 100 adult participants with varying ages and biology background (50 per group) and randomly assign them to one of the two study conditions. Because of the COVID-19 pandemic, our data collection stopped at 60 participants, and we received completed data from only 51 participants. Participants were randomly assigned to one of two versions of the 3D game: an HMD version and a non-HMD version. Participants took assessments of biology knowledge (pre- and post-gameplay) and answered demographic questions and background questions about game experience, VR experience, biology experience, and self-described interest in science (pre-gameplay only). Participants completed a delayed postassessment one week after their game session. Participants who completed all parts of the study were emailed a $20 egift card to Amazon.com. Participants also answered questions about mental workload and spatial awareness of the cell; however, those questions will be analyzed separately and will not be addressed in this paper.

### Sample

Participants were 51 adults with different nationalities including American, Chinese, Estonian, French, Indian, Israeli, Italian, Spanish, Taiwanese, Ukrainian, and Zambian. Their ages ranged from 18 to 65 years old ($M$ = 26). Participants' other demographic information, including gender, VR experience, gameplay experience, and ethnicity are shown in Table 1); 71% reported that they had VR experience only once, and 37% identified as gameplayers. Participants were from different ethnicities and mostly they identified as Asian and White.

| Gender, frequency (f), percent (%) | | VR Experience, f, (%) | |
|---|---|---|---|
| Female | 31 (61%) | Yes-many times | 7 (14%) |
| Male | 19 (37%) | Yes-only once | 36 (71%) |
| Other | 1 (2%) | No | 8 (16%) |
| **Game Player, f (%)** | | **Ethnicity, f (%)** | |
| Definitely yes | 19 (37%) | Asian | 18 (36%) |
| Probably yes | 13 (26%) | Black-African American | 4 (8%) |
| Might or might not | 8 (16%) | Hispanic-Latino | 10 (20%) |
| Probably not | 6 (12%) | White | 17 (33%) |
| Definitely not | 5 (10%) | Prefer not to answer | 2 (4%) |

*Table 1. Demographics and game and VR experience among study participants.*

## Analysis

Our research question is: "What effect does a stereoscopic view have on players' understanding of the complex cellular environment compared to a nonstereoscopic view?" We initially intended to answer that research question in two ways: through responses in the pre- and postsurveys assessing participants' knowledge of cells, and through reviewing participants' pre- and post- drawings of cells and their pre- and post- drawings of the process of translation. However, our data collection was disrupted by the pandemic. For this paper, we will focus on a comparison between participants' pre- and post- drawings of cells and their pre- and post- drawings of translation.

### Drawings of Cells With and Without HMD

Participants' drawings of cells and translation are our evidence of players' understanding of the complex cellular environment. As mentioned previously, participants were asked to draw a cell before and after gameplay, and to include and label all organelles. The presence of any of those items in the drawing received a score of 1, and scores of all items were combined for an overall drawing score.

### Number of Organelles in Post- Drawings

The total number of labeled organelles in the drawings from participants who had the stereoscopic condition ($n$ = 181) is slightly higher than the nonstereoscopic condition ($n$ = 165) in post- drawings of cells. As shown in Figure 2, cell membrane, rough ER, and lysosomes are the organelles that are most often drawn and labeled in the post- diagrams. As is clear from the bar chart, participants' total number of labeled organelles in both conditions are very similar.

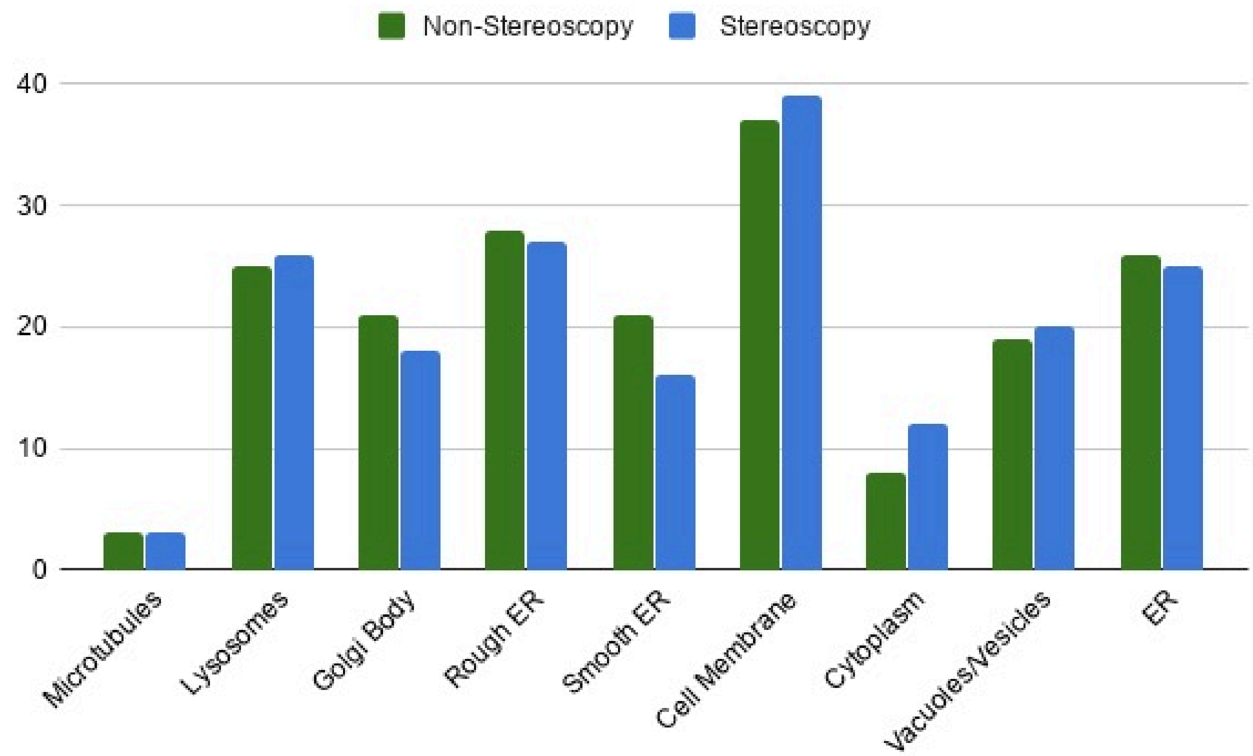


*Figure 2. Total number of organelles drawn in stereoscopic and nonstereoscopic conditions.*

We also compared the drawings before and after gameplay. As shown in Figure 3, the post- total number of labeled organelles is slightly higher than the pre- total number of labeled organelles in both the stereoscopic condition (pre- labeled organelles [MD: 5.00, CI: 4.23 ~ 6.27], post- labeled organelles [MD: 8.00, CI: 5.30 ~ 7.63]) and the nonstereoscopic condition (pre- labeled organelles [MD: 6.00, CI: 5.12 ~ 7.44], post- labeled organelles [MD: 8.00, CI: 5.10 ~ 8.10]).

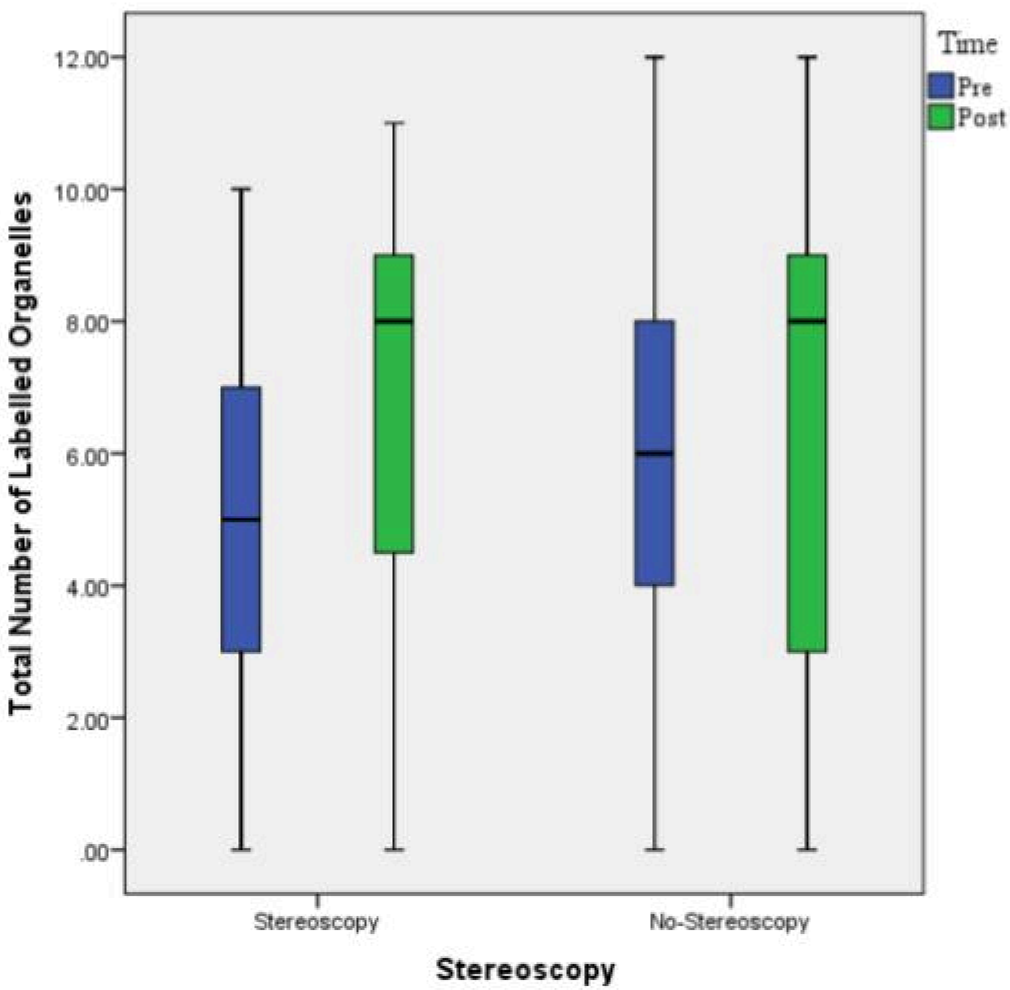


*Figure 3. Comparison of number of organelles in pre- and post- drawings between stereoscopic and nonstereoscopic views.*

## Discussion

The decreasing cost of virtual reality technology has prompted additional interest in VR as a learning tool. The stereoscopic viewpoint offered by VR HMDs is motivating to viewers and has shown promise in developing spatial awareness and understanding. This study focused on knowledge of the cellular environment as evidenced through their pre- and post- drawings of cells. Our findings suggest that the learning game provided gains for all players. We did not find any difference in learning gains between stereoscopic and nonstereoscopic displays, suggesting that knowledge of organelles and the density of the cellular environment can be gained with or without an immersive view of the material. We are also comparing the effect of stereoscopic versus nonstereoscopic viewpoints on understanding of cellular process of translation, mental workload, and spatial awareness of the cell, and we will address these analyses in separate papers.

## Contribution to the Field

Immersive visualizations afforded by VR have the potential to help learners develop better understanding of complex topics. This study focuses on the role of stereoscopic visualization in biology; however, learning how to leverage technology in support of learning has the potential to inform future curricula in biology and in other domains. As VR becomes more feasible as a learning tool, additional research will be needed to understand whether VR is effective and if so, how it is best integrated into educational experiences.

## References

*Cellverse*. Retrieved from https://education.mit.edu/project/clevr/

Ferdig, R., Blank, J., Kratcoski, A., & Clements, R. (2015). Using stereoscopy to teach complex biological concepts. *Advances in Physiology Education*, 39(3), 205–208.

Gauthier, A., & Jenkinson, J. (2017). Serious game leverages productive negativity to facilitate conceptual change in undergraduate molecular biology: A mixed-methods randomized controlled trial. *International Journal of Game-Based Learning* (IJGBL), 7(2), 20–34.

Huk, T., Steinke, M., & Floto, C. (2010). The educational value of visual cues and 3D-representational format in a computer animation under restricted and realistic conditions. *Instructional Science*, 38(5), 455–469.

Kaplan-Rakowski, R. (2019). The effect of stereoscopic three-dimensional images on vocabulary learning. *Contemporary Educational Technology*, 10(4), 324–337. doi:https://doi.org/10.30935/cet.634172

Loup-Escande, E., Jamet, E., Ragot, M., Erhel, S., & Michinov, N. (2017). Effects of stereoscopic display on learning and user experience in an educational virtual environment. *International Journal of Human-Computer Interaction*, 33(2), 115–122.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, 60, 225–236.

Mayer, R. E., & Fiorella, L. (2014). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 279–315). New York, NY: Cambridge University Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38(1), 43–52.

Michael, J., & McFarland, J. (2011). The core principles (“big ideas”) of physiology: Results of faculty surveys. *Advances in Physiology Education*, 35(4), 336–341.

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, 110(6), 785–797.

Remmele, M., Weiers, K., & Martens, A. (2015). Stereoscopic 3D’s impact on constructing spatial hands-on representations. *Computers & Education*, 85, 74–83.

Richards, D., & Taylor, M. (2015). A comparison of learning gains when using a 2D simulation tool versus a 3D virtual world: An experiment to find the right representation involving the marginal value theorem. *Computers & Education*, 86, 157–171.

Thompson, M., Uz Bilgin, C., Tutwiler, M. S., Anteneh, M., Meija, J., Wang, A., … Klopfer, E. (Under review). Isolating immersion from interactivity: Measuring the effect of the stereoscopic view on learning in immersive virtual reality.

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