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Pivoting an In-Person Multiplatform Science Program to a Virtual Program during a Pandemic: Lessons Learned

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Abstract
School closures because of natural phenomena, such as COVID-19, underscore long-standing gaps in access to science education in the United States of America, particularly for young students. When educators have to pivot to deliver virtual instruction, it is important to identify feasible remote learning strategies for science content across formal and informal learning environments. This article discusses two evaluation studies of a multiplatform science learning program was originally developed for an in-person, formal learning environment that was modified based on infrastructure, preparations, and resource availability to meet the needs of distance learning in formal and informal learning environments due to COVID-19.

Keywords: multiplatform science learning, distance learning, Next Generation Science Standards

School closures in response to the COVID-19 pandemic underscored long-standing gaps in access to science education in the United States, particularly for young students. For decades, U.S. schools serving students from disadvantaged communities have struggled with limited budgets to find resources and teachers for their science classrooms. On the National Assessment of Educational Progress in 2015, only 22% of U.S. fourth-grade students from low-income communities scored at or above proficient in science achievement (U.S. Department of Education, 2015). As schools across the country transitioned to virtual learning in response to the COVID-19 pandemic, addressing issues of access and equity in science, technology, engineering, and mathematics (STEM) education became more urgent than ever. It became important to identify feasible remote learning strategies for science content across formal and informal learning environments.

Hero Elementary, funded by the U.S. Department of Education Ready to Learn (RTL) grant, provides opportunities for early science engagement and learning across diverse student populations through multiplatform media collections. The overarching goal of Hero Elementary is "to build the science and literacy skills of diverse students ages five to eight and promote equity for historically underrepresented children in science (race-ethnic minorities, children in low-income households, children with disabilities, English learners)" (Ellington et al., 2021). It embeds Next Generation Science Standards (NGSS) learning opportunities for students in kindergarten through second grade across an animated show, digital games, non-fiction e-articles, hands-on activities, and a digital science notebook. In response to the need for distance learning during both the formal school day and informal learning time (such as after school and during the summer), the Hero Elementary developer further collaborated with researchers and educators to modify its content and delivery strategies. Specifically, Hero Elementary staff developed hands-on activity videos and activity plans for instruction with (1) whole-class, synchronous modes; (2) interactive learning for individual, asynchronous modes; and (3) hybrid modes. This paper presents two evaluation studies of Hero Elementary that analyze the wide variation in implementation of the multiplatform program across formal (Study 1) and informal (Study 2) learning environments that had pivoted to virtual instruction.

Theoretical Framework

There is a concerted effort to identify effective strategies to promote equity and access in STEM learning, including studying how the design of learning resources and pedagogical approaches can support historically underrepresented groups of students and encourage them to participate in STEM learning (Heaster-Ekholm, 2020; Lee et al., 2015; Ryoo & Calabrese Barton, 2018; Vossoughi et al., 2016). At the same time, technology resources have become more accessible, particularly among minority and low-income families (McClure et al., 2017; Rideout & Katz, 2016). Levinson and Barrod (2018) found that while hurdles still exist for low-income families (e.g., opacity of app stores, cost, technology infrastructure), these families utilize innovative approaches to integrate technology into their lives to enrich their children's experiences. Further, Lee and Barron (2015) reported that while Latinx families had the least access to technology, they still consumed educational media—via television and DVDs—and

participated in higher rates of joint media engagement than families who only spoke English.

While significant discrepancies in technology ownership exist between Latinx families and non-Hispanic families, over 60% of Latinx families have a television, computer, high-speed internet, video game player, and/or smartphone at home. Correspondingly, a growing body of literature has championed the design and use of digital resources to promote inclusion and accessibility for educational purposes (Caria et al., 2018; Cheng & Lai, 2020; Knight et al., 2013).

In the U.S., students typically participate in formal learning environments, which typically include traditional education in a classroom-based setting designed specifically to educate students. Many students also experience informal learning environments outside of formal school programming, such as before-school programs, after-school programs, clubs offered by community-based organizations, science centers at museum, and summer camps. Informal learning environments can be defined as "an array of safe, structured programs that provide children and youth ages kindergarten through high school with a range of supervised activities intentionally designed to encourage learning and development outside of the typical school day" (Little et al., 2008, p. 2).

Both formal and informal learning environments can benefit from including multiplatform educational resources. In contrast to a single medium, such as a television series or a digital game, multiplatform learning environments combine the use of multiple, related media platforms (e.g., a television series, a digital game, and hands-on materials) to address the same learning concepts, using the same characters and setting (Fisch, 2016). Well-designed multiplatform learning environments provide opportunities for students to extend their learning time and space across formal and informal learning environments while experiencing the affordances of game-like, narrative-based curricular materials, which may enhance students' motivation and engagement in the learning process (Lacasa, 2010). Research on multiplatform educational programs has found positive impacts in school and at home, including actively involving students in the narrative, creating a unified learning experience, improving the learning process by integrating students' knowledge and skills, developing 21st century skills (e.g., collaboration and critical thinking), and improving student achievement (Andreu et al., 2012; Cohen et al., 2012; McCarthy et al., 2015; Miller, 2012; Rosenfeld et al., 2019; Thai et al., 2019; Verbruggen et al., 2020).

The Impact of COVID-19 on Learning Environments

Beginning in March 2020, and continuing through the summer of 2020, the COVID-19 pandemic forced schools and informal learning environments to close their buildings and required "social distancing," or maintaining a distance of 6 feet or more from other people.

While the duration of these closures varied by U.S. geographical regions (e.g., 3 weeks to 1 year), the educational system abruptly pivoted to virtual learning out of necessity. Primary schools varied in the infrastructure that was available to

support teaching in this new environment. Science was often excluded from curricula because educators lacked the tools and capacity to teach science virtually as well as the time to synchronously teach their students. Moreover, because educators often could not provide one-on-one support to students in this virtual learning environment, adult caregivers were called upon to assist their children through school activities. However, many caregivers faced personal, technical, logistical, and financial barriers, which limited their ability to assist their students with virtual learning during the pandemic (Abuhammad, 2020). Feasible options in this emergency context where schools had to quickly implement a virtual learning experience were largely limited to pre- packaged curricula, such as video lessons and resources accessible to students asynchronously (i.e., resources that could be accessed any time; Daniel, 2020).

The Program

Multiplatform-based programs provide the opportunity to deliver early science content at a lower cost and on a flexible schedule, increasing opportunities for students to be exposed to science learning and maximizing the number of students who can benefit (Clark & Dede, 2009). Virtual environments for delivering programs also provide opportunities for personalization or flexible implementation suited to classroom needs (Kucirkova et al., 2021). Although literature has shown that multiplatform resources often produce greater learning than a single learning media, the benefits of multiplatform learning occur when related media and quality educational content are connected in meaningful and relevant ways for students (Fisch et al., 2016; Fisch et al., 2014; Piotrowski et al., 2012).

Hero Elementary is a multiplatform, equity-focused educational initiative that provides science and literacy instruction to learners in kindergarten through second grade from underserved communities. More specifically, Hero Elementary includes science content designed to meet the vision of the NGSS while supporting communication skills aligned with the Common Core standards for English Language Arts. It uses the *Transformative Transmedia Framework for Early STEM Learners* (Ellington et al., 2021) as a guide to support equity and access in science education. In addition, the design of Hero Elementary was informed by research on literacy for English learners, students with disabilities, Latinx learners, and students from low socioeconomic communities (National Academies of Sciences, Engineering, and Medicine, 2017), as well as Universal Design for Learning and computer-assisted instruction frameworks (CAST, 2011; Weng et al., 2014). Many best practices articulated in Universal Design for Learning emphasize flexible learning environments and multiple modes for learning to maximize accessibility and ensure that individual learning differences are accommodated during instruction.

Media collections referred to as “playlists” are central to the Hero Elementary design. Each playlist focuses on a given science concept and contains an animated television story in which the characters learn about the science concept; a live action, song-based video featuring the Superpowers of Science (science practices); a digital or analog game; two hands-on activities; a digital

journal for reflection and communication; and a non-fiction e-book. A noted feature of the Hero Elementary design is its openness to flexible implementation approaches. Educators are encouraged to customize Hero Elementary to suit their learning community by selecting high-interest playlists that align with their community's goals, rather than presenting the materials in a specific, predetermined sequence. Hero Elementary also provides professional development for educators to learn about the media resources, program design, and equity strategies that effectively engage young students in science learning. Table 1 summarizes the content types within Hero Elementary and their typical implementation in an in-person setting.

Table 1. Types of program content in Hero Elementary

Type of Content	Description	In-Person Implementation	In-Person Resources
Animated video	An 11-minute animated video, depicting a story in which a team of students explore core science concepts as they investigate a phenomenon using Science and Engineering Practices.	Students watch the video individually or as a whole group. This is followed with group discussion.	• 11-minute video • Co-viewing Guide to support student discourse • Content management system
Live-action music video	A 90-second live-action video based on a song that addresses one Science and Engineering Practice. The lyrics describe the practice, and the live action video shows students using the practice in an everyday scenario.	Students watch the music video individually or as a whole group.	• 90-second video • Content management system
Hands-on activity	A science investigation, facilitated by an educator. Includes scientific discourse.	Students may work as individuals, in pairs or small groups, or as a whole group. Activities include exploration and age-appropriate scientific discourse.	• Detailed activity plan • List of materials needed • (optional) "How-to" video
Digital game	A suite of digital games tied to science topics for grades kindergarten through second grade. Games are based on constructivist principles and feature core science concepts and Science and Engineering Practices.	Students play the game individually or they may share a device and play with a partner.	• Digital game • "How to play" video • Content management system
Analog game	A game that focuses on core science content, played in-	Students play the game with others.	• Detailed activity plan

	person by a group of students and facilitated by an educator.		• Game materials
Science Power Notebook	A digital science notebook tool in which students record their observations and work out their understanding about the science they are learning. Notebook pages are related to specific animated videos or hands-on activities. Directions for the Science Power Notebook pages are embedded within the hands-on activity plans or video co-viewing guides.	Students first discuss the page with a partner or in small groups. Then, they create their pages individually on a device. Finally, they share their pages with other students.	• Interactive digital notebook page • Directions for educators • Content management system
Non-fiction eBook	Informative articles in digital format, with available voiceover, that provide children with additional information about the science topic.	Students access the eBooks online and read or listen to the content.	• Digital eBook Content management system

Material Modifications Made to Hero Elementary Due to the Pandemic
Because of the COVID-19 pandemic and the shelter-in-place order, student learning transitioned from in-school instruction to distance learning. To determine the viability of implementing Hero Elementary in distance learning environments, the educational outreach team and the research team at Hero Elementary quickly reached out to educators via emails, phone calls, and online video meetings to learn how to best modify Hero Elementary to suit educators' changing teaching strategies. Educators reported that they used both synchronous and asynchronous instructional strategies during distance learning to address the varying needs of family schedules and technology accessibility. They also reported using a variety of platforms to communicate with students during closures, such as Class Dojo, Google Classroom, Google Calendar, Flipgrid, and Seesaw. Educators also created paper packets for students to pick up and provided instructional support via online platforms.

While the educational outreach team and research team gathered information directly from educators, the Hero Elementary content development team analyzed the affordances and challenges that arose when adapting content for distance-learning environments (Table 1). They drew on existing information to develop a plan for modifying content so that Hero Elementary could be flexible and support multiple distance implementation options. To provide a support system for students and their families, the modified Hero Elementary content encouraged educators to connect with individual students, either by phone or online. In addition to staying in touch with students and families, Hero Elementary encouraged educators to send home materials for hands-on activities and analog games, enabling students to have opportunities to do these activities in a similar

way as they would have in a classroom or an out-of-school program. Table 2 shows supports and modifications for implementing Hero Elementary in distance-learning environments. Resources and trainings related to Hero Elementary implementation in distance learning were made available to educators.

Table 2. Supports and modifications for distance implementation

Type of Content	Considerations for Distance Implementation	Modifications for Distance Implementation
Animated video	Students watching as a group online could discuss the content with an educator as usual. Students watching individually at home needed additional support for discussion: • Individual conversation with their educator online; • Have a whole-class discussion via Zoom; or • Support for a conversation with someone at home.	• Train educators to hold discussions with individual students who access the video asynchronously. • Home Co-viewing Guide document to support families in having conversations at home.
Live-action music video	Students could watch these short music videos individually or as a group online.	No need for additional support.
Hands-on activity (synchronous)	Students meeting as a group online could engage in a live, interactive demo and discussion with their educator, or they could watch a video demonstration of the activity as a group and discuss with their educator while online.	• Distance Implementation overview document helped educators select their approach. • Live Demo document supports educators to offer an interactive "live demonstration" of the activity in which students drive the investigation and engage in meaningful scientific discourse. Students decide how to investigate and direct the educator's action. They observe and analyze the results, and the educator facilitates discussion. If students have materials available at home, they may investigate along with the rest of the group. • Each hands-on activity was re-created in an engaging video. The video invites viewers to observe, ask questions, analyze data, and explain phenomena during

		the investigation. Educators can show the videos to students in online meetings instead of doing a live demo. They may then engage students in discussion following the video or pause the video and discuss as appropriate throughout the investigation.
Hands-on activity (asynchronous)	Students who do hands-on activities individually from home needed support for doing the activity. Educators had two options for creating opportunities for discussion among students who worked individually and asynchronously: • Educators could contact students and have one-on-one discussions. • Educators could schedule a synchronous, online discussion for their whole group.	• Distance Implementation overview document helped educators select their approach. • The home version of each activity was a modified version of the in-person, educator-facilitated activity plans, providing support for students to do the activities at home with adult oversight. These plans were written so that non- educators could follow the steps and engage in a fun family activity, incorporating meaningful science learning. Activities were written to be child-directed as much as possible. • The videos of hands-on activities were made available for students to watch at home if they were not able to do the activity themselves. • A Discussion Guide was developed for each activity to support educators in facilitating scientific discourse
Digital game	Digital games were originally designed to be played by individual students on their own devices	No modifications were developed for digital games.
Analog game	Modalities for analog games mirrored those for hands-on activities: • Students meeting as a group online could engage in a live, interactive analog game and discussion with their educator, or they could watch a video demonstration of the game as a group and discuss with their educator while online. • Students working	• Distance Implementation overview document helped educators select their approach. • Live Demo document supports educators to offer an interactive version of the game in which students drive game play and engage in meaningful scientific discourse. Students decide what to do on their turn and

	asynchronously from home needed support for playing analog games and educators needed to create opportunities for these students to discuss the analog games.	direct the educator's actions. • Each analog game was re-created in an engaging video. The video invites viewers to play along. Educators can show the videos to students in online meetings instead of doing a live demo. They may then engage students in discussion following the video or pause the video and discuss as appropriate during game play. • The home version of each analog game was a modified version of the in-person, educator-facilitated game, providing support for students to play the game at home with other family members. These plans were written so that non-educators could follow the steps and engage in a fun family game that includes science learning. Games were written to be child- directed as much as possible. • The videos of analog games were made available for students to watch at home if they were not able to play the games themselves.
Science Power Notebook	It was not feasible for students to engage in pair or small-group discussion as they would have done in person. Most students had only one digital device to use at home, and this was often a tablet or phone. Thus, engaging in a video chat while simultaneously opening their digital notebooks was not possible.	• The videos of analog games were made available to support use of the Science Power Notebook in the context of watching a video or engaging in a hands- on activity, the distance documents for hands-on activities and videos end by telling students to open their notebooks. In addition, the content management system lists the Science Power Notebook following the appropriate activities.
Non-fiction eBook	eBooks are available digitally via students' digital devices.	No modifications were developed for non- fiction eBooks.

Research Questions

The present paper includes two studies that sought to understand the virtual implementation of Hero Elementary across formal school and informal learning environments. Study 1, implemented in the spring of 2020, focused on the program's impact and implementation in a formal virtual classroom environment. Study 2, implemented in the summer of 2020, examined the program's implementation in an informal virtual environment.

Both studies addressed the following implementation research questions:

1. What were the variations in implementing the virtual Hero Elementary?

2. Which components of the virtual Hero Elementary were the most successful and/or challenging?

In addition to these questions, Study 1 examined the impact of the virtual program on students' science knowledge and engagement.

Study 1: Implementation of Modified Hero Elementary Resources in a Formal Virtual Learning Environment

Study Design and Sample

Study 1 used a multi-site cluster, randomized, experimental design that randomly assigned 34 second-grade classrooms (n = 810 students) from 20 schools in California that served economically disadvantaged students to either a treatment or control group. The treatment classrooms implemented the Hero Elementary intervention, while control classrooms implemented their business-as-usual science activities. The original study sample consisted of 810 students in 34 classrooms (17 treatment and 17 control classrooms). Although the sudden transition from in-school instruction to distance learning instruction due to COVID-19 created challenges for implementing Hero Elementary, 12 out of 17 treatment classrooms were able to continue Hero Elementary in distance learning environments. Similarly, 12 out of 17 control classrooms were able to remain in the study and provide valuable data on their remote instruction experiences and practices. To understand teachers' use of Hero Elementary and their science instruction, as well as the successes and challenges teachers faced during distance learning, we collected teacher survey and interview data.

In addition, 318 students (160 treatment students and 158 control students) completed a researcher-developed, NGSS-aligned online assessment. This assessment included 18 items that assessed second-grade students' knowledge of matter and its interactions. The reliability of the assessment is 0.70. Students completed the pre-assessment in school before school closures and completed the post-assessment at home during school closures. To ensure the integrity of the assessment scores, teachers communicated with parents about the importance of students completing the assessment independently and highlighted the expectation that parents would support students only with technical challenges. Given the circumstances of unexpectedly and rapidly transitioning to remote learning,

however, it is not surprising that students' completion of the post-assessment was low.

Analysis of the student demographic data indicated that more than three-fourths of the final analytic sample qualified for a free or reduced-price lunch program (indicating low socioeconomical status) and about 65% were Latinx. There were no statistical differences between the treatment and control groups on students' ethnicity, free or reduced-price lunch status, English learner status, or gender. Table 3 provides the demographic information for the impact sample.

Table 3. Demographic information for Study 1 sample, by condition

	Percentage of Treatment Students	Percentage of Control Students	Percentage of Total Students
Ethnicity			
Asian	14.65	19.87	17.25
Black/African American	5.10	7.69	6.39
Hispanic	68.79	60.90	64.86
White/Caucasian	8.92	5.77	4.15
Other	2.55	5.77	7.35
significance test[a]	p = .211		
Free / Reduced-Price Lunch			
No	19.44	23.58	21.50
Yes	80.56	76.42	78.50
significance test[a]	p = .413		
English learner			
No	55.06	62.66	58.86
Yes	44.94	37.34	41.14
significance test[a]	p = .173		
Gender			
Female	56.60	55.70	56.15
Male	43.40	44.30	43.85
significance test[a]	p = .910		

[a]Fisher's exact test (n = 160 for treatment group, n = 158 for control group, total n = 318)

Most teachers who participated in the study were regular classroom teachers with more than five years of teaching experiences and were responsible for providing instruction in all content areas. Two teachers were science specialists who provided only science instruction for several different classes. All teachers reported that they had no specialized science training outside of the general education classes that were required for their credentials.

Results

To study the impacts of Hero Elementary, the research team used a two-level hierarchical linear model to analyze student science content outcomes (i.e., scores on the post-assessment). This model considered the clustering nature of the data, as students were nested within teachers. The results indicated that treatment students performed better than control students on the post-assessment (the adjusted mean for the treatment group is 13.27 versus 12.76 for the control group; effect size is 0.15), although the difference was not statistically significant (Table 4).

Table 4. The effect of Hero Elementary on student science achievement

Adjusted means

Outcome measure	Treatment (standard deviation)	Control (standard deviation)	Difference (standard error)	*p*-value	Effect size	Unweighted student sample size
Post-assessment	13.27 (3.11)	12.76 (3.55)	0.51 (0.38)	.176	0.15	318

Note. Standard errors were estimated using the Huber-White procedure (Greene, 2003). Effect sizes were calculated by dividing impact estimates by the pooled standard deviation of the outcome variable.

The analysis of the treatment and control teacher interviews and surveys indicated wide variations in the virtual implementation of activities. Teachers reported that they used both synchronous and asynchronous instructional strategies during distance learning. They generally used Zoom or Google Meet to emulate in-school instruction and discussion. Most of the participating teachers scheduled one or two whole-class meetings per week. About a quarter of the teachers met with the whole class several times a day or met with small groups for discussions throughout the week. To address the varying needs of family schedules, teachers provided students with access to assignments asynchronously.

Science instruction during distance learning varied widely from none at all to daily. One teacher in the control group shared, "I can tell you now, that was non-existent, aside from the videos, because we were told we had to focus on math and language arts." Although science was de-emphasized in favor of English Language Arts and math at most sites, some control teachers tried to implement some form of science instruction at least once a week. The most common activities in control classrooms were watching a video from Mystery Science, BrainPOP, or other online sources and responding to questions during a class discussion or in writing. A few teachers

provided instructions for activities that could be done safely at home.

As all participating teachers adjusted their core course instructions to distance learning environments, treatment group teachers also modified their implementation of the Hero Elementary program to fit the distance learning environment. The treatment teachers continued to use videos and digital games throughout the implementation of the program, chose alternatives for hands-on activities, and implemented notebook and eBook activities when possible.

Video Activities

Among the playlist activities, teachers consistently found that the videos were the easiest activity to implement during distance learning, because, as one teacher explained, "all you have to do is put the YouTube video directly into the Google slide… when they put it in present mode, it just automatically plays."

Teachers reported that the videos were fun and engaging for students. One teacher pointed out, "The videos, I think, were really simple to put in because they were a highly preferred activity for the kids. They loved watching them, they enjoyed the songs, the interstitials… so that was really simple." Teachers also saw students connecting with the characters in the videos and believed this was a key factor in their students' high engagement levels. One teacher shared:

> *They, across the board, were connecting with the characters, which was really great to see… everyone was able to connect, and that's what I appreciated, that was across the board. I saw students from different genders, different ethnicities, all connecting to one character or another, or more than one character.*

Teachers also found that the videos engaged all students in a shared learning experience.

One teacher explained that the easy-to-understand storylines provided students with Individualized Education Programs and English learners "an entry point where they could actively participate in discussion about topics that they maybe didn't fully understand, but that they could connect to through the video and through the characters in the cartoon." Another teacher agreed, characterizing the episodes as "a great equalizer" that "created the most equal platform for special education, English learners, and other abilities to all come together." For these reasons, teachers found the episodes to be "one of the strongest components of the program."

Teachers appreciated that the videos established compelling, real-world contexts for the playlists' key science concepts. They found that students were able to understand the key idea in each video. Teachers also found that the videos supported students' learning by highlighting the Superpowers of Science (i.e., the scientific practices). The videos provided clear definitions and examples of the "superpowers." This was especially useful during distance learning because class discussions were challenging, and having a short, easy to understand video was an

effective way to introduce a scientific practice. One teacher explained:

> *in the distance learning I was using the videos, the little, short videos on what the superpowers were more than I was [using them] in the classroom. Just because in the classroom, I felt like I could just skip that and just go and talk to them about why this was important. Whereas, through distance learning, I was using those little videos because I didn't have the ability to explicitly state it.*

Digital Games

All treatment teachers implemented the digital games as individual activities during distance learning. Some teachers had students play the game during group meeting times to monitor them; others implemented the activities asynchronously. While some teachers reported that the games took a long time to load, most agreed that they were easy to implement. Students understood the game mechanics and could play independently, making the games well-suited to the distance learning environment.

According to teachers, students continued to find the games to be interesting, engaging, and easy to use during distance learning—just as they had while in the classroom. Students regularly chose to play the games when they had the freedom to choose an activity. Students enjoyed talking to each other about the games and would often comment on the games when they were together as a class. One teacher shared:

> *I had a lot of comments about the game. They really like it… students would say, 'You guys, it's so funny, you get to do X, Y, and Z. Got to try it out. This was my high score, what was your high score?' Different things like that.*

Hands-On Activities

Teachers identified students' lack of access to the physical hands-on activity materials as a prominent barrier to implementation during distance learning. However, many teachers found that the video of the hands-on activity was an effective alternative to the physical activity. Most teachers assigned videos of the hands-on activities for students to watch on their own; some teachers had students watch the video as a class on Zoom. They found that the explanations in the videos of the hands-on activities were thorough and easy to follow. One teacher shared:

> *I actually really thought she did a way better job than I could have done because she was really prepared and there's a script on how to tie in the concept and you know, how they talk about it. I think that was really helpful even in the future... Not that a teacher would use the video [in person], but they could watch it to see how to introduce it or what kinds of things you can say as you're talking about, talking through the experiment.*

Teachers also appreciated that the videos of the hands-on activities highlighted the Superpowers of Science. One teacher said:

> *With the distance learning, when I would send them the hands-on activity video, I love that… she always said, "We're going to use our Superpowers of Science," because I think my students, when we were implementing it in the class, I think that was when the dots were starting to connect, with each activity we do building on the next. I think that was definitely educational, those Superpowers of Science.*

When possible, some teachers demonstrated the activity live on Zoom. Some teachers sent instructions to students so that they could try the activities on their own at home if they had the materials. One enterprising teacher sent the materials to a subset of students and had them conduct the experiment live on Zoom for the rest of the class as the "professors of the classroom." Regardless of their approach to implementation, most teachers reported discussing the experiment during the whole-class Zoom meetings. Some teachers also posted questions for students to respond to asynchronously.

Overall, teachers noticed that student engagement during the distance learning setting was not as good as it had been during in-school implementation. Teachers attributed the lack of engagement to the fact that students were no longer directly interacting with materials, classmates, and their teacher:

> *I definitely think it would be more [engaging] if we were in the classroom and they were doing these experiments themselves as opposed to just watching and talking about it... I would say it was probably more [engaging] when we were in the class.*
>
> *I think when the kids see a stranger on their computer, it's less engaging than if you're like, "Oh, this is my teacher, and she's talking to me, and I haven't seen her."*

However, teachers reported high levels of engagement from several students who managed to conduct the hands-on activities at home, either individually or with parental support: "For students that got to try it on their own, it was amazing." One teacher described their students' enthusiasm:

> *I would ask, 'Oh, did anybody try out the experiments?' And we would have a little discussion, and it was so fun because they would bring in what they made or what they used, like the melting of the ice cubes and the heating and cooling. They showed a lot of cool melted things.*

Notebooks

Teachers attempted to implement the notebooks synchronously and asynchronously but encountered problems with both models. When implementing the notebooks synchronously, teachers observed that students needed significant support to navigate the platform. They noted that students had trouble fitting their work onto the digital notepad and accessing the camera and audio recording features. Students had similar issues when teachers assigned the notebook as individual, asynchronous work, and students often did not complete the activity. Teachers also

struggled to provide support for using the notebook remotely; students lost interest in the activity when they could not easily get answers to their questions.

Teachers reported that while students enjoyed using the notebooks when they were in the classroom before COVID-19, engagement dropped significantly in the distance learning environment. A key factor that contributed to lack of engagement was that many students switched from using the notebook on tablets in the classroom to using laptops at home. "The students lost their interest because it's not the same as on the tablet," explained one teacher. Another teacher added, "They can't take pictures. It was just like typing and dragging pictures."

eBooks

The majority of teachers assigned the eBooks to students as an individual activity. The rest of the teachers experimented with reading the eBooks as a class on Zoom. Some teachers read aloud, and others asked students to read aloud. Some teachers also supplemented the eBooks with their own materials. For example, one teacher asked students to record vocabulary words in science journals. Another teacher had students read independently and then created comprehension and "cite the evidence" questions for students to answer during discussion. A third teacher supplemented the text by asking students to answer questions about the eBooks' content, report something they had learned, and annotate the text.

Teachers reported that students' engagement in eBooks diminished after transitioning to distance learning. It was logistically challenging to access and navigate the eBook platform, which contributed to the low engagement levels. However, several teachers noted that the read-aloud feature of the eBooks was critical for engaging students who struggled to read, including English learners and students with Individualized Education Programs. "They were easy books for the struggling readers," one teacher explained and added, "The read-aloud feature made it accessible for English learners and struggling students." Another noted that this was especially important because, "A lot of my students struggle with reading still." Yet another teacher elaborated:

> *What I appreciated most… was that it read to them because I do have some students who would not have been able to access the text otherwise. And then I did have a few students who played with the Spanish version and were listening to that just because they wanted to. I do have some Spanish speakers, but they don't read in Spanish, not much, but it was a new feature for them. But definitely helped that it had the option [of it being] read to them.*

The distance learning context changed how teachers interacted with students to keep them engaged and motivated in science learning. Reflections from teachers indicated that they used a variety of strategies to adapt the activities to fit the sudden need for distance learning. Teachers adjusted how activities were implemented, as well as the format (synchronous versus asynchronous), attempting different methods to keep the students engaged in science learning as in-person, hands-on learning experiences were no longer an option.

Study 2: Implementation of Modified Hero Elementary Resources in an Informal Virtual Learning Environment

Study Design

This study examined how Hero Elementary was used in informal learning environments by studying six summer programs. The developers of Hero Elementary recruited organizations that implemented educational activities in informal learning environments. They also used a "train-the-trainer" model to teach the organizations to use the modified resources when implementing Hero Elementary virtually. All informal educators had access to the same training, educator resources, and technology. To help the developers improve the feasibility of implementing Hero Elementary in summer programs, the informal educators reported the successes and barriers of Hero Elementary implementation through interviews. Telemetry, or educator dashboard data, provided quantitative data on activities completed by students for each classroom.

Study Sample

The program was implemented by educators in informal environments serving English learners, students from low-income households, and Latinx populations. Two hundred and five students in 14 classrooms at six summer or after-school programs across six states participated in distance learning during the summer of 2020 (Table 5).

The informal educators ranged in their teaching experiences because in many informal learning environments, educators are not required to have a teaching license or a bachelor's degree. While some educators who taught in the summer school programs did have a teaching license and were formal educators during the school year, they co-taught with part-time staff members who were working towards college degrees. Moreover, as physical learning spaces (e.g., school buildings) were closing and shifting to virtual learning environments, many informal learning spaces were unable to retain staff, and thus the staffing was unpredictable from month to month, and the staff turn-over was high.

Table 5. Study 2 participation by program and location

Program Type	Location	Number of students	Number of playlists
Summer program	Central Minnesota	32	6
After-school	East Texas	27	12
After-school	East Texas	6	4
After-school	East Texas	20	14
After-school	South Dakota	16	6
After-school	South Dakota	7	2
After-school	South Dakota	7	3
Summer program	Northeast Ohio	9	4
Summer program	Northeast Ohio	7	2
Summer program	Northeast Ohio	7	3
After-school	Central Maryland	12	5
After-school	Central Maryland	29	2
Summer Program	Eastern Nebraska	6	9
Summer program	Eastern Nebraska	20	10

Results

Across 14 classrooms, educators implemented the program to best fit their schedules, resources, and communities. Some organizations implemented all the activities synchronously. For example, the educators played the digital games in real time as their students watched, and students participated by voicing their ideas for the next step that the teacher should take in the game. Some organizations also provided hardcopy resources (by driving and dropping off the materials at each student's residence) in response to students' lack of access to technology such as wi-fi and devices. These activity packets were supplementary resources to the program. Some organizations also allowed older students and older siblings to participate. The educators created roles for the older students so that they could support the younger students. Older siblings also provided technical support, such as logging into the program and providing digital game support.

Virtual Implementation Successes

The virtual "train-the-trainer" model of professional development highlighted flexibility and adaptation. The modified resources that were developed since the pandemic began were presented to educators as learning materials that could be modified to accommodate a broad range of students. Regarding the program

materials, an educator noted, "A lot of the materials given to us early on helped us get started... We also would look at some of the playlists and try to see how we can make it... fit our kids."

During the programs with students, educators would log onto a video conferencing platform such as Zoom at scheduled times of the week to synchronously implement the program. During this time, educators would often share their screen and focus on a particular activity (typically the hands-on activity or animated video episode). Other activities were usually reserved for asynchronous implementation, with debriefs and check-ins during the synchronous session. One educator reflected on the virtual implementation and said:

> *We show it [the episode] as a whole group over Zoom. We all watch it together. And then we have a group discussion afterwards with all the science questions, like whether it's investigating or comparing. We have those discussions afterwards. We use the guide that gives the questions.*

While on Zoom, some educators encouraged students to use the chat feature during the hands-on activity to express ideas, predictions, and encouragement. One educator explained, "We get the kids to use their chat. Kindergarten to second grade, they know how. They use the chat not so much with the cartoon [episode] part of it, but when we do the actual experiment."

Moreover, the range of different activities (videos, digital games, hands-on activities, eBooks, and a digital notebook) and multiple representations of key NGSS-aligned science concepts woven throughout each of the activities engaged students with different learning preferences and abilities. One teacher noted:

> *It was particularly great for them to have five different types of activities, each that appeared to be helpful for different students, like those who are English learners, have Individualized Education Programs, or are visual learners and kinesthetic learners, the ones that really like the hands-on activities. They can see the content in different ways, in different modalities.*

Some educators took advantage of the fact that students accessed the virtual program materials from home. Educators would ask students to collect materials from their homes during the synchronous session so students could complete part of the hands-on activity. Educators would use the "advance" and "pause" features of the recorded video to discuss and reflect on the activity with the students and have students try aspects of the activity with the materials they had at home. Students then had an opportunity to share their experience to the group: "We have to do scavenger hunts or different things to make it hands-on with the different materials. We don't know what they have at home, but we encourage them to find things that they have at home."

Another unique feature of implementing the program that was only possible in this virtual learning environment was the participation of siblings. Older siblings could

support their younger siblings in using Hero Elementary virtually, especially if their parents were not available or were unfamiliar with technology. Older siblings and friends who participated in the synchronous sessions frequently praised and encouraged younger students as they made predictions and discussed possible outcomes and results.

Educators noticed that students continued to log on and remained engaged with the virtual program. Educators reported that students were eager to engage in the activities, which allowed for successful lessons. One educator explained:

> *What's so encouraging is that these kids continue to come on Hero Elementary virtual learning to participate after being in [virtual] school continuously. They're enjoying it and they love it. That means whatever we put into them [the lessons] is productive. If not, then they wouldn't continue to return.*

Educator comments and telemetry showed that educators attempted different strategies to implement the activities (e.g., conducting a live demonstration versus sharing a video demonstration, or implementing one playlist per week versus one playlist biweekly) based on students' capacities and abilities. This meant that while students were assigned the same playlist, they worked on different playlist activities. These findings about the successes of implementing Hero Elementary in a virtual environment suggest that educators' adaptations of the resources, including accommodations and modifications, provided students with greater access to the virtual learning content.

Virtual Implementation Barriers

Many students experienced barriers to participating in the virtual learning program. Technology was the first and most significant barrier to program access, including lack of reliable internet connectivity and lack of an available device, which prevented some students from logging onto their Hero Elementary accounts. Some of the activities in the playlist, such as the digital game, require a strong internet connection, so children with weak connections could not complete these activities. Additionally, during synchronous sessions using Zoom, many students could not access Hero Elementary at the same time because their devices did not allow two browser windows to operate simultaneously. Lack of access to technology was particularly challenging in rural communities. Some caregivers lacked the necessary devices and wi-fi access, and others had the devices but had to learn how to use them. Limited experience with technology was a barrier for caregivers supporting their child's participation in the virtual learning program (e.g., caregivers had difficulties logging children into the web platform).

Additionally, there was inconsistent participation for students who lived and traveled between two households, which led to inconsistent access to internet connectivity and caregiver support. Some households also lacked parental supervision during the school hours due to work schedules. In many of these cases, older siblings would keep the younger sibling safe but would forget to log into the virtual learning platform at the designated synchronous time. Hence, given the

numerous barriers that impacted families as schools and programs suddenly switched to virtual learning, there was inconsistent attendance and completion of activities across playlists.

Furthermore, because educators were not physically present with students and the additional support at home from caregivers or siblings may have been inconsistent, it was difficult to observe or provide individual support for students in this learning environment. One educator explained:

> *You can't really know exactly what a child is thinking per se over the internet. And they're not going to ask [as many] questions. Their questions are different than say if they were there physically [together] looking at a hands-on to this activity, rather than doing it over the Zoom.*

Discussion

Study 1 and Study 2 shed light on successes, challenges, adaptations, and modifications that educators experienced as they pivoted to a virtual learning environment from an in-person environment. Findings from both studies—across both formal and informal virtual learning environments—stress the importance of using learning platforms that are flexible. Across both studies, each implementation of Hero Elementary was unique. Though all sites struggled with technology issues, whether students faced unreliable internet connectivity or lack of technology support, it was clear that both formal and informal educators were able to adapt the program to fit the needs of their students and this new learning environment. The modified documents and options provided by the developers offered an opportunity for formal and informal educators to try new methods of delivery and assess how to best meet the needs of their students. These choices ultimately allowed sites to successfully implement the virtual Hero Elementary across a full semester.

The present studies highlight the implementation of a science program in a virtual learning environment in two different learning settings, formal and informal. Students participating in Hero Elementary through their formal classrooms were led through the program by trained second-grade teachers, while students participating in informal, summer Hero Elementary programs were led by informal educators who varied in their teaching experience and use of tools and techniques. Formal teachers had support from their school administration because the entire school was switching to a virtual learning environment; this may have led to a smoother transition and more consistent implementation of the program as compared to the informal learning environment. In contrast, the informal environment may have lacked the infrastructure to pivot to distance learning, which may have caused delays and inconsistent implementation of the program. Nonetheless, informal programs were also able to implement a modified version of the distance Hero Elementary program among students who had access to technology, thus highlighting the feasibility of program implementation across both formal and informal contexts.

Conclusion

The COVID-19 school closures underlined the importance of effective distance learning strategies. Since the spring of 2020, temporary school closures in over 180 countries have kept 1.6 billion students out of school (Azevedo, 2020; World Bank, 2020). The stressors associated with the pandemic and lack of access to schools (e.g., loss of routines, social isolation, lack of technology) have challenged teachers to provide developmentally appropriate educational experiences to all students.

Practical Contributions

The present evaluation studies documented the rich, complex, lived educational experiences of children and educators who abruptly transitioned from their typical learning environments to a novel virtual learning environment. Once distance learning became a reality in the spring of 2020, schools were forced to make decisions about how much time students would spend learning online. This resulted in science and other subjects being considered as optional for distance learners at some schools. Schools with adequate resources may not have had to sacrifice certain subjects in the transition to distance learning. However, students attending schools that were not requiring all subjects to be taught during distance learning did not have the benefit of accessing a well-rounded education, which may result in educational discrepancies and delays in the future. The disruptions to student learning due to COVID-19 may have longer-term impacts on student learning, depending on the resources they had to decrease the opportunity gaps that were heightened during the pandemic.

The teacher interviews underlined the inequities that students and their families face on a regular basis. Distance learning provided a glimpse into the homes of families that did not have access to the technology necessary for their students to function as online learners. Many families lacked devices like computers, laptops, and tablets, as well as access to high-speed internet. The cost of technology was a major barrier to access for some families; families may have used older computers or students may have had to share devices with their siblings.

Teachers mentioned additional inequities in the form of insufficient adult support and guidance for young students and those with Individualized Education Programs. Many parents and guardians did not have the time to help their students or the computer literacy to navigate online activities. Some caregivers also faced language barriers when attempting to communicate with their child's teacher. Parents and guardians of students with Individualized Education Programs also may not have had the requisite pedagogical skills to assist their child when schools were not providing the appropriate support. One teacher summarized:

> *Yeah, so that is another equity issue where students with Individualized Education Programs and students from lower socio-economic backgrounds had a lot less support in general during distance learning because they didn't have their parents, they didn't have any of the pullout services, they didn't have anyone providing guidance, and so that was one of the hardest affected groups in my classroom and unfortunately probably one of the groups that had the least engagement with Hero Elementary.*

Our findings provide strong practical support for (1) equitable access to technology, such as wi-fi connection and tablets, (2) access to a flexible virtual learning program, and (3) foundational technological knowledge—for both educators and families—to provide robust educational opportunities and support for students across formal and informal learning environments.

Scientific Contributions

To provide effective virtual learning and draw upon best practices to ensure students are engaged in science and are accessing quality education, teachers, school principals, and district leadership need to acquire new technologies and instructional approaches, as well as develop creative and effective ways to connect with students (Kaden, 2020). It is imperative that Hero Elementary and programs like it can be implemented flexibly in different environments to ensure that students have continued learning opportunities despite interruptions to the typical learning environment. Hero Elementary's multiplatform design, which presented the same learning concepts in multiple related media formats, allowed students to flexibly engage in learning through whatever types of media suited their needs best. Indeed, the results from Study 1 indicated that Hero Elementary was positively associated with gains in students' science knowledge (specifically, matter and its interactions; effect size = 0.15), although differences from the control group were not statistically significant. In addition, treatment teachers reported that students were using more scientific vocabulary and making connections between the activities in Hero Elementary and their own lives. While multiplatform programs like Hero Elementary have shown initial evidence of promoting science learning in virtual learning environments, future research can continue to explore (1) the strengths in and affordance of each medium for enhancing science learning, (2) the potential impact of multiplatform programs on in-person formal and informal learning environments, and (3) the expected implementation fidelity and impact on learning in environments where all students have access to sufficient technology.

The findings of these evaluation studies contribute to research by documenting the efforts of teachers, researchers, and program developers working together to address students' needs based on schools' infrastructure, preparations, and resource availability. There are a large number of socioeconomically disadvantaged students in today's public school classrooms. Approximately 24% of schools in the U.S. are considered high-poverty—that is, having more than 75% of students eligible for free or reduced-price lunch (U.S. Department of Education, 2009-2015). To reach diverse populations of student learners, researchers have emphasized the importance of identifying and implementing best strategies when designing learning resources (Smith & Abrams, 2019; Davey & Marx, 2020; Dyjur et al., 2021). Hero Elementary provides an example of using effective design strategies and pedagogical practices to create accessible science learning experiences. The implementation of Hero Elementary in formal and informal learning environments contributes to a growing effort to support historically underrepresented groups of students to participate in science learning through multiplatform products. This research shines new light on the field's understanding of which of the available remote learning strategies are most effective—with or without the internet, web-enabled devices, and comprehensive educational support. Multiplatform learning

environments such as Hero Elementary demonstrate the potential to address student needs in distance learning.

Researchers and developers of multiplatform programs can continue to leverage play and television narratives in their designs to develop interactive experiences that are engaging and meaningful for students. Such designs should include socio-technical structures that engage users, allow for individuals' continual growth within the communities and cultures in which they are nested, and encourage active learner, child-centered, inquiry-based learning (Barab et al., 2005, Clarke & Dede, 2009).

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