# Comparison of CS Middle-School Instruction during Pre-Pandemic, Early-Pandemic and Mid-Pandemic School Years

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# **ABSTRACT**

In 2020, the world confronted an unprecedented event affecting education globally: COVID-19. Events that disrupt education are not new; Homelessness or trauma negatively impact education at an individual level, whereas war stops education completely. This event is unique in that it caused the cessation of in-person instruction for all but with a rapid transition to remote instruction.

In this study, we explore how the COVID-19 pandemic affected instruction of Scratch Encore Curriculum, a Scratch curriculum typically used in middle grades with students between 10-14 years old. We analyzed a variety of data sources, including partner classroom-level data as well as anonymous download data. We found that instruction halted abruptly in the United States at the beginning of the March lockdown, with no further instruction that spring. With the introduction of online instructional materials, instruction resumed to normal levels during the 2020-21 school year (which was remote instruction for much of the year). In addition, students completed projects with similar accuracy and completeness during remote instruction as compared with in-person instruction prior to the pandemic.

### CCS CONCEPTS

 $\bullet$  Social and professional topics  $\rightarrow$  Computer science education.

# **KEYWORDS**

Computational Science Education; K-12 education; Scratch

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#### 1 INTRODUCTION

In 2020, the world confronted an unprecedented event affecting education globally: COVID-19. Events that disrupt education are not new; Homelessness or trauma negatively impact student performance at an individual level, whereas war stops instruction completely. This highlights two separate aspects of educational disruptions: disruptions to the individual and disruptions to the education system.

The COVID-19 pandemic saw both types of disruptions; it caused the cessation of in-person instruction for all but with a rapid transition to remote instruction while at the same time affecting learners emotionally. The rapid switch to virtual instruction potentially greatly affected teachers' ability to provide high-quality computing instruction. First, this was a time burden, requiring them to rapidly change how they delivered instruction in all subjects, and potentially making them prioritize which subjects to focus on and which to drop. Second, this changed the modality available to them (virtual only), reducing and/or changing their curricular choices. In addition, job losses, deaths, fear of death, protests, and fear of police brutality affected students individually. Learners experiencing long-term trauma (releasing stress chemicals in the brain for extended periods of time [38]) have trouble paying attention and committing information to memory [50].

This study explores the pandemic's effect on both aspects - class-room instruction and student performance - on middle grades class-rooms (10-14 years old, spanning late primary and early secondary school). Using a combination of a natural experiment and design-based research methods, we draw from a variety of sources to compare instruction and student performance across three years: 2018-19 (Pre-pandemic, the full school year before the pandemic began), 2019-20 (early-pandemic, the school year during which the pandemic began), and 2020-21 (mid-pandemic, the school year for which teachers had time to prepare for virtual instruction but also contended with moving back into the classroom).[12] We explore the following research questions:

- RQ1: How did the pandemic affect instruction?
  - RQ1a: How much instruction occurred during the rapid transition to virtual instruction?

- RQ1b: How much instruction occurred during the mid-pandemic year of planned virtual instruction and return to in-person instruction?
- RQ2: How did the pandemic and virtual instruction affect student performance?

### Our major findings are:

- Virtually no instruction occurred during the spring during the rapid transition to virtual instruction
- Students received about half of the normal instruction in the early pandemic year (2019-20)
- Instruction returned to normal amounts during the mid-pandemic planned virtual instruction and hybrid instruction (2020-21)
- Student performance was equivalent during pre-pandemic (2018-19) and mid-pandemic (2020-21) years

### 2 THEORETICAL FRAMEWORK

This paper explores questions of the impact that the COVID-19 pandemic had on instruction and student performance. While these two questions are related, they are very distinct.

The first research question is related to instruction. The CAPE framework provides a framework for considering different equity issues that function as barriers to high-quality CS instruction [15]. The first level is *Capacity*, which includes human and financial resources such as qualified instructors, equipment, and space to offer courses. The next level is *Access*, which involves barriers allowing some students to take courses but not others (such as transportation, knowledge about opportunities, or time commitments) [22]. Next is *Participation*, or whether students participate in available instruction [19, 28]. Finally, the last one considers the *Experience* or outcomes, such as whether different groups excel at the same rate [45].

Once instruction is available to students, we must consider how the pandemic affected their capacity for learning. Maslow's Hierarchy of Needs theorized a set of "deficiency" needs (e.g. food, safety, well-being) that must be present before people are motivated by "growth" needs [30]. In later years, Maslow adjusted the interpretation of the hierarchy to be more flexible, meaning that lower needs need not be 100% satisfied before higher ones, nor is the order set in stone [31]. Regardless of the specifics of exactly how each element contributes to a person's motivation, this idea implied that there are basic needs unrelated to education that heavily influence a learner's ability to learn in an educational setting. This has greatly impacted educational design, one relevant example being traumainformed instruction [7]. Trauma-informed instruction recognizes that learners experiencing trauma (releasing stress chemicals in the brain for extended periods of time [38]) have trouble paying attention and committing information to memory [50]. Such students are more likely to be categorized as "unruly", miss school, and diagnosed with learning disabilities [5]. Given the stress involved in the pandemic, including job losses, increased death rates, and protests responding to police brutality and racial injustice, a higher percentage of students could be experiencing these symptoms.

# 3 RELATED WORK: LEARNING AND TEACHING DURING THE COVID-19 PANDEMIC

In this section, we focus on published work about learning and teaching during the COVID-19 pandemic. We begin with the learning perspective. Early research on learning in a pandemic shows unsurprising results. Students face challenges such as unstable and/or distracting living situations [6, 21], mental health problems [1, 6, 21, 33], a lack of access to technology and resources [6, 16, 21, 35], and financial instability [1]. In response to their many stressors, students had to adjust their habits to learn during the pandemic [9].

Similar results have been found in CS education-specific research. Research on CS education in the pandemic ranges from formal to informal [8, 17, 27] and covers primary [27] to post-secondary students [2, 26, 41]. Surprisingly, one study found that their postsecondary CS students experienced lower stress and found their studies to be less challenging than before [26], perhaps in part due to educators' adjustments due to societal instability. However, the majority of the research contradicts those findings. Financial [47], mental health [47], identity [34], and interpersonal [26] problems also affected CS students. In a larger study on students' interactions in a CS eBook before and during the pandemic, YeckehZaare et al. found that students spent a shorter amount of time and had fewer interactions in the eBook during the pandemic than they did before the pandemic [51]. In their report on Teacher Perspectives on COVID-19's Impact on K-12 Computer Science Instruction, Martin et al. found that "54% of teachers at high-URM schools indicated distance learning is a major challenge (vs. 38% in low-URM schools)" suggesting that the pandemic exacerbated existing disparities.[29]

On the positive side, studies showed that CS students also felt support during the pandemic from faculty members and peers [47], and some students liked their more flexible schedule and reduced commute time [40]. Researchers also found promising results about virtual collaboration and socialization [17, 23, 27, 36], virtual (research experiences for undergraduates [post-secondary students]) REU programs [2, 41], and informal programs, such as hackathons [17] and primary and secondary camps [8, 27, 32]. Researchers even found promising results after implementing a CS1 MOOC; the students' completion rate was over 10 times that of similar MOOCs [39]. Some post-secondary instructors sought to rethink how they should evaluate students' CS knowledge [25, 42], which was met with mixed results.

Early on in the pandemic, primary and secondary CS educators and researchers made valiant efforts to shift from in-person to virtual and hybrid learning [8, 27, 32]. Researchers continued to work and support teachers and meet their needs [37]. This includes the implementation of many virtual professional development programs [3, 20, 46, 48], all of which showed promising results for reaching and training teachers in local and broader contexts. Surveys show that CS educators felt varying levels of comfort and support while shifting to online learning [10, 18], with one study showing higher levels of confidence from primary and secondary educators than post-secondary educators [10]. Educators also varied in how much they had to adjust their materials to shift to teaching online [11, 18].

Overall, the education and CS education communities have found varying results in terms of students' and educators' experiences with learning and teaching in a pandemic. An initial study on post-secondary students' CS activity suggests that students were negatively impacted by the pandemic [51]. In our work, we conduct a similar analysis with primary and secondary teachers and students, focusing on their activity before the pandemic, during the early stage of the pandemic, and partway through the pandemic.

# 4 METHODS

The methods of this paper are a hybrid of natural experiment and Design-Based Research.

A natural experiment is the study of the effects of naturally-occurring events [12], often because creating a controlled study would be either impossible or unethical. In such studies, conclusions are made based on available data gathered from a variety of sources. The goal is to identify comparison groups that are as similar as possible to a randomized-controlled trial. In alignment with this method, we have studied the effects of the pandemic, not in a controlled study, but by analyzing various data sources that existed for other purposes.

Unlike natural experiment, however, we are not merely observers. Like Design-Based Research, as a result of the educational needs, we evolved our resources to better support teachers and learners [4]. Design-based research is "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" [14]. In particular, when transitioning our materials online for use during the pandemic, we did not copy our materials exactly. Instead, we used student performance in previous years as well as considered the affordances that Google Forms provide in order to make some modifications to some questions on worksheets. For example: we observed that in the physical version of the create worksheets for the Events module, when instructed to circle the events to which each sprite would respond students would sometimes forget to circle any of the presented options, by contrast, in the Google form version the events are presented with tick boxes which make it more explicit to students that they are expected to select at least one event. Our goal is, despite the changes that occurred between successive groups, to identify research-based findings that are relevant beyond our specific project.

We now describe the instructional environment (curriculum and circumstances), data sources, and analysis methods used in this study.

#### 4.1 Scratch Encore Curriculum

This study is specifically about instruction that occurred within a particular Scratch curriculum. The Scratch Encore Curriculum is an introductory coding curriculum for students in middle grades (ages 10-14). The curriculum is separated into modules (units) based upon the main CS Concept addressed in the module (e.g. Events, Animation, Conditional Loops). A total of 15 modules are included in the curriculum, with each module taking 3-5 lessons to complete. Each module uses the Use→Modify→Create scaffold to gradually

release tasks to students, creating agency [24]. The CS Concept is introduced using an Engage activity that connects to the students' lives. Students *Use* a pre-created Scratch project using the TIPP&SEE strategy to observe the concept from a user perspective (e.g. rabbit hops across the stage) and explore the code for the corresponding actions from a programming perspective (e.g. animation: using repeat loop with a change costume, wait and move block) [44]. Students then *Modify* the same project to practice coding and increase their understanding of the CS concept (e.g. adding animation to a different sprite). Finally, students *Create* an open-ended project that includes requirements for coding the focal CS Concept (e.g. Creating a project that includes animating one or more sprites).

The worksheets, including TIPP&SEE scaffolds, student checklists and Create planning guides, were originally available as printed worksheets or Google Docs. As a result of the pandemic, we added the option of Google Forms. The Google Forms versions were not identical to the worksheets. Changes were made both based on formatting constraints in Google Forms as well as wording changes for questions that had low rates of accuracy in previous years. In addition, we created introductory videos for every computer science concept.

# 4.2 Period of Study

We included three years for comparison in this study. Here, we describe both the general instructional environment in the United States for that year, as well as the state of our curriculum used in partner classrooms. Because vaccine timelines were very different depending on the country, we are focusing our text on the circumstances in the United States.

Pre-Pandemic (2018-19). Year 1 represents business as usual, prior to any major global disruptions caused by the pandemic. In partner classrooms, the Scratch Encore Curriculum was taught in-person. Most teachers used paper copies of all worksheets, and teachers and students were both present in the classroom during coding projects. However, a few teachers had their students use Google Docs versions of worksheets in the classroom.

Early-Pandemic (2019-20). In year 2, until mid-March 2020, the educational environment was similar to Year 1. The exact date that instruction went virtual differed slightly by district. On March 13, 2020, all in-person instruction halted for our partner district, and teachers switched to remote teaching using Google Meet and Google Classroom. Some technology teachers were converted into technology assistants to help in multi-subject classrooms. No changes were made to Scratch Encore Curriculum during this year, so virtual instruction could use Google Docs coupled with the Scratch programming environment.

Mid-Pandemic (2020-21). In year 3, many districts began the year with remote learning, including our partner district. Vaccines became available in December 2020, and K-12 educators became eligible in January - March, depending on their state of residence. This heralded a movement to return to in-person instruction. In our partner district, students returned in March. Some students returned to in-person instruction 2 days a week (remote 3 days), some 4 days a week (remote 1 day), and some students remained remote for the rest of the school year. As a DBR project, we responded to the data

showing the massive drop in teaching during the spring of the early pandemic year by adapting the Scratch Encore Curriculum to meet the needs of virtual teaching by including Google Forms, Google Slide, and student-facing videos. In order to prevent "Zoom fatigue" with virtual learning, our partner district limited synchronous instruction, dividing the school day into periods of synchronous and asynchronous work. Some partner teachers used the synchronous meeting times to introduce and engage students in the CS concepts and explain project tasks, while having students complete projects asynchronously. Other teachers used synchronous meet times as above and provided synchronous times for students to work on their projects.

# 4.3 Data Collection and Analysis

Our goal is to compare three years of computer science instruction. We collected data from three distinct sources:

- Classroom data: provided to us by teachers from our partner district enrolled in two to three years of our research studies.
- (2) Scratch Encore Curriculum teacher registrations: collected by us anytime a teacher requests access to the Scratch Encore Curriculum material.
- (3) Web scraped data: gathered from Scratch.mit.edu.

When a disparity is observed, we calculate a disparity index, which can be generally applied to any metric [49].

4.3.1 Classroom Data. Teachers included in this IRB-approved study are a subset of teachers involved in recurring multi-year studies with the large, metropolitan partner district. In order to provide more accurate comparisons between years, the five teachers included in this paper participated in more than one year of the study. They completed a professional development workshop which helped them experience and learn to teach the Scratch Encore Curriculum to students in middle grades (ages 10 - 14). Three years of Scratch projects from the five teachers' classrooms (approximately 557 students) were analyzed. Tables 1 and 2 below provide detailed information about the three different years of the study and teacher demographic information.

Classroom data was used for two purposes. First, it was used to determine how many modules each teacher had completed each year. This was determined by counting how many sets of worksheets and Scratch studios were submitted for each teacher. Second, it was used to determine student performance. For each Scratch Encore Curriculum Modify and Create task, there is a set of requirements (Modify tasks have more specific requirements than Create tasks). For example, if a project requires a student to make and animate sprite movement (where animation is defined as some repeated, timed movement), the autograder would parse the code and search for "move" and "wait" blocks nested within a "repeat" block. We ran all of the students' Scratch projects through an automated assessment tool, (henceforth called the "autograder"), which parses the code to analyze how many of the project requirements of each project were completed.

4.3.2 Scratch Encore Curriculum Teacher Registrations. Before an instructor is able to access the lesson plans and other class materials that make up the Scratch Encore Curriculum, they must first fill out a simple registration form that collects basic demographic

information such as email addresses, teaching position, student grade level(s), educational setting (private school, public school, or out-of-school activity), and location.

For this study, we first filtered out registrations from people who indicated they were not teachers (mainly researchers and grad students) and any duplicates. We then used the email address provided to distinguish between teachers from our partner district and other teachers, categorizing them separately. We then sorted by timestamp and counted the number of registrations that occurred in each month in each category (partner district vs. global).

4.3.3 Web Scraped Data. Given the constructivist nature of the Scratch Encore Curriculum, a key aspect of all instructional modules involves providing students with a semi-complete starter project that they then modify based on what they learned in that module. Furthermore, in order for students to make use of our autograder the project must be shared publicly which makes it so that completion of modules in the Scratch Encore Curriculum tends to have the side effect of generating a publicly available record. Taking advantage of this, we downloaded the metadata for every single Modify and Create project that was 'remixed' from the Scratch Encore Curriculum account and then shared publicly. 'Remixing' is the method in Scratch that supports a teacher providing a starting project and having students modify it as their own. A total of 26,826 projects were found by our web scraper, of which 26,009 were created between August 2018 and July 2021.

Our web scraper captured all project derivatives from our starting projects; That is, it captures not only remixes of our projects, but also the remixes of those remixes. This recursive traversal is to include projects when teachers remixed our projects before distributing to their students.

All scraped projects were then sorted by time-stamps and grouped into days and weeks. We counted the number of projects remixed each day and summed those into the number of projects remixed each week.

We must emphasize that we made no attempt to de-anonymize the users and as such make no claims as to the specific demographics of the authors of the remixed the projects, nevertheless, given the nature of the projects coupled with the fact that dips in activity that correlate to weekends, holiday breaks and testing periods are clearly visible, it seems reasonable to the authors to assume the majority of remixed projects belonged to students completing the Scratch Encore Curriculum.

# 5 RESULTS

We first explore how much instruction occurred, inspecting project activity levels, teacher registrations, and modules covered by partner teachers. We then turn to individual student performance, analyzing student projects for completion rates.

# 5.1 Scratch Encore Curriculum Instruction occurring

We begin by presenting the Scratch Encore Curriculum project activity levels. There are two sources of data for this analysis.

First, Figure 1 represents every Scratch project that was remixed from the Scratch Encore Curriculum account and then publicly shared from August 2018 to July 2021. Each remixed Scratch project

Year	# Teachers	# Classes	Grade Level(s)	# Students	# Projects
1: Pre-pandemic (2018-19)	4	8	5,6,7,8	208	2150
2: Early-Pandemic (2019-20)	5	7	5,6,7	202	719
3: Mid-Pandemic (2020-21)	4	9	5,6,7,8	147	2488

Table 1: Study Year Breakdown

Teacher	Subject(s)	Grade	Age	Years in	Asian	Black	Hispanic	White	Other	Low
	Taught	Level(s)	Range	Study						Income
A	Tech	5	10-11	PP,EP,MP	1.9%	2.7%	84.5%	7.3%	3.6%	84%
В	Tech	5,6	10-12	PP,EP,MP	0%	88.9%	5.6%	2.5%	3%	37%
С	Science	6,7,8	11-14	PP,EP,MP	76.1%	1.2%	16.3%	5.2%	<2%	83%
D	Sci/Tech	7	12-13	PP,EP	0%	5.8%	92.3%	0.6%	1.4%	83%
Е	Library/Technology	7,8	12-14	EP,MP	9.7%	1.2%	45.8%	37.5%	6%	51%

**Table 2: Teacher Data & Student Demographics** 

corresponds to the number of students completing a single coding exercise within the curriculum. The red bars represent the number of daily remixes, whereas the black lines represent a sevenday rolling average. Over 25,000 individual projects were counted, which allows us to present an extremely granular view of the extent to which instruction was taking place on any given day: weekends, holidays and U.S. standardized testing periods (Spring) can be inferred from the activity taking place.

Second, Figure 2 shows the total number of instructional modules completed by teachers who were enrolled in our study in two or three of the early pandemic (2019-20), pre-pandemic year (2018-19), and the mid-pandemic (2020-21) school years. These teachers shared their students' completed worksheets and Scratch projects with our team. This gives an idea of how much instruction occurred within each classroom and allows us to compare each year's level of learning activity.

# Finding 1: Instruction stopped immediately following the federal government's declaration of a national lockdown, and remained virtually nonexistent for the rest of spring.

The level of detail of the *web scraped data* presented in Figure 1 allows us to depict the abruptness of the transition students and teachers made from conventional schooling to emergency learning. The plot for the 2019-20 school year shows a similar pattern of activity as compared with 2018-19 until March. Then, as different geographical areas began shutting down school districts, there is a rapid decline in usage, culminating in the U.S. Government's March 16th announcement of a national lockdown.

For the rest of the spring, there is virtually no activity, with just a smattering of remixes throughout the remainder of the school year. This indicates either that teachers were not given the time to prepare for remote instruction or that the materials were not conducive to remote instruction. At any rate, instruction remained largely absent for the rest of spring.

# Finding 2: Teachers covered, on average, 45% of the material in 2019-20 compared with the previous year.

Teachers from our *partner district* covered fewer modules in 2019-20 compared with the previous year. Teachers are considered

"covering" a module if we have access to the Scratch studio for the Modify and Create projects for that module. Figure 2 shows that of the 8 pre-pandemic classrooms in our study who began the curriculum in 2018 (top graph), all of them covered Modules 1-5, and 5 of them covered Module 6. In 2019 (middle graph), in contrast, only 4 out of the 7 classrooms completed at least 3 modules. Thus, it is likely that the abrupt cessation of in-person learning resulted in a loss of learning during that school year. Teachers covered an average of 2.4 modules each in 2019-20 compared with 5.3 the previous year, for a disparity index of 0.45. In addition, this figure does not include classrooms that planned to begin instruction after March 13th; those students received no instruction at all.

Beyond our partner classrooms, according to Figure 1, there were only 5,186 projects remixed in the early-pandemic year, compared with 11,502 projects in the pre-pandemic year. This results in a disparity index of 0.45. The same trend held for partner classrooms, with a total of 719 projects completed in the early-pandemic year compared with 2150 in the pre-pandemic year. This results in the following disparity index:

$$DI_{\text{early-pandemic projects}} = \frac{719}{2150} = 0.3344$$

# Finding 3: Instruction rebounded to pre-pandemic levels during the mid-pandemic year.

While remote learning in 2019-20 resulted in reduced instruction, by contrast, instruction levels rebounded strongly during remote instruction in the mid-pandemic year. In particular, the first quarter of the 2020-21 school year shows noticeably more projects being remixed than during either of the preceding years (Figure 1). In total, 11,718 projects were remixed in the mid-pandemic year, which is more than pre-pandemic (11,502) and early-pandemic (5,186) years. The level of activity then remains steady for the remainder of the year, with less dramatic peaks and valleys than in the pre-pandemic year (perhaps due to the cancellation of some standardized tests that year).

Finding 4: Teachers covered an equivalent amount of Scratch Encore Curriculum modules with online instruction as they had in person.

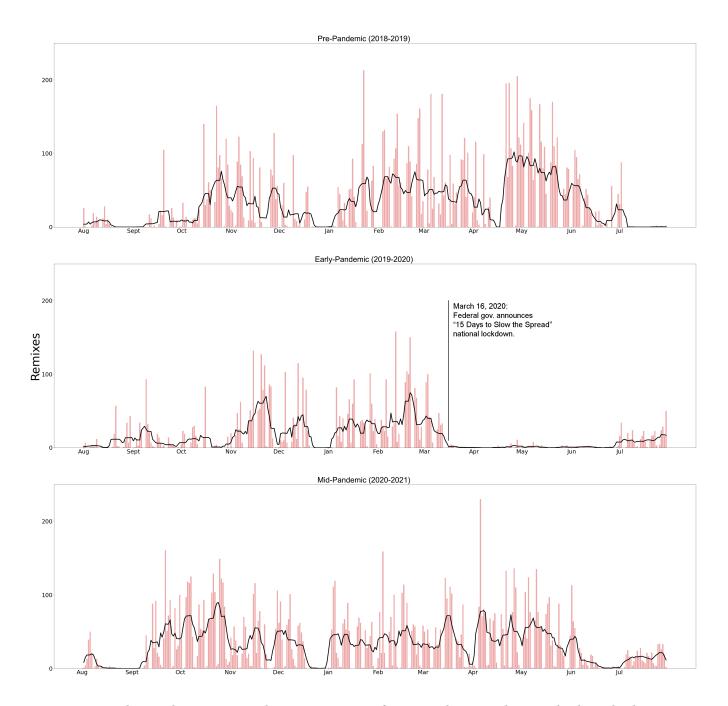


Figure 1: Daily Scratch Encore Curriculum Project Remixes for pre-pandemic, pandemic, and online school years.

Data from partner classrooms bolster the claim that similar levels of instruction occurred mid-pandemic (2020-21). In 2018-19, all 8 classrooms completed either 4 or 5 modules (3 classrooms completed 4, and 5 classrooms completed 5). In 2020-21, all classrooms who started in Module 1 also completed 4 or 5 modules (3 classrooms completed 4, and 2 classrooms completed 5). In addition, more projects were completed by students in partner classrooms

during the mid-pandemic year than the early-pandemic year:

$$DI_{\text{mid-pandemic projects}} = \frac{2488}{2150} = 1.1572$$

We conducted a Mann-Whitney U test to determine if there was a difference in the number of modules completed by the classes in the pre-pandemic and mid-pandemic years. The difference was not statistically significant (U = 53.5, p = 0.072).

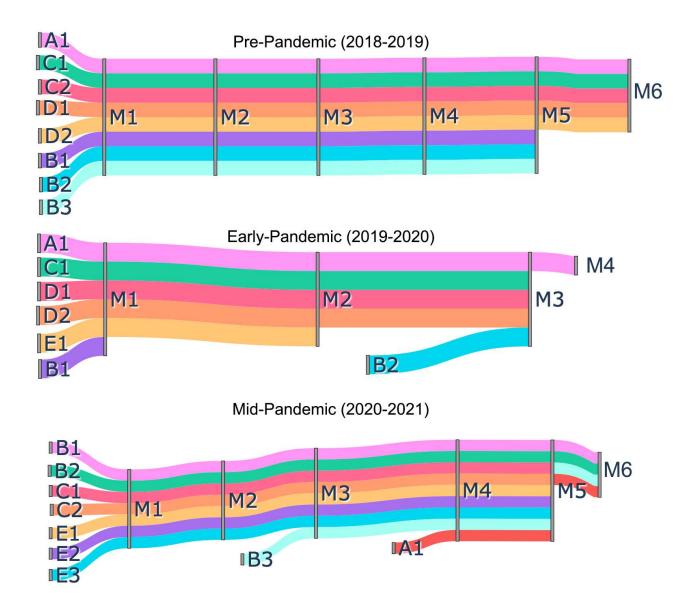


Figure 2: Scratch Encore Curriculum Modules Completed By Teachers In Partner District

# Finding 5: There was a surge in new teacher Scratch Encore Curriculum registrations for remote materials.

Figure 3 shows the number of new teachers registering to receive access to the Scratch Encore Curriculum on any given month. The brighter colors at the bottom of each bar depict instructors from our partner district (as determined by the email they used during registration) while the higher, darker colors represent those who did not sign up with emails from the partner district.

Of note, is the fact that there is an increase in the total number of registrations starting the summer before the mid-pandemic school year. This is particularly noticeable during June, July (orange bars) and August (green bar) of 2020.

This could be partially explained by the fact that we offered an online PD course during the Summer 2020. Surprisingly, though,

this surge did not result in a substantially higher number of remixes in 2020-21 as compared to 2018-19. Therefore, while teachers may have been interested in exploring resources for remote instruction, this interest did not result in a higher amount of instruction with Scratch Encore Curriculum globally mid-pandemic compared to pre-pandemic. This may be because teachers were in a phase of exploring many curricula, ultimately choosing only one of the many they downloaded.

### 5.2 Student Behavior

We now transition to looking at not just what material was covered in the classroom, but how well students in partner classrooms did on that material. Note that this is not the same as analyzing how

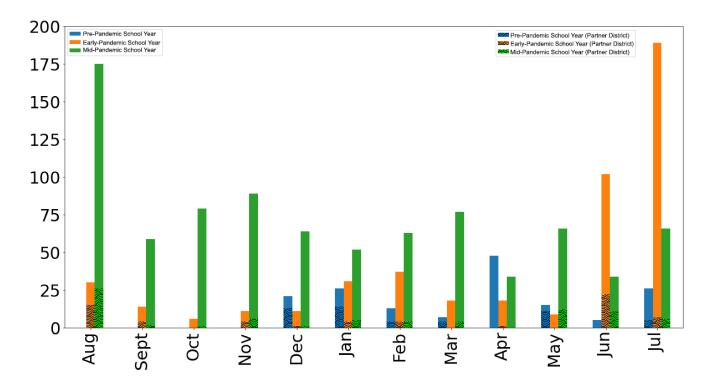


Figure 3: Scratch Encore Curriculum New Teacher Registrations

much students *learned*, just how many of the assigned tasks they completed.

Figure 4 shows the extent to which students completed the requirements for the Scratch Encore Curriculum projects of a given module. Each module has two projects. MXL1 is the Modify project, and MXL2 is the Create project. Each project has specific requirements a student is supposed to complete, with Modify projects being much more prescriptive than Create projects. The height of each bar is the average of the percentage of the requirements met of all projects in partner classroom studios. For example, the Create project M1L2 had high completion all three years, whereas M2L1 has a lower completion rate.

Both the pre-pandemic and early-pandemic years represent inperson instruction because, as we know, little to no instruction took place in spring 2020 during the initial remote instruction. The midpandemic year, on the other hand, included a substantial amount of remote instruction, with some in-person instruction in spring.

Finding 6: Student performance on meeting Scratch Encore Curriculum project requirements suffered during the earlypandemic year, but students in the mid-pandemic year performed similarly to the pre-pandemic year.

To determine if there were differences in student project completion based on the year, we conducted Kruskal-Wallis H tests for M1L2, M2L1, M2L2, M3L1, M3L2, M4L1, and M4L2. Results of the tests are displayed in second column of Table 3. Statistically significant differences are denoted with a \*. Pairwise comparisons

were performed using Dunn's [13] procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented in the last three columns of Table 3.

We then conducted Mann-Whitney U tests for M5L1, M5L2, M6L1, and M6L2 to determine if there were differences in student project completion based on only comparing pre-pandemic and mid-pandemic years (since no early-pandemic classrooms reached M5). There were statistically significant differences between pre- and mid-pandemic projects for M5L1 (U = 18012, p < 0.001) and M6L1 (U = 6529, p < 0.001). The differences between pre- and mid-pandemic projects for M5L2 (U = 8639, p = 0.891) and M6L2 (U = 459, p = 0.522) were not statistically significantly different.

We can see from the results that when comparing pre-pandemic and early-pandemic years, students in the pre-pandemic year did statistically-significantly better on four projects (M1L2, M2L1, M2L2, and M3L1), whereas students in the early-pandemic year did so on M4L1. This indicates that, even before the cessation of instruction, students might have been experiencing challenges in their work. When we compare pre-pandemic and mid-pandemic years, however, student performance has more than recovered. Students in the mid-pandemic year did statistically-significantly better on five projects (M1L2, M2L1, M4L2, M5L1, and M6L1), whereas students in the pre-pandemic year did so on only one project (M4L1).

### 6 DISCUSSION

We now take a step back and look at all of the evidence for both questions.

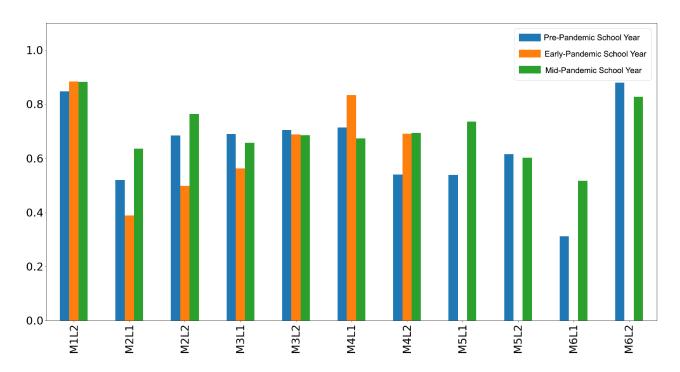


Figure 4: Average Scratch Encore Curriculum Project Completion by Students in Partner District

	Results	Pre and Early	Pre and Mid	Early and Mid
M1L2	H(2) = 8.566, p = 0.014*	p = 0.019*	p = 0.026*	p = 1
M2L1	H(2) = 23.818, p < 0.001*	p = 0.02*	p = 0.003*	p <0.001*
M2L2	H(2) = 43.417, p < 0.001*	p <0.001*	p = 0.078	p <0.001*
M3L1	H(2) = 4.887, p = 0.087	p = 0.045*	p = 0.856	p = 0.123
M3L2	H(2) = 0.062, p = 0.97	p = 1	p = 1	p = 1
M4L1	H(2) = 28.414, p < 0.001*	p = 0.005*	p <0.001*	p <0.001*
M4L2	H (2) = 21.437, p <0.001 *	p = 0.075	p <0.001*	p = 1
M5L1	N/A	N/A	U = 18012, p < 0.001*	N/A
M5L2	N/A	N/A	U = 8639, p = 0.891	N/A
M6L1	N/A	N/A	U = 6529, p < 0.001*	N/A
M6L2	N/A	N/A	U = 459, p = 0.522	N/A

Table 3: Results of Kruskal-Wallis H tests. Statistically significant differences denoted with a \*.

In what ways was instruction affected by the pandemic? When the pandemic first interrupted instruction, computer science was particularly hard hit. Partner teachers covered only 45% of the material they had in the previous or following years, and, beyond our partner schools, a similar level of activity was observed through remixes. Drawing from the CAPE framework, we would say that the school district no longer had the *capacity* to offer computer science instruction.

Three factors contributed to the cessation of instruction in our partner district. First, some technology teachers got pulled from their technology classes to become technology assistants for the classroom teachers who were thrown into virtual instruction with little to no training and familiarity with the platforms. Second, the district was trying to limit the number of minutes students had to

participate in Google Meet, so they prioritized core subjects. Finally, while Scratch Encore Curriculum had some online resources in the form of Google Docs, many teachers preferred physical worksheets, and Google Docs do not accumulate results from multiple students for easy grading. Our curricular changes the following summer, in collaboration with the district, created resources that teachers felt were easy to use virtually.

Once teachers had the opportunity to plan for virtual instruction during the mid-pandemic year (2020-21), and resources were created to support them, however, instruction returned to pre-pandemic levels. Feedback from partner teachers was overwhelmingly positive, and anecdotal evidence is that many teachers who had not taught Scratch Encore Curriculum previous to the pandemic are likely to adopt it, which may increase use in coming years. Our data shows

that in the mid-pandemic year, students had equal *capacity*, *access*, and *participation*. Without assessment data, however, we are unable to analyze whether there was similar *experience* or outcomes.

The only surprising finding was that the steep increase in teachers downloading the curricular resources resulted in only a modest increase in remixed projects. This might indicate that teachers were looking at many choices for virtual instruction, but they settled on other curricula.

In what ways was individual performance affected by the pandemic?

We can see that the pandemic did, indeed, affect students performance, but only during the early-pandemic year. Students in our partner district faced a number of stressful events, including widespread protests, parental job losses, economic instability, and high COVID death rates. Several teachers came from partner schools with over 80% of students in low-income households, which were disproportionately affected by both economic challenges due to job loss and COVID death rates. In addition, the geographical region covered by this district had active protests -most notable of which were those against racial injustice triggered by the murder of George Floyd- for several weeks at a time. As per Finding 1, though, instruction stopped immediately after the national lockdown was announced by the U.S. government, as such we know that all instruction that did take place in the early-pandemic school year occurred before the shift to emergency learning and before many students had been directly impacted by many of the negative effects of the pandemic. Thus, it would be reasonable to believe that students would feel negative effects more in the mid-pandemic year than the early-pandemic year.

During the early pandemic, however, student performance did suffer - the comparison between the early-pandemic year and prepandemic year shows that student performance suffered on four projects. While it is impossible to explain all the reasons for such differences, such early negative ramifications might suggest that the extensive news coverage of the early developments of the pandemic had already begun to cause anxiety amongst the students.

The authors find it reassuring and surprising that of all instances (M1L2, M2L1, M4L1,M4L2, M5L1, M6L1) where there were statistically significant differences between the mid-pandemic year and the pre-pandemic year, only once (M2L1) did the students in mid-pandemic year perform worse than those in the pre-pandemic year. We believe our findings provide strong evidence that teachers were able to adapt and continue to teach the Scratch Encore Curriculum effectively despite the substantial challenges posed by the remote and hybrid learning which defined the mid-pandemic year. Maslow's hierarchy of needs would suggest that students would experience challenges in the classroom, and we are heartened to see that while the pandemic continued through the mid-pandemic year, students may have been given the support they needed at home and at school to successfully engage with the material.

A second possible reason for the recovery in the mid-pandemic year is the level of scaffolding students received. Previous research has shown that highly scaffolded computer science instruction using TIPP&SEE effectively supports students with a variety of risk factors, including low socioeconomic background [43]. It could be that this strategy also supports students who are undergoing trauma in their lives.

#### Reception of virtual curriculum materials

Given that the Scratch Encore Curriculum's transition from conventional/physical materials to an entirely virtual experience was driven by an emergency need to address the seismic shift in the educational landscape as schools began to shut down, we do not currently have extensive data to present on teacher reception to the new virtual materials. We did, however, conduct weekly meetings with district leaders as well as conduct interviews with a handful teachers in our partner district who have experience teaching both versions of the curriculum. The labels used to identify the teachers correspond to those in Figure 2.

When our online materials were introduced, the teacher responses to district leaders was overwhelmingly positive. District leaders stated that teachers who had not had time to explore Scratch Encore prior to the pandemic were now using it because of the virtual materials. Teacher B called the Google Forms versions "great." Teacher E also found the video content was 'great,' however felt that "the kids doing the [paper] worksheets seem[ed] to be grasping it better [than the google form versions], but thought maybe it was... flipping between screens was a problem." Teacher E also converted the Google Forms from surveys to quizzes to take advantage of automatic grading.

When analyzing student data from the pandemic years, we also observed that the changes we made in the sheets when transitioning from physical to virtual resources, such as using the affordances of Google Sheets to convert some open-ended questions into more structured questions (e.g. check boxes), may have provided additional scaffolding that helped students successfully complete more project requirements.

# 7 LIMITATIONS

Given the natural experiment occurring during the middle of a "once in a generation" pandemic, this work has limitations. The most useful question, "how much did the pandemic impact student learning?" was not possible. Our measures capture only student performance (requirement completion rates), not learning. We are not able to claim that students learned the same amount of content during the pre and mid-pandemic years but rather that they demonstrated similar levels of competency at completing the programming requirements. We restricted our questions to what the available data could answer - about teacher instruction and student activity but even within these questions we have an incomplete picture.

Most of the data analyzed was *student artifacts* rather than *direct classroom observations*. This limits what conclusions we can draw and the level to which we can explain the data. For example, measuring *instruction* by inspecting *student artifacts* is a very imprecise measure - we know what lessons were covered, but we could not determine the *quality* or *duration* of instruction. In addition, the large-scale web-scraped data was anonymous, so we cannot guarantee the work was performed within formal classroom settings by students. Finally, factors due to the pandemic could have changed how much students received help - by teachers in in-person instruction or by siblings or parents in virtual instruction.

As a design-based research study, the resources were changed between the pre-pandemic and mid-pandemic years. The changes made were a combination of required changes to adapt to the affordances of Google Forms, optional changes to streamline the process for teachers given the features of Google Forms, and changes made based on data collected from previous years' use. We are not able to discern to what degree the pre-pandemic year of instruction might have been better supported through the use of the updated Google Forms, as well.

All of the individual student data we collected all came from our partner district:a large urban Midwestern school district with a dedicated office of Computer Science that might not be representative of other, smaller, school districts. We know that the most detrimental impacts of the pandemic were not experienced equally [29]: students from well funded school districts and private schools with dedicated IT departments undoubtedly received a different level of CS education than those in districts where the few CS instructors were pressed into service as tech support agents. Similarly, schools with the resources to quickly acquire protective equipment would have been able to implement hybrid and in-person instruction months before underfunded schools. Without knowing who the students completing the Scratch Encore Curriculum curriculum were, it is impossible to answer some of the most pressing equity-based questions raised by the pandemic.

Finally, while the autograders used to evaluate student projects for completeness are created specifically for each module in the Scratch Encore Curriculum, given the open-ended nature of programming, it is possible for a project to satisfy the 'spirit' of a requirement but in an unexpected way that the autograder is unable to recognize the behavior. To mitigate this, several student projects and the corresponding autograder result were spot-checked for correctness and in no instance was a student incorrectly deducted points.

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