Evaluation of Playground Physics: Implementation and Outcomes

2020–21

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March 2022

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Acknowledgements

This project was supported by Education Innovation and Research grant U411B180028 from the US Department of Education to the New York Hall of Science.

The authors would like to thank our research partners at the New York Hall of Science (Steve Uzzo, Michaela Labriole, and Laycca Umer) and New York State Association for Computers and Technologies in Education (Linda Brandon) for input on an earlier version of this report and assistance in compiling extant data. We thank Courtney Tanenbaum for reading and reviewing an earlier version of this draft.

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Introduction

The New York Hall of Science (NYSCI) developed the Playground Physics program to enable middle school students to connect physics concepts to their own playful activities. This supplemental curriculum comprises three units, each addressing the core physics concepts of motion, energy, and force (respectively). During Playground Physics lessons, students ask questions and define problems, plan and carry out investigations, identify patterns in data, and analyze and interpret charts. The Playground Physics app supports students' explorations of the relationships between their embodied experiences during play and the scientific ideas embedded in their curriculum. Toward this end, the app allows students to visualize the physics concepts embodied in their own playful activities. A Teacher Activity Guide provides guidance on how to incorporate this app into each unit of the curriculum.

NYSCI received an Education Innovation and Research Mid-Phase Grant to scale up the program across New York State. In collaboration with the New York State Association for Computers and Technologies in Education (NYSCATE), NYSCI trained and supervised a cadre of coaches who trained the participating teachers. In this train-the-trainer model, NYSCATE and NYSCI provided an initial 2-day training workshop for coaches, conducted quarterly virtual meetings to address emerging questions and challenges, and facilitated an online community of practice (CoP) for ongoing support. Six coaches participated in this model and conducted professional development workshops (delivered with synchronous and asynchronous components) to teachers. The coaches provided follow-up support for teachers via an online CoP.

During the 2020–21 school year, the American Institutes for Research® (AIR®) conducted a study in 46 New York schools to examine implementation and outcomes of Playground Physics. AIR's study was supported through an Education Innovation and Research Mid-Phase Grant to NYSCI. AIR randomly assigned half of these schools to receive training on Playground Physics and then implement the program and half of these schools to implement their business-as-usual physics curriculum. This report examines implementation of the program's key components, as well as the outcomes of middle school students whose teachers implemented Playground Physics (compared with students whose teachers did not implement this program).

Notably, this study took place during the COVID-19 pandemic, which had a dramatic and unprecedented impact on the learning environment in schools across the country. Learning environments shifted from in-person to fully remote and/or to hybrid models, often more than once, through the year as schools opened and closed in response to rising and falling cases of COVID-19 and federal, state, and local policies and guidelines. Within hybrid instructional models, many teachers were required to conduct their classes in both face-to-face and virtual environments, using a virtual platform to connect and engage online students with what was happening in the physical classroom. Because of these challenges, 13 of the 23 schools in the sample that were originally assigned to implement Playground Physics dropped out of the project during the 2020–21 school year.

Research Questions and Study Design

The experiment randomly assigned 46 schools either to use Playground Physics to teach the concepts of motion, force, and energy or to teach these topics using their regular curriculum. The study examined whether, after the experimental period, students in schools that used Playground Physics were more knowledgeable of key physics concepts (motion, force, energy) and more engaged in science class compared to students in schools that used their regular physics instruction. In addition, the study examined whether there were differences in student attitudes toward science learning and interest in science after the experimental period. Pre- and post-test student knowledge assessments and surveys, as described in the Study Sample and Data Sources section, were used to collect data on student characteristics and capture changes in the outcomes. In addition, teacher surveys, professional development delivery, and attendance records and materials delivery records were analyzed to determine whether the program's key components (professional development, delivery of curriculum materials, and classroom use of Playground Physics) were implemented with fidelity.

Drawing on data from a survey of teachers implementing the program, as well as on extant data generated from the program taking place, AIR examined the following evaluation questions:

1. What were teacher perceptions of the quality and effectiveness of professional learning opportunities?
2. To what extent and in what ways did teachers participate in the online CoPs?
3. To what extent and in what ways did teachers implement the Playground Physics curriculum? What were barriers and facilitators of implementation?
4. What are teacher perceptions of the usefulness of the Playground Physics curriculum for supporting physics instruction?
5. To what extent did program staff (NYSCI and NYSCATE) and program participants (teachers in New York State) implement Playground Physics with fidelity?
6. What impact did participation in Playground Physics have on student knowledge of physics, engagement in physics lessons, and attitudes toward physics?

Study Sample and Data Sources

In this section, we present the experiment's sample and data sources.

Sample

AIR, in partnership with NYSCI and NYSCATE, recruited 46 schools throughout New York State to participate in the study in the 2020–21 school year. To be eligible, schools needed to meet the following criteria:

- Serve a high-need student population (defined as at least 40% of students in economic need or at least 40% of students from a racial/ethnic group underrepresented in STEM fields)
- Have computing devices compatible with the Playground Physics app available for distribution to students
- Have at least one science teacher who teaches physics concepts to students in sixth, seventh, or eighth grade
- Agree to be randomly assigned to one of two conditions:
  - For treatment schools, to participate in Playground Physics professional development in fall 2020 and implement the curriculum during the 2020–21 school year
  - For control schools, to teach their business-as-usual physics curriculum during the 2020–21 school year and wait until the fall of 2021 to receive the Playground Physics professional development and program materials

Prior to the 2020–21 school year, researchers from AIR randomly assigned the 46 recruited schools to two conditions: 23 schools to the treatment (Playground Physics) condition and 23 schools to the control (business as usual) condition.

Sample Attrition

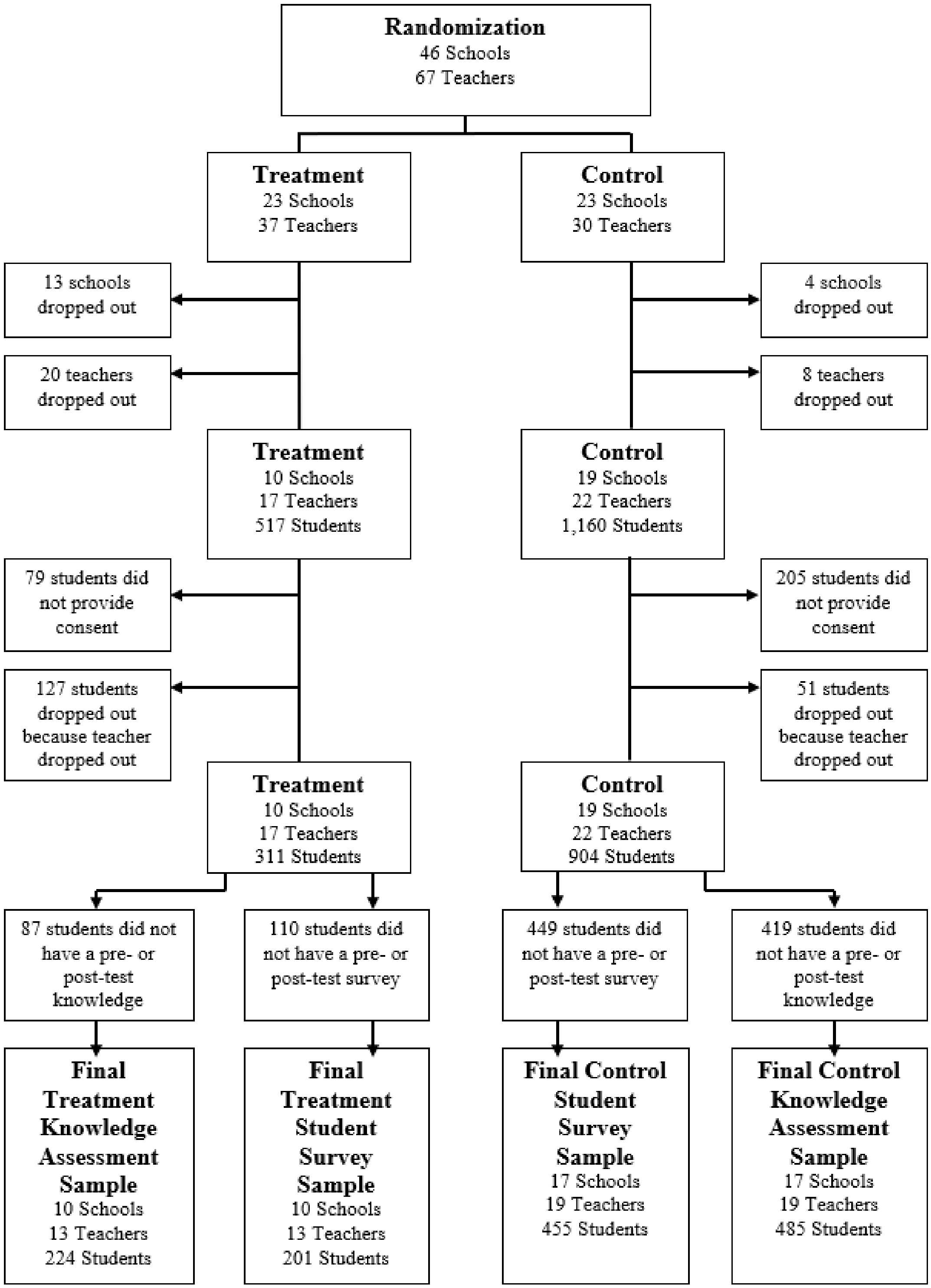
This section summarizes the reasons for attrition among schools and students in our sample. In the treatment condition, 13 of the 23 schools (57%) left the study. Treatment schools dropped out for the following reasons: logistical challenges as a result of remote learning (eight teachers); competing priorities (two teachers); or they did not provide a reason (three teachers). Rosters from the remaining 13 treatment schools indicated that they taught 680 students; 162 (24%) of these students did not assent or have parental consent, and 179 students (25%) moved or left the study.

In the control condition, 4 of the 23 schools (13%) left the study. Control schools stated the following reasons for dropping out: They had competing priorities (one school), or they did not provide a reason (three schools). Rosters from the remaining 19 control schools indicated that they taught 1,315 students; 290 (22%) of these students did not assent to participate or did not have written parental consent,[1] and an additional 251 students (19%) moved or left the study.

Student attrition from the analytic sample. AIR researchers created two analytic samples: one sample for completion of the knowledge assessment and one sample for completion of the student survey (comprising three attitudinal outcome measures). To be included in either sample, students needed to have a pre- and post-test for the instrument. In the treatment condition, 124 (36%) students of the 348 students did not have a pre- and post-knowledge assessment, and 145 (42%) students did not have a pre- and post-test student survey. In total, the final treatment analytic sample was 224 students for the knowledge assessment and 201 students for the student survey. For the control condition, 289 (37%) students of the 774 students did not have a pre- and post-knowledge assessment, and 302 (40%) students did not have a pre- and post-test student survey. In total, the final control analytic sample was 485 students for the knowledge assessment and 455 students for the student survey.[2] Removing students in the control condition who did not have pre- and post-test student survey reduced the control teacher sample from 21 teachers to 20 teachers for the study survey sample. Exhibit 1 provides a consort diagram for teachers and students.

[1] To participate in the study, students needed to assent to participate and provide written parental consent. Teachers, with support from NYSCI, coordinated distribution and collection of parent consent and student assent forms.
[2] In some cases, students did not complete all five measures included on the survey. Therefore, the *n*s for the survey-based measures vary within conditions.

Exhibit 1. Consort diagram of impact study analytic sample



Note. For students to be included in the study, student assent and parental consent of school records were needed.

Sample Characteristics

The study team examined whether teacher and classroom characteristics differed by condition. With respect to teachers, we analyzed data on instructional experience and degree attainment. With respect to classrooms, we examined the grade levels of classrooms in each condition.

Teacher characteristics. Teachers self-reported their instructional experiences and educational backgrounds in a survey to which 12 of 14 teachers in treatment schools and 21 of 23 teachers in control schools responded. The level of teacher experience was generally similar across the two conditions, although teachers in treatment schools had slightly more experience than teachers in control schools had on average. For example, teachers in treatment schools had an average of 12.2 years of science instruction experience compared to 10.0 years of science instruction experience among teachers in control schools (Exhibit 2). With respect to educational background, teachers in both the treatment and control schools most frequently reported having earned a master's degree or above (92% and 85%, respectively). We suggest that the two groups of teachers have similar levels of instructional experience and similar levels of education.

Exhibit 2. Teacher instructional experience, by condition

	Treatment (n = 12)		Control [a] (n = 19)	
Experience	Mean	Standard Deviation	Mean	Standard Deviation
Total instructional experience	13.8	9.1	10.8	7.5
Science instruction	12.1	9.2	10.0	7.8
Physics instruction	5.8	7.0	5.8	7.1

Source: Treatment and control teacher survey.

[a] Two surveyed teachers in the control group did not respond to this question in the teacher survey.

Student grade level. The two conditions differed somewhat with respect to grade level (Exhibit 3). Students in the treatment condition most frequently (37%) did not report a grade level, whereas students in the control condition most frequently (46%) reported being in Grade 8. Given the observed differences, we controlled for grade level in the impact analysis model.

Exhibit 3. Number of students, by grade and condition

Grade	Treatment (*n* = 224)	Control (*n* = 485)
6	55 (24.5%)	65 (13.4%)
7	67 (29.9%)	174 (35.9%)
8	20 (8.9%)	176 (46.3%)
Did not report grade	82 (36.6%)	70 (14.4%)

Source: Author generated.

Data Sources

This section describes the data sources used to examine program implementation and student outcomes.

Program Implementation Data

The Playground Physics program had four critical implementation components: coach training and support (e.g., train-the-trainer workshops and online CoP), teacher professional development and support (e.g., training workshop and ongoing coaching via CoP), curriculum materials (app and Teacher Activity Guide), and classroom implementation of Playground Physics.[3] Section 5 of this report provides a detailed description of each component. Implementation data sources included a teacher survey of curriculum implementation and records of participation in professional development and in an online CoP.

Teacher survey. AIR administered the teacher survey to teachers in the treatment and control conditions, upon their completion of instruction related to motion, force, and energy. The overall response rate to the survey was 89% (Exhibit 4). Teachers in both conditions described the number of days spent on the physics topics of motion, force, and energy. Teachers in treatment schools responded to items specific to their engagement with and use of the Playground Physic program. These survey items addressed the following topics:

- Extent to which the professional development workshop and online CoP supported implementation of Playground Physics (Teachers also provided open-ended feedback regarding how to improve these professional resources.)
- Level of participation in the online CoP and barriers teachers encountered to participating in it

[3] The program developer (NYSCI) defined these critical components and their criteria.

- Number of lessons teachers implemented in each of the three Playground Physics units (motion, force, energy) and the educational environment for each unit (i.e., in person, remote, or blended)
- Extent to which unit-specific program materials for each of the three Playground Physics units supported teachers' instruction of motion, force, and energy (Teachers also provided open-ended feedback regarding how to improve the curriculum materials.)
- Level of student engagement with Playground Physics lessons relative to lessons taught with the regular (i.e., business as usual) curriculum
- Approach to integrating Playground Physics with regular curriculum

Exhibit 4. Survey response rate

Condition	Teachers in Study	Responses to Survey	Response Rate
Control	23	21	91%
Treatment	14	12	86%
Total	37	34	89%

Attendance records. AIR requested attendance records from NYSCATE staff to determine the participation of coaches in train-the-trainer workshops and participation of teachers in the online synchronous professional development workshop. AIR also collected records of attendance at quarterly synchronous virtual meetings for coaches.

Online CoP participation data. There were two separate online CoPs corresponding to two different training cohorts of teachers. Cohort 1 comprised six teachers participating in the professional development workshop in October 2020, and Cohort 2 comprised eight teachers participating in the workshop delivered in December 2020. NYSCATE also established an online CoP forum for the coaches. AIR collected and analyzed data on the implementation of the CoPs on the following:

- Number and frequency of posts of CoP participants
- Type of supports teachers received, as indicated through qualitative coding of the purpose and topic of each discussion thread
- Resources posted in the coach and teacher CoPs

Student Outcomes Data

Student outcomes data sources included a pre- and post-test knowledge assessment and survey of student science attitudes and engagement.

Student science knowledge assessment. Students' physics content knowledge was assessed before and after teachers completed physics instruction using either Playground Physics or their regular curriculum. The research team developed the assessment as part of a previous study of Playground Physics (Friedman et al., 2017) and aligned the assessment items to the New York State Science Learning Standards. For the present study, the research team discontinued four items that did not align well to the revised version of these standards adopted in 2016. We also revised six items to improve clarity. The pre- and post-test knowledge assessments each had 20 items, 14 of which were overlapping (for a total of 26 unique items). The internal consistency ratings for these instruments, as measured by the Rasch statistic, surpassed the What Works Clearinghouse (WWC) benchmark of 0.5 (WWC, 2014; Exhibit 5).

Student science-related attitudes survey. Students completed an online survey of their science-related attitudes before and after their teachers completed physics instruction using either Playground Physics or their regular curriculum. The student survey included forced-choice questions related to the following three constructs: engagement in science class, perceived utility of physics, and interest in physics. The pre- and post-test versions of the survey were identical, and the internal consistency ratings surpassed the WWC benchmark (Exhibit 5).

- **Engagement in science class.** The survey measured the student's experience of concentration, enjoyment, and interest while participating in science class during the preceding 2 weeks. The research team adapted the 15 items in this scale from the engagement with science lessons scale (Wang et al., 2016). The items ask students to rate their agreement with statements such as the following: "I want to understand what is learned in science class." "I enjoy learning new things about science." Students responded using a using a 4-point *agree* to *disagree* scale.
- **Perceived utility of physics.** The survey measured student-perceived utility of physics through four forced-choice items, using a 7-point *not at all true* to *very true* scale. The research team adapted these items from a perceived utility scale developed by Harackiewicz et al. (2016). The items ask students to rate the extent to which they think the statements, such as the following, are true: "I think what we are learning about physics is important."
- **Interest in physics.** The survey measured student interest in physics through 11 items using a 4-point *agree* to *disagree* scale. The items relate to student interest in physics (e.g., "Physics is a topic that I enjoy studying." "I would like to learn more about physics."). We adapted the scale from the Interest in Science scale used by Friedman et al., (2017).

Administration of knowledge assessment and survey. To understand how student affect and knowledge changed as a result of students participating in the Playground Physics program, we captured data using a student survey and knowledge assessment. Teachers administered the knowledge assessment and survey at two points in time—prior to teacher implementation of Playground Physics and within 2 weeks after completing their final instructional unit. NYSCI staff communicated with teachers about their anticipated completion of their physics instruction for the year, and AIR researchers emailed posttest forms to coincide with each teacher's date of completion. AIR researchers requested that teachers administer the posttests as soon as possible after completion of instruction (and no more than 2 weeks following completion). Because of variations in the timing of physics instruction across teachers, posttest data collection extended from February 2020 through June 2020. The following sections provide more detail about the instruments used to measure student outcomes.

Internal consistency of student outcomes instruments. We used Rasch analysis (Andrich, 1978; Wright & Masters, 1982) implemented with WINSTEPS (Linacre, 2005) to psychometrically scale the knowledge assessments and the student survey constructs. This procedure converted the ordinal data from the surveys and the binary data from the knowledge assessment into interval scale scores using a logit metric. We included these scale scores in analyses of program impact.

The present study estimated two measures—Rasch reliability and Cronbach's alpha—of the functioning for each construct of the student outcomes. Rasch reliability incorporates information about the precision of the estimates of respondents' scores and the fit of individual response patterns to model predictions. Cronbach's alpha is an index of the reliability of raw survey responses. Exhibit 5 describes the internal consistency of the student outcomes instruments reported in the study. Internal consistency ratings for all outcome measures, as measured by the Rasch statistic, surpassed the WWC benchmark of 0.5 (WWC, 2014).

Exhibit 5. Student outcomes instrument reliability and internal consistency

Instruments	Internal Consistency (Cronbach's Alpha)	Rasch Reliability
Knowledge Assessment		
Pretest	0.60	0.57
Posttest	0.78	0.74
Student Science-Related Attitudes Survey [a]		
Engagement in science class	0.89	0.87
Perceived utility of physics	0.82	0.79
Interest in physics	0.92	0.89

Source: Author calculation.

[a] The student affect surveys were identical at pre- and post-test. The data from the two administrations were combined to examine reliability and internal consistency.

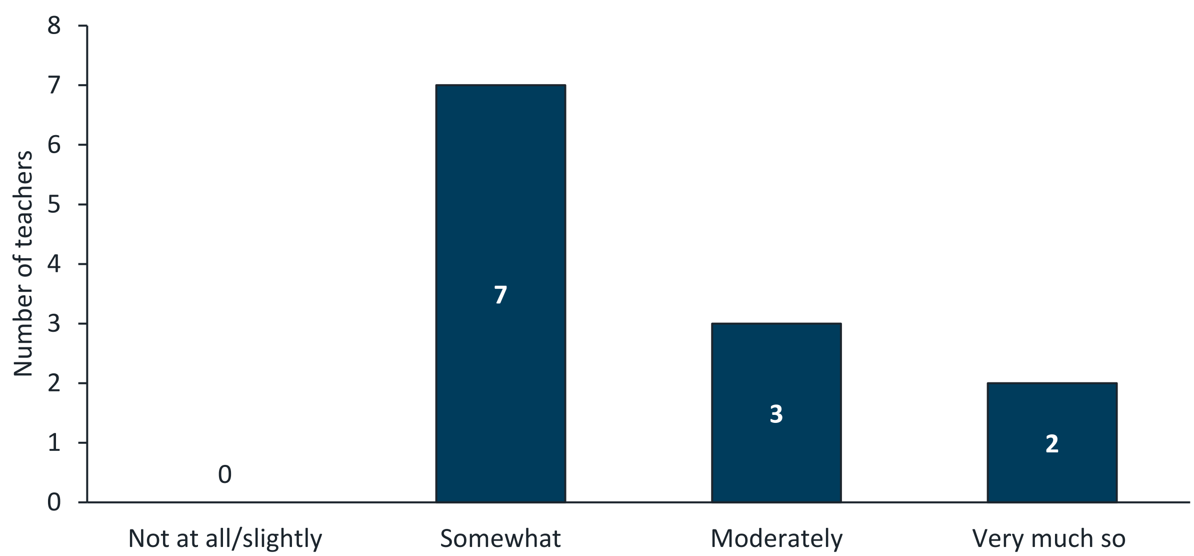
Section 1. What were teacher perceptions of the quality and effectiveness of professional learning opportunities?

This section summarizes findings about teacher perceptions of the professional development workshops and online CoP, drawing on data from the survey responses of 12 teachers in the treatment condition. A majority of teachers reported that they were somewhat prepared to teach Playground Physics after the professional development workshop. Most teachers reported that the CoP somewhat supported implementation of Playground Physics, and no teachers reported that the CoP at least moderately supported implementation.

Most teachers perceived the workshops and online CoP to be somewhat supportive.

Teachers perceived that the professional development workshop somewhat prepared them to implement the program. More than half of teachers (7 of 12 teachers) reported that the workshop prepared them somewhat well to teach Playground Physics. The remainder of teachers (five teachers) said that the workshop prepared them moderately or very well. No teachers reported that the workshop did not prepare them at all or prepared them only slightly well to teach Playground Physics.

Exhibit 6. Most teachers reported that the NYSCI professional development workshop prepared them somewhat well to teach Playground Physics.



Note. *N* = 12. The survey item asked, "How well did NYSCI's professional development workshop prepare you to teach Playground Physics?"

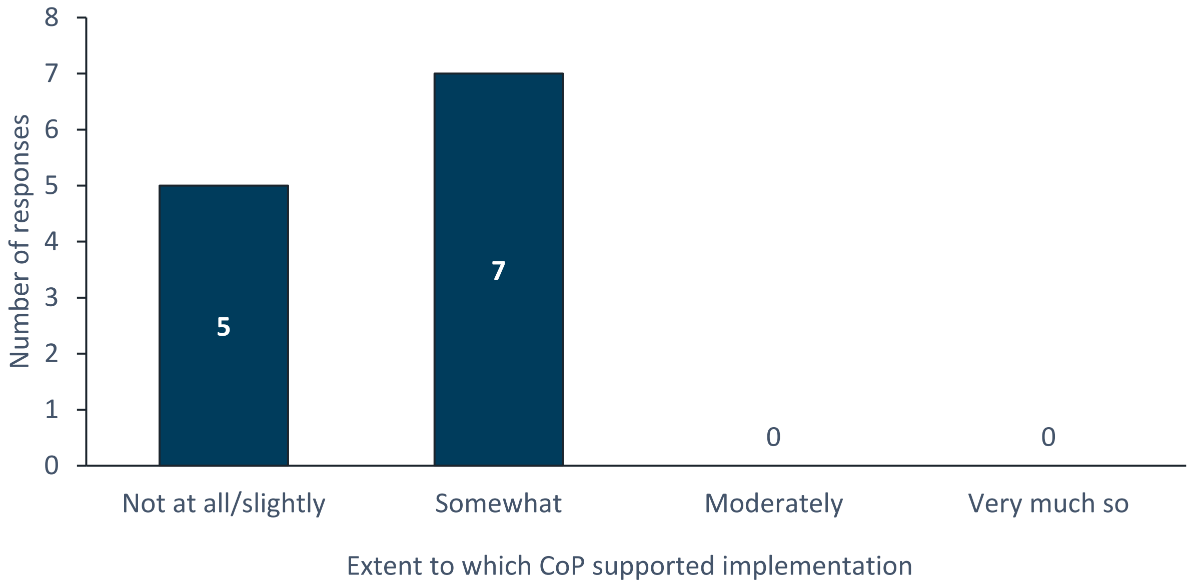
Six teachers elaborated on their experience with the professional development workshop in response to an open-ended survey item.

- **Three teachers stated that the workshop prepared them well to implement the Playground Physics curriculum.** One of these teachers elaborated that they felt less prepared for data collection activities involved in the study, including administering pre- and post-intervention assessments and surveys, than for teaching the Playground Physics curriculum.
- **Most teachers experienced at least a 2-month gap between the workshop and the start of their implementation.** Based on the start dates teachers reported in the survey, 11 of 12 teachers had at least a 2-month delay between the training workshop and the first lesson they taught from the curriculum. In open-ended comments, two teachers remarked about the challenges presented by this gap. For example, one teacher stated, "I did the workshop in the fall. By the time I got to implementing the unit, I was rusty myself with how to use the app and the lessons." Another teacher mentioned that the content of the example used in the workshop did not match the unit that they implemented.[4]
- One teacher expressed that it would have been beneficial to meet in person instead of remotely.

Teachers reported that the online CoP was no more than somewhat supportive. Teachers rated the extent to which the CoP supported their implementation of Playground Physics. A majority of teachers (seven teachers) said that the CoP somewhat supported implementation. The remainder of teachers (five teachers) said that the CoP did not support implementation or only slightly supported implementation. Section 2 explores teachers' engagement with and feedback about the CoP in more detail.

[4] The synchronous workshop used the Motion unit to model the structure of the curriculum, and participants explored the Force and Energy units asynchronously on the online CoP, according to email communication from NYSCI program staff.

Exhibit 7. All teachers reported that the online CoP either did not support or somewhat supported implementation of Playground Physics.



Note. *N* = 12. The survey item asked, "To what extent did the online community of practice support your implementation of Playground Physics?"

In summary, most teachers reported that the professional development workshop prepared them somewhat well to teach Playground Physics and that the CoP somewhat supported implementation. However, the remaining teachers rated the workshop more positively than the modal *somewhat* rating, whereas the remaining teachers rated the CoP less positively than this modal rating. A few teachers expressed that the workshops were not well aligned to the timing or content of physics instruction.

Section 2. To what extent and in what ways did teachers participate in the online CoPs?

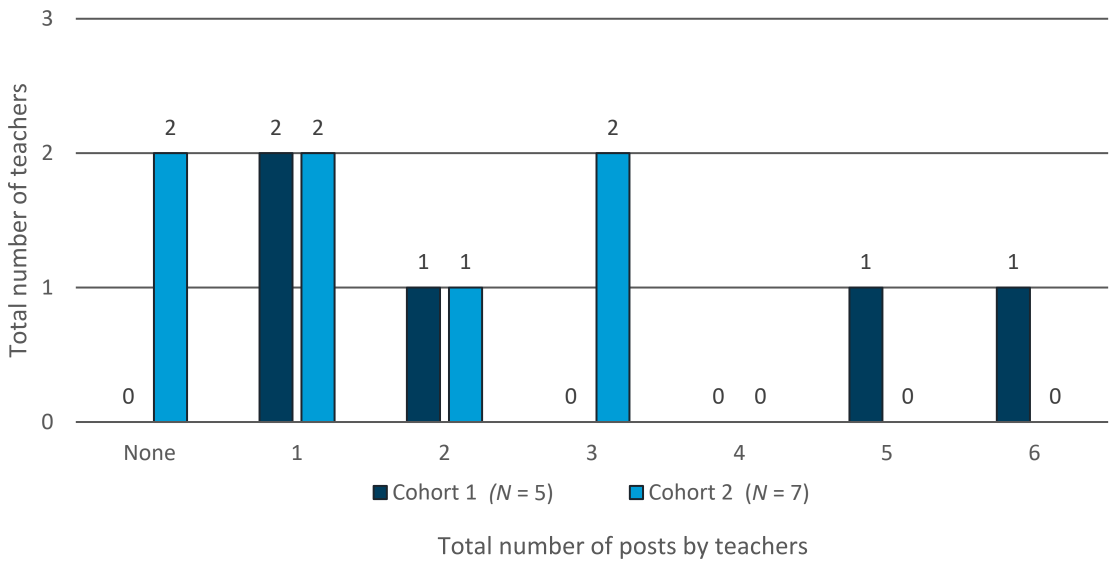
This section summarizes the frequency and types of interaction by teachers and coaches in the online CoPs. The CoPs were hosted on an online platform and were meant to provide forums for teachers and coaches to interact by sharing resources, asking questions, and providing advice on best practices. Program developers anticipated that teachers would engage in the CoP biweekly during their classroom implementation period[5] and that coaches would post weekly prompts to foster discussions about program implementation. Our findings indicate that only one teacher engaged in the online CoP during the period in which they implemented the program. The other teachers engaged before or after their period of implementation. A majority of teachers' posts were introducing themselves to other participants or requests for technical assistance. Among teachers who engaged at all in the CoP, most teachers found that the CoP somewhat supported their implementation of Playground Physics, and the remainder of teachers found that the CoP did not support or only slightly supported implementation.

Most teachers posted to the CoP one to three times and reported low levels of engagement.

AIR accessed the online CoP and counted the number of posts made by treatment group teachers in each cohort. Because the two cohorts participated in separate online CoPs, we analyzed each CoP separately. We found that 10 of the teachers total across the two cohorts posted at least once in the CoPs. Two teachers in Cohort 1 posted more than five times, and two in Cohort 2 did not post at all (Exhibit 8).

[5] Classroom implementation period was determined based on responses to the teacher survey.

Exhibit 8. Most teachers participated in the CoP one to three times.



Most teachers did not seek support from the CoP during their classroom implementation. We cross-referenced teacher responses to the teacher survey with the extant data of their participation in the CoP. We found that one of the teachers in the treatment schools engaged in the online CoP during the classroom implementation periods they indicated on the survey.[6] All other teachers engaged in the online CoP prior to implementation and following implementation.

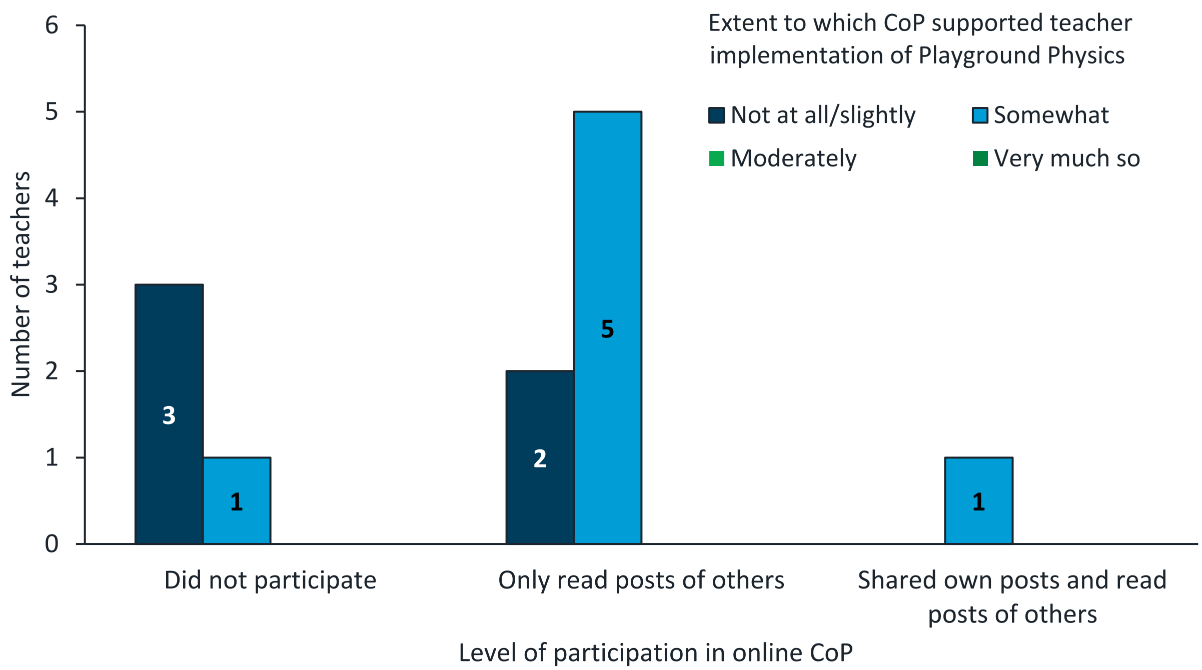
Teachers reported low levels of engagement with the CoP. We asked teachers to report how they participated in the CoP, if at all, and to describe the extent to which the CoP supported their implementation of Playground Physics. Exhibit 9 describes teachers' self-reported levels of participation with the CoP and, for each level, the frequency of their ratings of the CoP's usefulness.

- **Teachers typically participated by reading others' posts in the CoP, although several teachers reported not participating at all.** The majority of teachers (7 of 12 teachers) reported that they would read the posts of others but did not share any comments or questions of their own in the CoP. Four teachers reported that they did not participate at all in the CoP. Only one teacher reported sharing comments or questions of their own.

[6] A member of the NYSCI project team (M. Labriole) stated that coaches and teachers sometimes communicated through channels other than the CoP's online forum. AIR did not have access to data that captured these types of interactions.

- **Of teachers who participated at all in the CoP, most teachers (six of eight teachers) found that the CoP somewhat supported their implementation of Playground Physics.** However, no teachers reported that the CoP moderately or very much so supported implementation.
- **Lack of time was a factor in low participation.** In open-ended comments, two teachers suggested that they did not have time to participate in the CoP; in one case, this lack of time was attributed to an increased workload during the past year, possibly due to the COVID-19 pandemic.

Exhibit 9. Teachers typically read others' posts and rated the CoP as somewhat supportive.



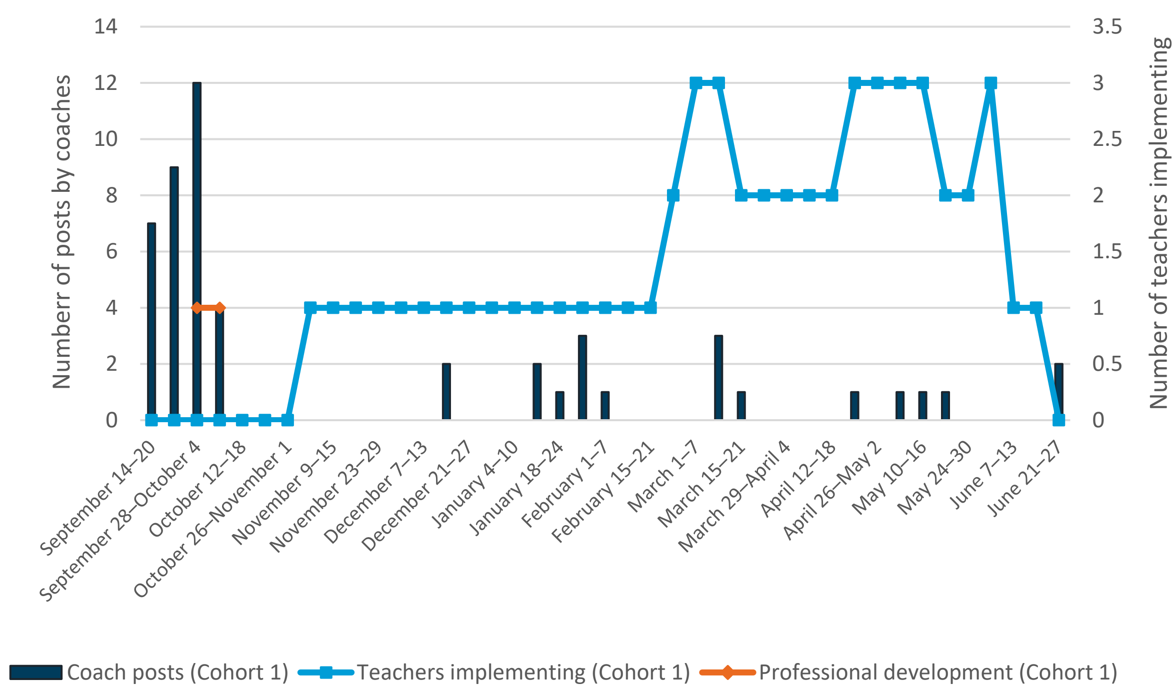
Note. *N* = 12. The level of participation in the online CoP was addressed in the question, "Please describe how you participated in the online community of practice for teachers on Schoology?" with the following options: "I did not participate at all—I did not read any posts or share any comments/questions," "I would read the posts of others but did not share any comments or questions of my own," and "I would read the posts of others and also share comments or questions of my own." The extent to which the CoP supported a teacher's implementation of Playground Physics was addressed in the question, "To what extent did the online community of practice support your implementation of Playground Physics?"

Coaches typically participated in the CoP just before and during the teacher professional development workshops.

In the 2020–21 study, six coaches were trained to support the teachers throughout the implementation process. According to the project team's stated implementation model, coaches would provide at least one prompt per week in the CoP to foster teacher discussion and engagement. Coaches made a total of 81 posts in the CoP, although there were some weeks without any coach engagement. A majority of the coaches' posts (*n* = 33) occurred right before and during the teacher professional development workshops (Cohort 1: October 3 and 10; Cohort 2: December 5 and 12). These posts were all introductions to the teachers and coaches. For Cohort 1, the coaches posted 16 times in the 2 weeks leading up to the teacher professional development sessions. For Cohort 2, the coaches posted six times during the week of September 14 to 21, which was 11 weeks before any of the teacher professional development sessions occurred. These posts included prompts that were meant to be used during the teacher professional development sessions. Of the 34 weeks during which teachers were implementing Playground Physics, coaches engaged in the online CoP during 19 of those weeks (Exhibits 10 and 11).[7]

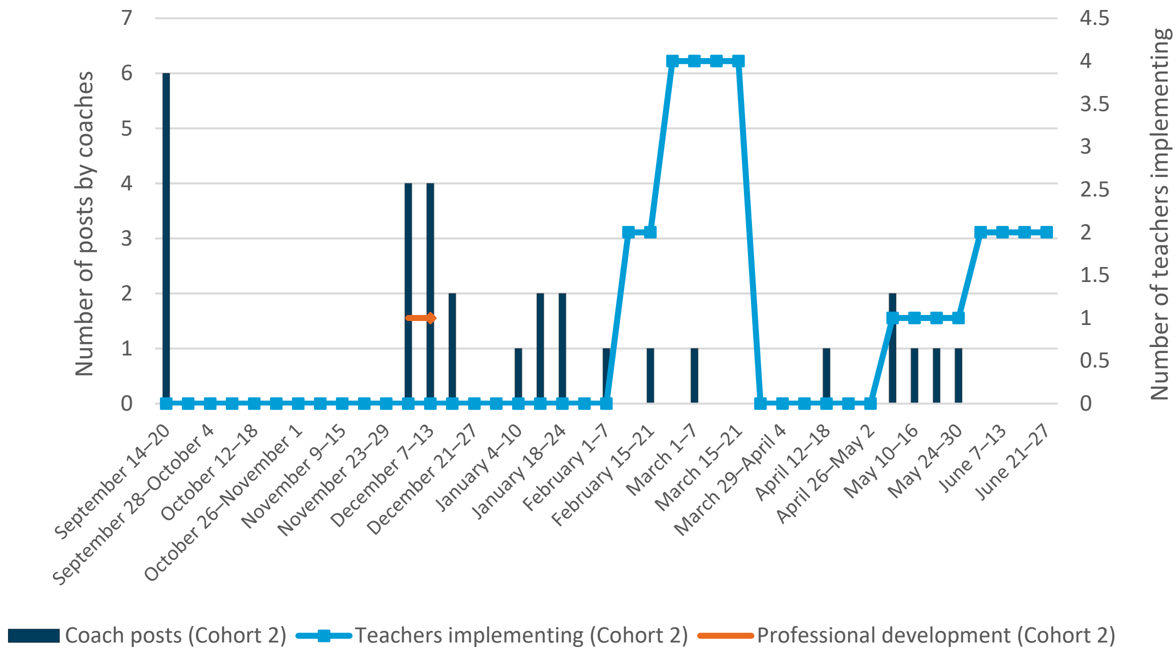
Based on our review of teacher level of engagement with the coaches' posts, teachers engaged more when the posts were about getting to know the teachers. Teachers engaged less when coaches posted about implementation (e.g., asking about teacher progress and sharing curriculum resources). The level of engagement is defined by how many teachers responded to a coach post. Teachers responded 22 times to the introductory posts, whereas teachers responded 6 times to posts about implementation.

Exhibit 10. Cohort 1: Coaches' posts in the CoP partially align with teachers' periods of implementation.



[7] Implementation period was determined based on responses to the teacher survey.

Exhibit 11. Cohort 2: Coaches' posts in the CoP partially align with teachers' periods of implementation.



Besides introductions, teachers and coaches most frequently used the CoP to discuss topics related to technology use.

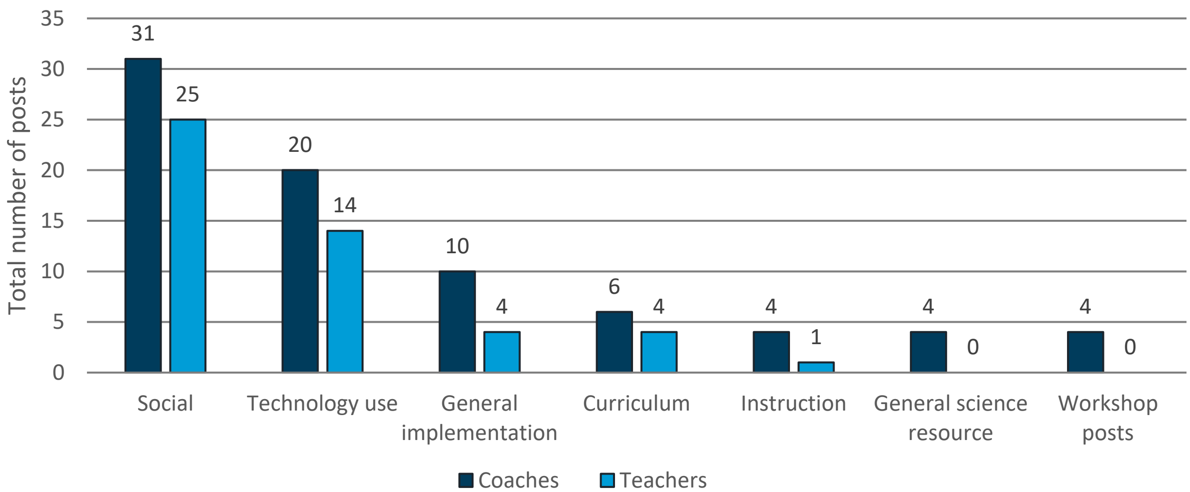
AIR coded each post in the online CoP to establish the topics that were discussed. AIR coded each post only once. For the purpose of this analysis, we combined threads in the two cohorts, given that the distribution by topic was similar in both cohorts.

The number of posts (of a total of 131) varied by topic, with introductions and technology use being the most frequently discussed topics (Exhibit 12). The breakdown of posts by topic is as follows:

- **Social.** About 43% of the posts (*n* = 56) fell under the social category of topics. These posts included introduction posts (*n* = 42), getting to know each other posts (*n* = 10), and thank-you posts (*n* = 4).
- **Technology use.** About 26% of the posts (*n* = 34) discussed technology issues and included posts about best practices for using the app (*n* = 12), posts about challenges with using the app (*n* = 11), and posts about access to compatible devices (*n* = 11).
- **General implementation.** Around 11% of the posts (*n* = 14) discussed implementation of Playground Physics. These posts included probing questions by coaches about how the Playground Physics program is going for teachers (*n* = 10) and updates from teachers about how implementation of the curriculum is going (*n* = 4).

- **Curriculum.** Roughly 8% of the posts (*n* = 10) were related to the Playground Physics curriculum. These posts included analyses on the lessons or the curriculum (*n* = 6) and discussions about supplementary resources or lesson plans (*n* = 4).
- **Instruction.** Roughly 4% of the posts (*n* = 5) were general posts about how to teach the Playground Physics curriculum (*n* = 3) and teaching in a virtual environment (*n* = 2).
- **General science resource.** About 3% of the posts (*n* = 4) shared general science resources, unrelated to Playground Physics.
- **Workshop posts.** Around 3% of the posts (*n* = 4) were related to the professional development workshops hosted by NYSCI in October and December.
- **Evaluation activities.** About 3% of the posts (*n* = 4) included discussions about the teacher survey (*n* = 2) and about pre-post testing (*n* = 2).

Exhibit 12. The main topics of CoP posts were introductions and technology use.



Number of posts, by topic, in the CoP

In summary, coaches and teachers did not frequently engage in the online CoP. Four of the 12 responding teachers did not participate at all in the CoP. When the teachers did engage in the CoP, the majority of their posts were to introduce themselves to other teachers and coaches; express challenges with the technology; or, much less frequently, request and share best practices for using the curriculum and the app. Although the anticipated purpose of the CoP was to support classroom implementation, teachers infrequently posted to the online CoP during the period when they implemented the program. By the same token, coaches' posts to the CoP did not closely match teachers' self-reported periods of classroom implementation.

Section 3. To what extent and in what ways did teachers implement the Playground Physics curriculum? What were barriers and facilitators of implementation?

This section summarizes findings about how teachers implemented Playground Physics and how they adapted the curriculum. Teachers adapted the curriculum in a variety of ways, including their choice of which units and lessons to use, their approach to integrate Playground Physics with their regular curriculum, and their approach to introducing the app (see Box 1 for additional information about the curriculum). Seven of 12 teachers in treatment schools implemented at least one complete unit of Playground Physics. Most teachers used Playground Physics to supplement rather than replace their existing curriculum. Teachers reported that the greatest barriers to implementing Playground Physics were remote learning and issues with the app.

BOX 1. PLAYGROUND PHYSICS CURRICULUM AND ORGANIZATION

The Playground Physics curriculum comprises three supplemental middle school physical science units addressing topics of motion, force, and energy (respectively). This curriculum is designed to supplement any existing middle school science curriculum. During these units, students ask questions and define problems, plan and carry out investigations, identify patterns in data, and analyze and interpret data presented in graphs and charts. The centerpiece of the curriculum is an app that enables learners to visualize and reflect on scientific data to deepen their learning of physics concepts. Students use the app to record a video of an action (e.g., swinging, running). This video becomes a subject for students' investigations. In the "motion" lens, students connect the performance with variables such as distance, speed, and direction change. In the "force" lens, students identify force pairs (i.e., pull, push) at work in the action. In the "energy" lens, students explore a person or object's potential and kinetic energy.

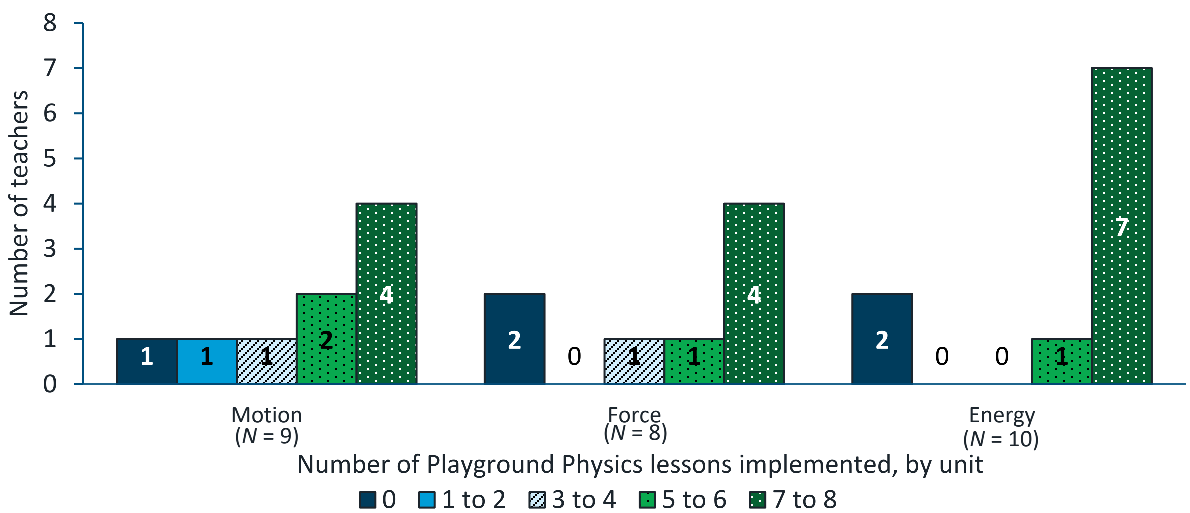
Each Playground Physics unit comprises seven or eight lessons. The duration of each unit is 1 to 2 weeks, for a total of 3 to 6 weeks for implementation of the entire curriculum. The initial lesson in each unit employs a series of questions to guide teachers in assessing students' prior content knowledge. Subsequent lessons build on one another to actively engage students through the use of the app and unit activities. Students are encouraged to engage in conversations prompted by questions that come up while they are exploring their video performances and associated graphs.

Teachers typically implemented most of the lessons in a Playground Physics unit.

A majority of teachers implemented at least one full unit of Playground Physics. Exhibit 13 shows the distribution of teachers across the number of Playground Physics lessons implemented in each unit. Each unit comprises seven to eight lessons. The chart includes teachers who taught at least one class period related to a given topic area (motion, force, or energy), regardless of whether they used the Playground Physics unit associated with that topic. Appendix B documents the number of teachers who implemented each lesson, both in aggregate and by learning environment (in person, remote, or blended).

- **Seven of 12 teachers reported implementing at least one Playground Physics unit in its entirety** (i.e., all lessons in the unit). Four of seven teachers completed three units in their entirety, and the remaining three teachers completed one unit in its entirety. The latter three teachers all completed the energy unit. One teacher did not use Playground Physics at all and instead used their regular curriculum to teach physics topics. Of the remaining four teachers, each teacher implemented a subset of lessons in just one of the three units.[8]
- **For any given unit, one to two teachers taught the topic without using any Playground Physics lessons.** These teachers used their regular curriculum to teach motion, force, or energy.
- **Relatively few teachers implemented only some of the lessons in a unit.** Partial completion was more common in the Motion unit—four teachers implemented some but not all of the lessons. Only one or two teachers implemented some but not all lessons in the Energy and Force units, respectively.

Exhibit 13. Teachers typically used most or all lessons in each unit, conditional on teaching the topic area associated with that unit.



Note. Teachers who reported teaching 0 total lessons in a given topic area are excluded. The survey item asked, "For each of the following Playground Physics lessons from the [Motion, Force, or Energy] unit, indicate the instructional format you used or indicate that you did not teach the lesson." The exhibit aggregates the total lessons taught in any format.

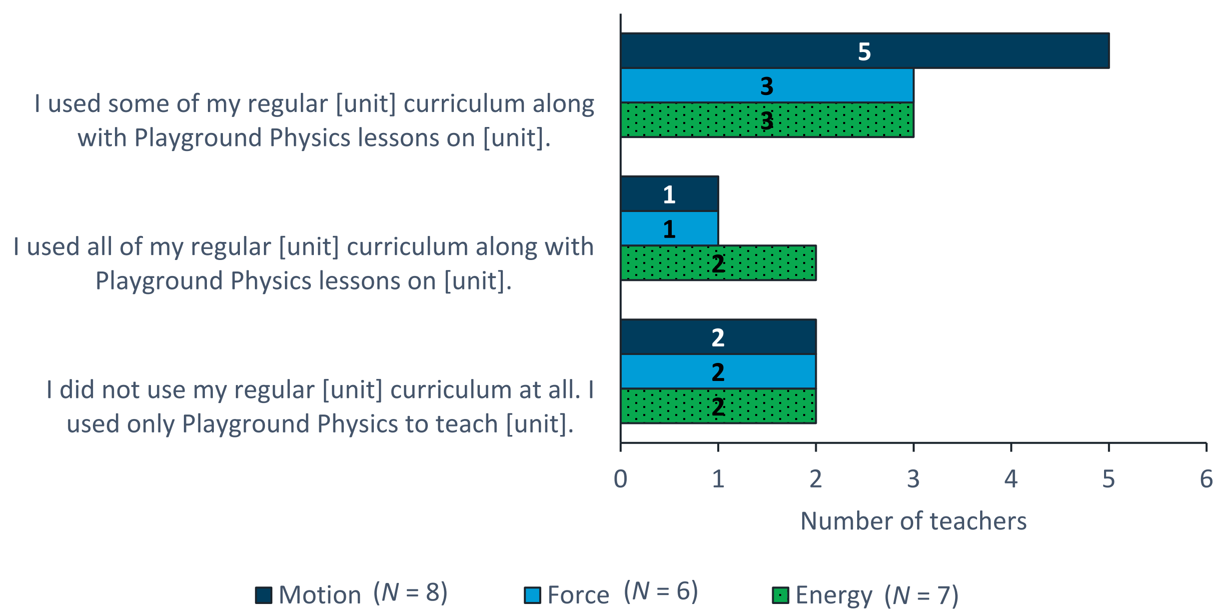
[8] Specifically, three teachers used lessons in the Motion unit (three, five, and five lessons, respectively), two teachers used lessons in the Force unit (five and four lessons, respectively), and one teacher used lessons in the Energy unit (six lessons).

Teachers adapted Playground Physics to integrate with their regular curriculum.

Most teachers reported that they used Playground Physics to supplement rather than replace their existing curriculum. Among teachers who used Playground Physics for a given topic, a majority of the teachers used at least some of their regular curriculum alongside Playground Physics (Exhibit 14).

- **Teachers most frequently reported that they used some of their regular curriculum along with Playground Physics lessons.** This was particularly common in the Motion unit—a majority of teachers (five of eight teachers) who used this unit did so in combination with a portion of their regular curriculum, compared to three of seven teachers who used at least some portion of the Energy unit and three of six teaches who used at least some portion of the Force unit.
- **Relatively few teachers used the entirety of their regular curriculum with Playground Physics.** This was somewhat more common in the Energy unit—two of the seven teachers who used the unit (and responded to this survey question) also used the entirety of their regular curriculum, compared to one of eight teachers in Motion and one of six teachers in Force.
- **Two teachers per unit replaced their regular curriculum with Playground Physics.** In other words, these teachers used Playground Physics to address the topic of the particular unit.

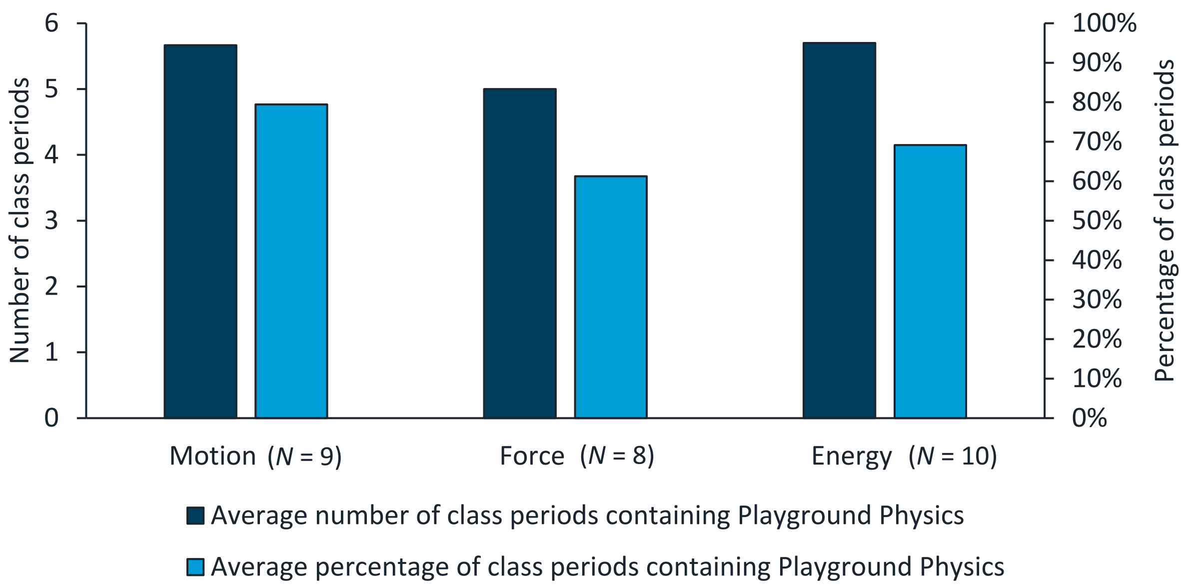
Exhibit 14. Most teachers used their regular curriculum alongside Playground Physics.



Note. The survey item asked, "Please describe how you integrated Playground Physics into your regular [motion, force, or energy] curriculum." Teachers who did not use Playground Physics for a given unit or did not respond to this question are excluded.

We asked teachers to report the number of class periods in which they taught motion, force, or energy, regardless of whether they taught these topics using the Playground Physics curriculum, their regular curriculum, or some combination of both. Among teachers who reported that they taught a given topic area (with or without Playground Physics), the average teacher used Playground Physics in five to six class periods per unit (Exhibit 15, dark blue bars).

Exhibit 15. The average teacher used Playground Physics in a majority of class periods per unit.

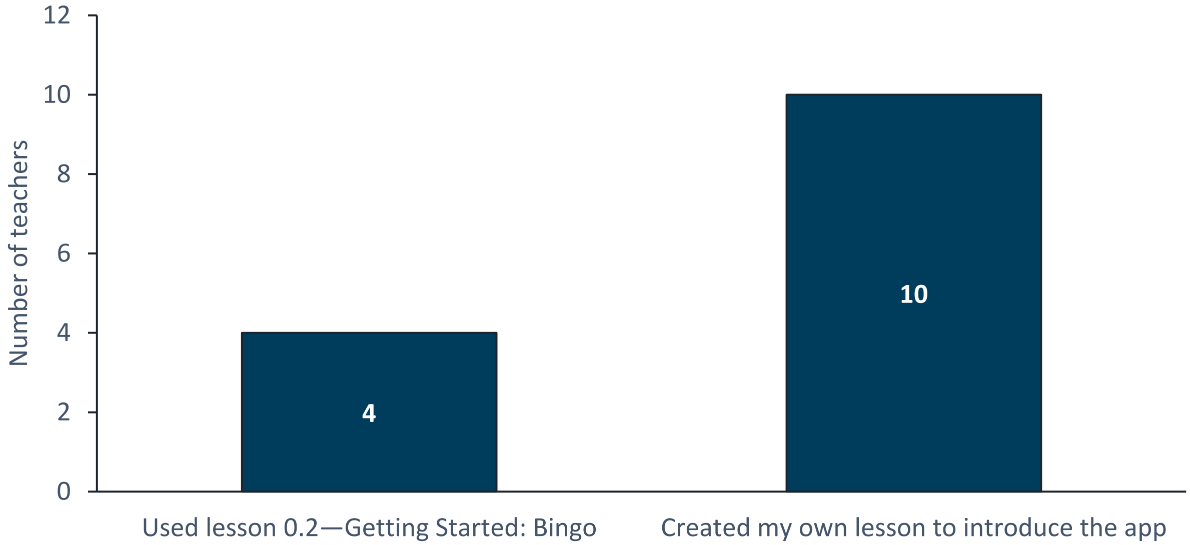


Note. Teachers who reported that 0 class periods included lessons on a given topic are excluded. Teachers who did not use Playground Physics at all are included. If a teacher reported fewer total class periods in a unit than class periods including Playground Physics in that unit, the number of class periods including Playground Physics was replaced with the total reported number of class periods in that unit. Bars show the average plus or minus the standard deviation.

Playground Physics lessons constituted a high proportion of the lessons taught on physics topics. When teaching lessons on motion, nearly four fifths of class periods included a Playground Physics lesson (Exhibit 15, light blue bars). By contrast, Playground Physics lessons comprised about three fifths of lessons on force, which is consistent with the finding that most teachers reported using at least some of their regular curriculum in addition to Playground Physics.

Most teachers customized the introductory lesson to Playground Physics. Nearly all surveyed teachers in the treatment condition (10 of 12 teachers) designed their own lesson to introduce the Playground Physics app. Four teachers used Lesson 0.2, “Getting Started: Bingo,” either on its own (two teachers) or in addition to a custom lesson (two teachers). No teachers selected response options of modifying lesson 0.2 (“Getting Started: Bingo”), using lesson 0.3 (“Fun With Physics Centers”), or not teaching a separate lesson focused on how to use the app.

Exhibit 16. Nearly all teachers created their own lesson to introduce Playground Physics.



Note. *N* = 12. The survey item asked, "How did you introduce the Playground Physics app to your target class? (Choose all that apply.)"

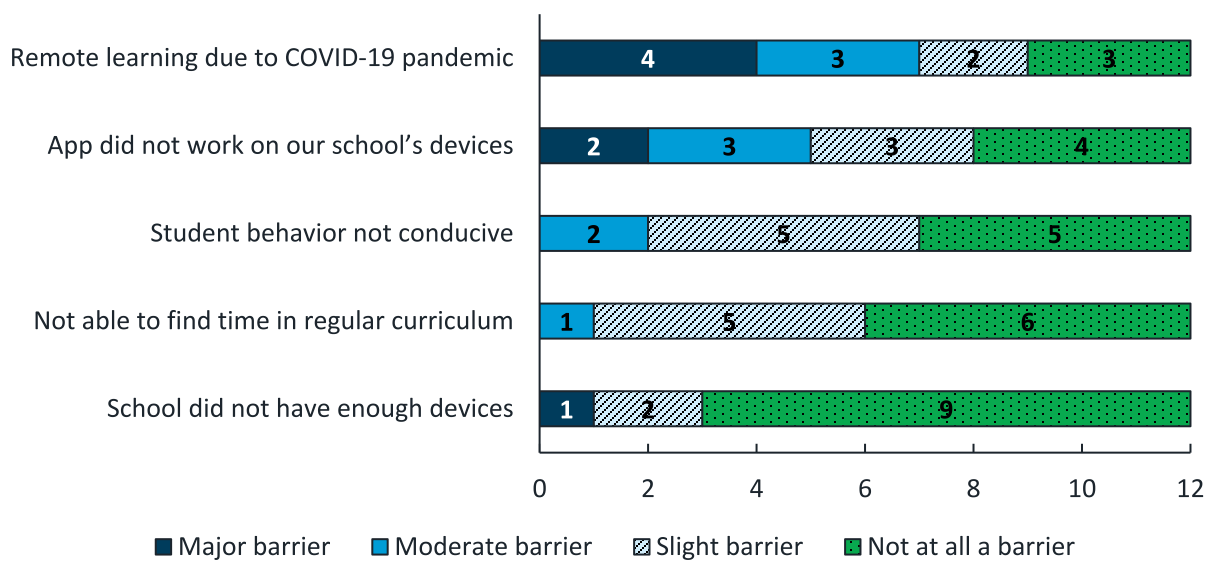
Remote learning was the most frequent barrier to implementation.

Remote learning due to the COVID-19 pandemic posed the greatest barrier to implementing Playground Physics, according to surveyed teachers in the treatment condition. Teachers rated the extent to which five factors posed barriers to implementation on a 4-point scale (Exhibit 17). Several teachers also encountered issues with using the app on student devices.

- **Seven of 12 teachers reported that remote learning was a barrier to implementing Playground Physics.** Four of these teachers rated remote learning as a major barrier, and three teachers rated it as a moderate barrier. One teacher explained that students learning remotely had difficulty completing activities: "The students that were [remote] had a much more difficult time doing the pendulum (swinging) activity at home." Another teacher added that students learning remotely did not always have devices to use with the app.
- **Five teachers reported that the app's performance on school devices was a barrier**, with two teachers rating the app's performance as a major barrier and three teachers rating the app's performance as a moderate barrier. In open-ended comments, teachers reported challenges with installing the app on students' devices (two teachers), using the app with devices that do not have touch screens (one teacher), and recording videos in the app (two teachers). Section 4 explores teachers' comments and recommendations regarding the app's usability.

- **Only one teacher reported that not having enough school devices was a major barrier**, and nine teachers did not find a lack of devices to be a barrier at all.
- **No teachers reported that student behavior or a lack of time in the regular curriculum posed major barriers**, but two teachers and one teacher (respectively) found student behavior and lack of time to be moderate barriers. One teacher elaborated that it was difficult to keep students on task while completing Playground Physics activities on the playground. Another teacher attributed the lack of time in their regular curriculum to a "shortened week." This teacher implemented all Playground Physics lessons in a blended format (both in person and remote) and may have been referring to a practice in some districts whereby some students attended school in person only some days of the week during the COVID-19 pandemic.
- One teacher reported, in an open-ended response, that coordinating parental consent forms to allow students to participate in the study was a major barrier to implementing Playground Physics.

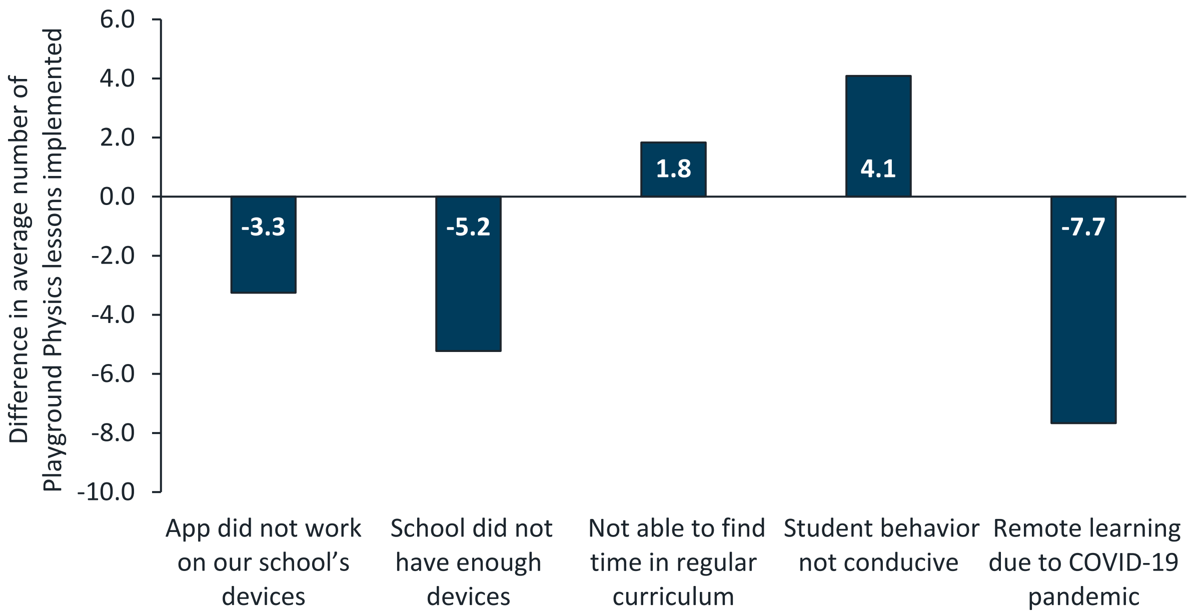
Exhibit 17. Greatest barriers to implementing Playground Physics include remote learning and technical issues using the app on school devices.



Note. *N* = 12. The survey item asked, "Please rate the extent to which each of the following was a barrier to your implementation of Playground Physics."

Teachers who reported implementation barriers due to remote learning taught fewer Playground Physics lessons than did teachers not selecting this barrier. Reported implementation barriers related to the school not having enough devices or the app not working on school devices were also associated with teaching fewer Playground Physics lessons, but to a lesser extent than remote learning (Exhibit 18). Teachers who considered remote learning to be at least a slight barrier used 7.7 fewer Playground Physics lessons, on average, than did teachers who did not consider remote learning to be a barrier. This finding is consistent with the high frequency with which teachers indicated that remote learning posed a barrier to Playground Physics implementation.

Exhibit 18. Teachers who experienced at least slight barriers with remote learning, device availability, or the app taught fewer lessons in Playground Physics.



Note. This figure plots the difference between the average number of Playground Physics lessons implemented by teachers for whom a given factor was at least a slight barrier and by teachers for whom the factor was not a barrier at all. The total number of Playground Physics lessons that could be implemented is 22 (8 in Motion, 7 in Force, and 7 in Energy).

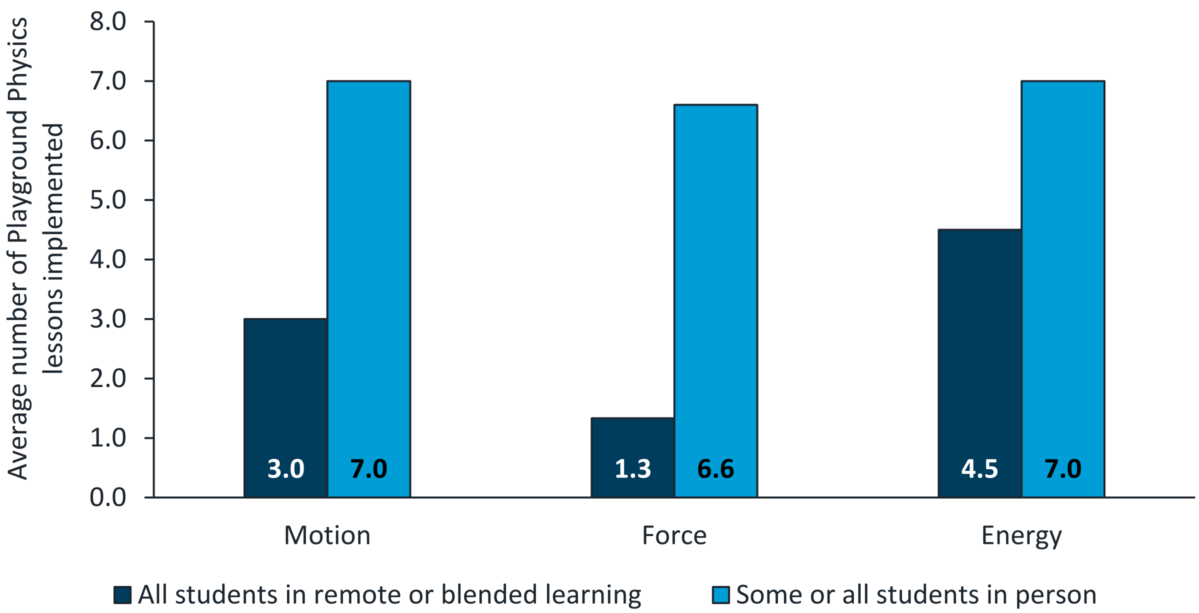
Teachers implemented fewer Playground Physics lessons in remote or blended environments than in in-person environments. For each topic area, we asked teachers to report the percentage of students who participated in person, remotely, or both in person and remotely (blended).[9] Exhibit 19 shows the average number of Playground Physics lessons implemented among teachers whose students engaged exclusively in remote or blended learning, compared to teachers with at least some full-time, in-person students. The exhibit includes only teachers who taught a given topic area (with or without Playground Physics). Whereas Exhibit 18 demonstrates that implementation levels were lower among teachers who reported that remote learning posed a barrier to implementation, Exhibit 19 shows that implementation

[9] A blended environment here refers to a situation in which an individual student engages in both in-person and remote learning. An exclusively blended classroom is a classroom where all students learn remotely some of the time.

levels were also lower among teachers who were primarily engaged in remote or blended teaching, regardless of whether they reported remote learning as a barrier.

- **Teachers with any students learning in person taught an average of 6.6 to 7 lessons in each Playground Physics unit.** Given that each unit contains a total of seven to eight lessons, this finding suggests that teachers with students learning in person tended to teach all or nearly all the lessons in each unit. It should be noted that many teachers in this category had entirely in-person classrooms. Of the four to five teachers with any students learning in person in each unit, two to three teachers reported that 100% of their students participated in person (see note to Exhibit 15).
- **Teachers with students who engaged exclusively in remote or blended learning taught relatively few Playground Physics lessons on average.** Teachers who reported that 100% of their students engaged in remote or blended learning in motion, force, or energy taught an average of 3, 1.3, and 4.5 Playground Physics lessons in that topic (respectively). In each unit, teachers with students who engaged exclusively in remote or blended learning taught fewer lessons in Playground Physics, on average, than did teachers with students learning in person, with the largest difference occurring in the force topic area (5.3 fewer lessons) and the smallest difference occurring in the energy topic area (2.5 fewer lessons).

Exhibit 19. Teachers with students who engaged exclusively in remote or blended learning taught fewer Playground Physics lessons, on average, than did teachers with any students learning in person.



Note. Sample sizes are as follows: Motion (remote or blended = 4 teachers, in person = 5 teachers), Force (remote or blended = 3 teachers, in person = 5 teachers), Energy (remote or blended = 6 teachers, in person = 4 teachers).

Two teachers described additional barriers in response to open-ended survey items that asked why a teacher did not use Playground Physics to teach motion, force, or energy. Both teachers experienced challenges with the timing of Playground Physics implementation. One teacher reported that they began teaching physics in October, before completing the data collection and professional development activities required to implement Playground Physics. One teacher who did not use Playground Physics at all reported that managing parental consent forms to participate in the study was a time-consuming process and that they were not able to get approval from the district to download the app to school iPads in a timely manner. This teacher suggested that these issues were compounded by the fact that Playground Physics training did not begin until the start of the school year. Delays associated with pre-implementation data collection or technical difficulties may have prevented this teacher from using Playground Physics in November, the period when they reported teaching motion, force, and energy topics.

In summary, 7 of 12 teachers in the treatment condition completed at least one full unit of the program (i.e., all lessons in at least one of the three units). When implementing the program, teachers typically implemented all lessons from a unit. Teachers tended to implement Playground Physics alongside at least some of their regular curriculum, and teachers typically used Playground Physics in a majority of class periods in each topic area. The greatest reported barrier to implementation was remote learning due to the COVID-19 pandemic, followed by issues with using the app on school devices.

Section 4. What are teacher perceptions of the usefulness of the Playground Physics curriculum for supporting physics instruction?

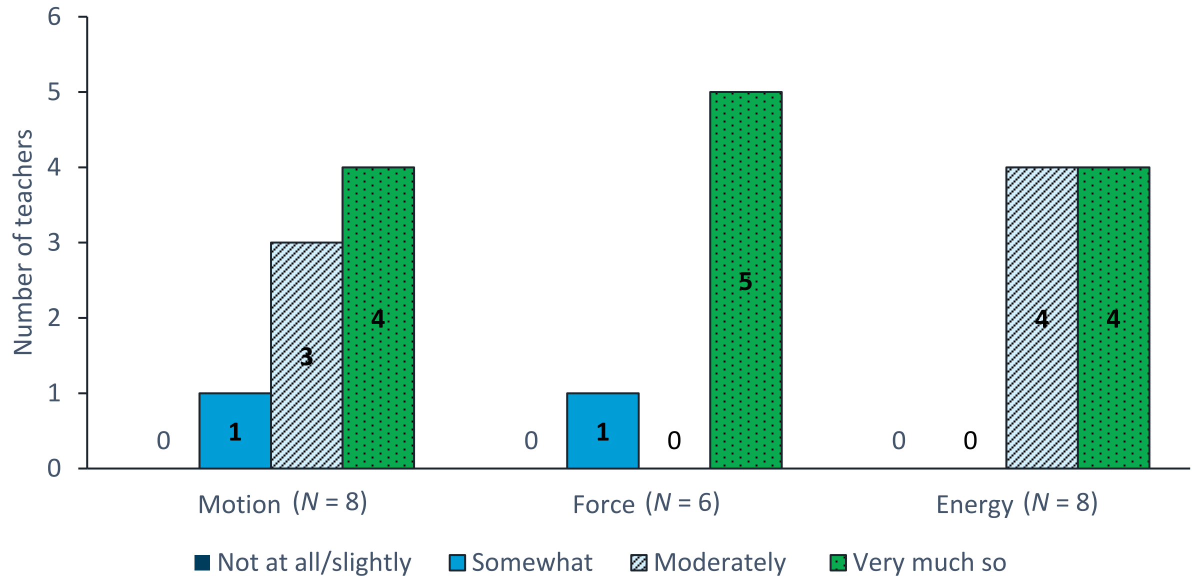
This section summarizes findings about teachers' perceptions of the extent to which Playground Physics supported student learning and engagement, drawing on survey responses of teachers in the treatment condition. Almost all teachers reported that Playground Physics at least moderately supported instruction, especially by helping students to visualize physics concepts and providing students with hands-on activities. Most teachers reported high levels of student engagement with Playground Physics; however, as noted in the prior section, some students were unable to use the app on their devices or had trouble performing activities due to complications with accessing the app or teacher implementation associated with pandemic-related remote learning environments. Teachers recommended several changes to instructional materials, such as restructuring student assignments and making materials more accessible to students with diverse learning needs. Teachers also recommended changes to the app, particularly related to recording or uploading videos.

Most teachers reported that Playground Physics supported instruction.

When asked to rate the extent to which Playground Physics supported their instruction of physics concepts, teachers generally reported high levels of support. Among surveyed teachers who used Playground Physics to teach motion, force, or energy, almost all teachers reported that Playground Physics at least moderately supported instruction in that unit (Exhibit 20).

- For both motion and energy, half of the eight teachers (four teachers) who used Playground Physics reported that it very much supported instruction.
- Of the six teachers who used Playground Physics to teach force, all but one teacher reported that Playground Physics very much supported instruction. However, fewer teachers used Playground Physics to teach the Force unit than the other units.
- No users reported that Playground Physics did not support or only slightly supported instruction in any unit.

Exhibit 20. Most teachers reported that Playground Physics at least moderately supported instruction in motion, force, and energy.



Note. The survey item asks, "To what extent did Playground Physics support your instruction of [motion, force, or energy] concepts?" The exhibit excludes teachers who reported that they did not use Playground Physics at all for a given unit.

In an open-ended survey item, 10 teachers described how Playground Physics enhanced their instruction of physics concepts. Teachers most frequently commented about the program's visualizations (e.g., graphs and videos), followed by real-world applications and explorations of challenging concepts.

- **Six teachers reported that Playground Physics enhanced instruction by helping students visualize physics concepts.** For example, one teacher wrote that the program helped with "[a]nalyzing reaction forces, by visualizing them," and another teacher said, "It gave the students a nice visual of the energy at work." One teacher emphasized the interactivity of the app's visualizations, noting, "Adding stickers to performances also creates a strong visual for students to connect concepts with experience." This same teacher mentioned that Playground Physics "took the math out of the motion unit" by graphing motion for students. Two teachers who highlighted visualizations added that Playground Physics helped students to apply physics vocabulary.
- **Four teachers said that students benefited from the app's activities.** Specifically, these teachers described the activities as beneficial to students in their "simple," "real-world," "everyday," or "hands-on" design (respectively). One teacher stated that students could "personally relate" to these activities. Another teacher said that "allowing students to

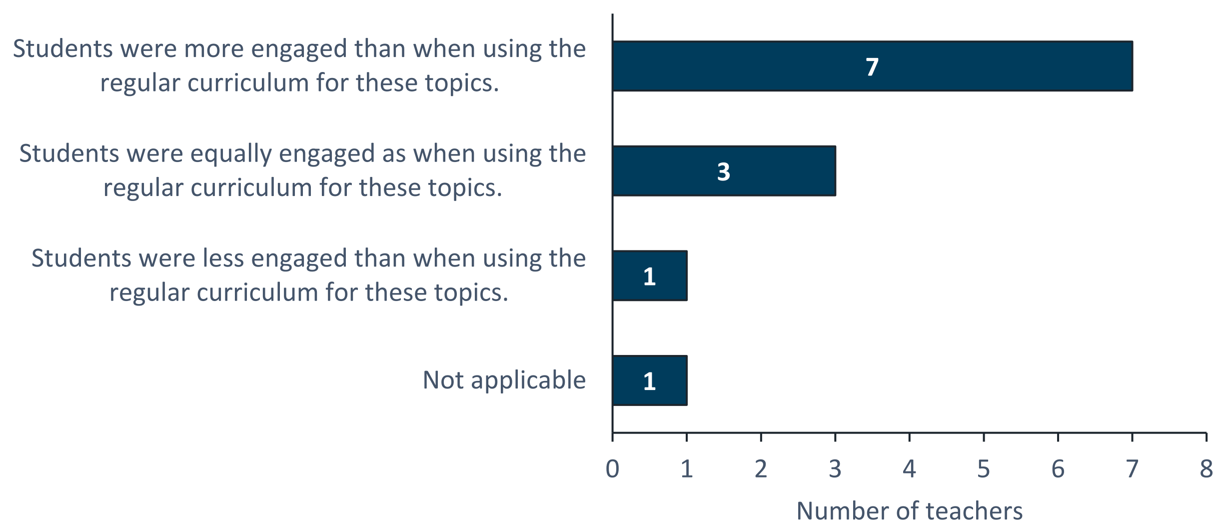
record and analyze their own data helped students to develop a deeper understanding" of physics concepts.

- **Four teachers said that Playground Physics helped students understand specific concepts**, which was particularly the case among teachers reporting on the Energy unit. One teacher indicated that energy is generally a difficult topic for students, writing, "My students struggle with energy, and the app really helped them identify and understand the different aspects of energy." Three teachers specifically mentioned kinetic and potential energy, and one teacher mentioned mass and speed. Although teachers did not always specify the mechanism through which Playground Physics helped students understand these concepts, one teacher pointed to visualizations, saying that Playground Physics gave students "a good visual of what is happening with the kinetic and potential energy."

Teachers reported high levels of student engagement with Playground Physics.

We asked teachers to compare the level of student engagement when using Playground Physics to the level of student engagement when using the regular curriculum alone. Slightly more than half of teachers (7 of 12 teachers) reported that students were more engaged during Playground Physics lessons than when using the regular curriculum. Three teachers reported that students were equally engaged as when using the regular curriculum. Only one teacher reported that students were less engaged, and one teacher did not use Playground Physics at all.

Exhibit 21. The majority of teachers reported higher levels of student engagement when using Playground Physics.



Note. *N* = 12. The survey item asked, "Please compare the level of student engagement during the Playground Physics lessons with the level of student engagement you have observed in prior years."

In an open-ended comment, 10 teachers elaborated on their ratings of student engagement to describe what features of the lessons seemed to most stimulate student interest and engagement with the content. In general, and discussed in more detail below, teachers tended to find that students were highly engaged in the hands-on activities included in the curriculum (although, as previously discussed, student engagement was hindered at times due to issues with accessing or using the app on available devices and/or complications engaging with Playground Physics materials associated with the remote learning environment).

- **Five teachers expressed that students benefited from hands-on activities that allowed them to generate their own videos, data, and/or ideas.** Four of these teachers suggested that students enjoyed these activities. For example, one teacher noted, “Students loved making the videos and annotating their motion,” and another teacher noted that students “really enjoyed coming up with their own ideas, asking questions, and then being able to test it out to find an answer.” The fifth teacher did not specifically indicate that students were not engaged but did indicate that students’ engagement levels were not necessarily motivated by enjoyment or more interest in the content than when learning via the regular curriculum. This teacher wrote, “Because students had to create experiences that they could analyze [using Playground Physics] they had little choice but to be engaged with lessons.”
- **Three teachers reported that students were equally engaged when using the Playground Physics curriculum as when using the regular curriculum without Playground Physics.** One of these teachers suggested that students would have been highly engaged regardless of the curriculum, adding, “They are a great group of students that love to learn.” Another teacher stated that students were initially eager to try Playground Physics but that “it was not as ‘exciting’ as they thought it would be.”
- **Two teachers reported that remote learning hindered student engagement.** Two teachers expressed that remote learning due to the COVID-19 pandemic made implementing Playground Physics difficult. For example, one teacher noted that students learning remotely did not always have the materials they needed to complete activities, such as the pendulum (swinging) or ball drop. This teacher noted that students in hybrid learning environments enjoyed the hands-on activities and did not encounter these same problems.
- **Two teachers described issues with students using the app on their devices..** For example, one teacher needed to display the app to the whole class on a single screen because students could not use the app on their individual devices (an approach that NYSCATE coaches termed “single-use implementation”). This teacher noted that single-use

implementation was a poor substitute for students being able to "manipulate parameters and make it their own."[10]

Teachers recommended changes to instructional materials and the app.

When asked what advice they would give to NYSCI about how to improve the Playground Physics app or Teacher Activity Guide, eight teachers in treatment schools recommended changes to materials (including assignments, assessments, and teacher materials), and five teachers discussed changes to or problems they encountered with the app. In both cases, several teachers focused on making instructional materials or the app more user friendly and accessible for all students.

Eight of 12 teachers recommended changes to instructional materials.

The following are major themes. Exhibit C6 in Appendix C includes comments about improvements to specific lesson activities.

- **Five teachers recommended specific changes to student assignments or assessments.** Two teachers suggested changes to extended (written) response questions—one teacher said that some of these questions should be converted to multiple choice questions "as kids have a tendency to shut down with extended responses lesson after lesson," and another teacher suggested breaking down the writing assignments into step-by-step prompts "to support students organizing their ideas and thoughts as they construct explanations." Another teacher felt that it was "boring" for students to encounter questions that are repeated for different activities in the Force unit. One teacher said that the physics knowledge assessment (administered by AIR for research purposes) was "difficult to comprehend" and suggested using three rather than four answer options for multiple choice questions, as well as rewording questions so that "they aren't too difficult for 6th graders."
- **Two teachers recommended additions to the Teacher Guide**, including providing teachers with additional problem-solving exercises or more extensive explanations of physics content that could serve as the basis for a lecture (e.g., a PowerPoint presentation).
- **Three teachers suggested that instructional materials and/or the app should be more accessible to students with diverse learning needs and backgrounds.** One teacher stated that the audio and video components of the app should be more accessible to students with special needs and that the app should be bilingual. Another teacher said, "The reading was difficult for students in a self-contained classroom." A self-contained classroom refers to a classroom in which all students have special learning needs. A third teacher stated, "I truly

[10] Elsewhere in the survey, a second teacher suggested developing alternatives to single-device implementation, such as "interactive PearDeck slides" or a desktop version of the app that "doesn't need to be downloaded to an iPad and already has preloaded videos with it."

do like this program and would like to see it used in the future, but changes need to be made to make it user friendly to students with special needs within a co-taught classroom."

Six of 12 teachers recommended changes to the Playground Physics app.

The following are major themes. Exhibit C6 in Appendix C includes comments about specific improvements to the app.

- **Five teachers recommended that the app should include additional functions or address errors in existing functions.** Two teachers mentioned that students encountered an error in the app that prevented them from recording videos directly in the app. Suggestions for improvements include allowing students to upload videos from their devices, allowing teachers to use the app on their desktop computers, making it easier to use the app on devices without touch screens, and simplifying the buttons used to navigate through the app.
- **Two teachers described issues with installing the app on student devices.** One teacher recommended that NYSCI "[t]alk to the [district] so that the app is already or easily installed on student devices."

Additionally, two teachers mentioned that they were disappointed that they did not have the opportunity to meet with the project team to discuss their feedback about Playground Physics. Before implementing Playground Physics, teachers participated in one professional development workshop run by NYSCATE and one data collection webinar run by AIR, both over Zoom. One teacher wrote, "If we are piloting a program, then we should have had another face to face meeting. I felt that if we did, then what we might have said may have [led] to ideas to brainstorm or questions and answers to bounce off one another. I am very disappointed." While no face-to-face (in-person) meetings associated with Playground Physics took place due to the COVID-19 pandemic, this teacher may have been referring to another Zoom meeting (as opposed to communicating in the online CoP) or suggesting that an in-person meeting should have been scheduled.

In summary, most teachers who used Playground Physics reported that the program enhanced student experiences in terms of both learning and engagement, especially through visualizations and hands-on activities. Teachers tended to attribute negative experiences with Playground Physics to remote learning environments forced by the COVID-19 pandemic and technical issues that arose related to accessing or using the app, such as limited or lack of available devices for all students or devices that did not fully support the app. Teachers also suggested changes and improvements to teacher support and/or student instructional materials and format, particularly to support accessibility and engagement of students with diverse language and/or learning needs.

Section 5. Fidelity of Program Implementation

This section presents findings about implementation fidelity for each key component of the Playground Physics program: coach training and support, teacher professional development and support, curriculum materials, and classroom implementation. For each component, the NYSCI project team identified one or more indicators, along with criteria for adequacy of implementation. This section describes the indicators for fidelity of implementation for each component and summarizes the findings. Some of the findings in the foregoing sections draw on the same data as some of these indicators draw on, but the purpose of this section differs in focus; specifically, we use the data collected here to evaluate whether implementation met these a priori criteria (see Exhibit 22 for a summary table).

Coach Training and Support

Coach training and support has four fidelity indicators: coaches attend training, coaches receive materials, coaches participate in virtual meetings, and coaches participate in the online coach CoP.

- **Coaches attend training (met).** The criterion for the indicator of coach attendance at training is for 80% of coaches to attend both days of the 2-day training. Staff from NYSCATE kept attendance records and shared these records with AIR. All six coaches attended training both days, meeting the criterion.
- **Coaches receive materials (met).** The criterion for implementation fidelity is for the facilitator guide, training PowerPoint, and supplemental handouts to be posted to Schoology. Staff from NYSCATE shared documentation showing that they posted all materials for the coaches to Schoology, meeting the criterion.
- **Coach participate in virtual meetings (met).** The criterion for implementation fidelity is for 80% of coaches to attend three or more of the quarterly meetings. Staff from NYSCATE shared the attendance data with AIR. Of the four quarterly meetings, all six coaches attended at least three, meeting the criterion. Two coaches missed one session but attended a follow-up session to make up for their absence.
- **Coaches participate in the online coach CoP (not met).** The criterion for implementation fidelity is for 80% of coaches to post to the coaches' online CoP biweekly. None of the coaches posted to the coach CoP on a biweekly basis, not meeting the criterion.

Teacher Professional Development and Support

Teacher professional development and support has three fidelity indicators: teachers attend training workshop, teachers participate in the online CoP, and coaches facilitate the online teacher CoP.

- **Teachers attend training workshop (met).** The criterion for implementation fidelity is for 80% of teachers to attend both days of the 2-day training workshop or the make-up session. NYSCATE shared attendance data with AIR. Eighty-six percent of teachers attended both days of the training workshop, or the make-up session, meeting the criterion.
- **Teachers participate in the online CoP (not met).** The criterion for implementation fidelity is for 65% of teachers to participate in the CoP biweekly (i.e., at least once in each 2-week period) during their individual classroom implementation periods. We used teacher survey responses to determine classroom implementation periods for each of the 12 respondents in the treatment condition. Then, we reviewed the threaded discussions in the teacher CoP and counted each time a teacher participated in the discussion (i.e., by initiating a thread or responding to a discussion prompt). These data indicate that one of these 12 teachers participated in the CoP at least biweekly during their individual classroom implementation periods, not meeting the criterion.
- **Coaches facilitate the online teacher CoP (not met).** The criterion for implementation fidelity is for at least one coach to facilitate the online CoP in 75% of the weeks during which at least one teacher is implementing the Playground Physics curriculum. We operationalized coach facilitation as posting a discussion prompt that encourages teachers to ask questions or discuss implementation experiences.[11] By reviewing the threaded discussions, we determined that coaches facilitated the CoP by posting discussion prompts in 56% of the weeks during which teachers were implementing the Playground Physics curriculum, not meeting the criterion.

Curriculum Materials

Curriculum materials have two indicators: teachers receive the Playground Physics app (Chrome OS or iOS), and teachers receive the Playground Physics Teacher Activity Guide.

- **Teachers receive the Playground Physics app (met).** The criterion for implementation fidelity is for the Playground Physics app to be available to teachers in Chrome OS or iOS. NYSCI shared documentation confirming the Playground Physics app was made available to teachers through the Chrome Web Store during the 2020–21 school year, meeting the criterion.
- **Teachers receive the Playground Physics Teacher Activity Guide (met).** The criterion for implementation fidelity is for teachers to have digital access to the Teacher Activity Guide prior to the start of professional development in October 2020. NYSCI shared documentation confirming that they made the Teacher Activity Guide and Student Workbook available to teachers in Schoology in September 2020, meeting the criterion.

[11] For example, one coach posted, “Just checking in with everyone to makes sure that it is all going OK. Do you have any further questions, or need help with anything for your implementation? If you are finished, *research questions* notwithstanding, how’d it go? Let us know, we are here to help.”

Classroom Implementation

Classroom implementation of Playground Physics has one indicator: teachers implement Playground Physics in their classroom.

- **Teachers implement Playground Physics in their classroom (not met).** The criterion for implementation fidelity is for 80% of teachers to implement one full unit (i.e., every lesson in that unit). Based on responses to the teacher survey, 58% of teachers implemented one full unit of the Playground Physics curriculum, not meeting the criterion.

Summary. Looking across the indicators of implementation, as summarized in Exhibit 22, reveals the following patterns:

- **Lower than anticipated participation in online CoPs.** Three different indicators address participation in the online CoPs: coach participation in the coach CoP and coach and teacher participation in the teacher CoP (respectively). Observed participation did not meet the criterion for any of these indicators. It is possible that the teachers and coaches did not find the online forum to be particularly useful and therefore declined to participate; teacher survey responses (reported in Section 1) lend support to this possibility. In addition, given the high levels of attrition in the study, the ratio of coaches to teachers was 2:1. It is possible that coaching occurred via email rather than through the CoP, a possibility suggested by NYSCI staff (M. Labriole, personal communication).
- **On-time development of program materials.** Three fidelity indicators relate to NYSCI's completion of program materials and distribution of these materials to participants, which included the coaching materials, Playground Physics app, and curriculum materials (Teacher Activity Guide and Student Workbook). NYSCI completed these materials and shared them along the expected timeline.
- **Coach participation in train-the-trainer model.** Apart from the low participation in the coach CoP, coach participation in the train-the-trainer model met other fidelity criteria—coaches participating in training workshops and periodic virtual meetings.
- **Inconsistent teacher implementation of program components.** Three indicators of implementation fidelity pertain to teachers, namely, their participation in the training workshop and online CoP and their curriculum implementation. Their participation in the training workshop met the fidelity criterion, their participation in the online CoP did not nearly meet the criterion, and their level of classroom implementation approached but did not meet the criterion.

Exhibit 22. Program implementation met fidelity criteria for some but not all indicators.

Indicator	Data Source(s)	Criterion	Actual Implementation	Met?
Coach Training and Support				
Coaches attend training	Attendance log	80% of coaches attend both days of training	100% of coaches attended both trainings	Yes
Coaches receive materials	Coach group in Schoology	Coach materials are posted to Schoology	Coach materials were posted to Schoology	Yes
Coaches participate in virtual meetings	Attendance log	80% of coaches attend 3 or more quarterly meetings	100% of coaches attended at least 3 of the quarterly synchronous virtual meetings	Yes
Coaches participate in the online coach CoP	Online CoP artifacts	80% of coaches engage in CoP activities biweekly	No coaches engaged in CoP biweekly	No
Teacher Professional Development and Support				
Teachers attend the training workshop	Attendance log; online artifacts	80% of teachers attend the training or make-up session	86% of teachers attended both days of the training	Yes
Teachers participate in the online CoP	Online CoP artifacts	65% of teachers engage in CoP activities biweekly during their classroom implementation	One teacher (7%) logged in to Schoology biweekly during their classroom implementation period	No
Coaches facilitate the online CoP	Online CoP artifacts	Coaches facilitate CoP in at least 75% of weeks during which teachers were implementing the curriculum	Coaches facilitated in 56% of the weeks during which teachers were implementing the curriculum	No
Curriculum Materials				
Teachers receive the Playground Physics app (Chrome OS)	Chrome Store	App is available to teachers in the Chrome Store	The Playground Physics app was made available to teachers in the Chrome Store	Yes
Teachers receive the Playground Physics Teacher Activity Guide	Schoology	Teacher Activity Guide is posted to Schoology	The Teacher Activity Guide was posted to Schoology	Yes
Classroom Implementation				
Teachers implement Playground Physics in their classroom	Teacher survey	80% of teachers implement at least one full unit	58% of teachers implemented one full unit	No

Section 6. Student Outcomes

An earlier experimental study of Playground Physics impact found that students in classrooms using Playground Physics had significantly higher engagement in science lessons, deeper and more effective learning of science concepts, and more positive attitudes about science than students in classrooms that did not use Playground Physics (Margolin et al., 2020). This section reports findings from the experimental study of the outcomes of this similar Playground Physics intervention. We report findings for the following outcomes: science knowledge, science engagement, intrinsic motivation, attitudes toward science, and educational aspirations.

Baseline Equivalence

In this section, we examine the baseline equivalence of treatment and control group students on the pretest measures of the outcomes: science knowledge, science engagement, intrinsic motivation, attitudes toward science, and educational aspirations.

We evaluated baseline equivalence on pretest measures by calculating effect sizes (Hedges' *g*) for the differences between students of treatment and control teachers on each measure. Following Ho et al., (2007), we adopted a criterion of an effect of greater than .25 to indicate that the groups are nonequivalent. Students in treatment schools had higher mean scores on the engagement and interest premeasures with a Hedge's *g* greater than .25 (Exhibit 23). In addition, students from treatment schools had higher mean scores on a measure of perceived physics utility, but the difference did not exceed the criterion of greater than .25. To minimize the influence of differences in student perceived physics utility and physics knowledge prior to participation in the study, statistical adjustments were made in the student outcomes analyses; pretest measures were included as covariates in the statistical models of program impact.[12] For the two outcomes with baseline effect size differences greater than .25, students in the treatment schools were matched with students in the control schools by their pretest scores, using a propensity score matching method. We matched students using a 1:1 ratio without replacement. Details about the analytic model used to estimate baseline differences can be found in Appendix D.

[12] According to the What Works Clearinghouse Procedures and Standards Handbook (v. 3.0, p. 15), effect size differences for a baseline characteristic between 0.05 and 0.25 require a statistical adjustment to satisfy baseline equivalence.

Exhibit 23. Means and standard deviation in pretest measures between students of treatment and control teachers

Pretest Measure	Number of Students		Pretest Mean (*SD*)		Effect Size (Hedges' *g*)
	Treatment	Control	Treatment	Control	
Knowledge assessment	224	485	6.58 (2.70)	6.41 (2.85)	0.06
Engagement	201	455	3.87 (0.56)	3.71 (0.54)	0.29
Perceived physics utility	201	455	3.78 (0.61)	3.67 (0.56)	0.20
Interest	201	455	3.17 (0.64)	2.98 (0.56)	0.33
Engagement (matched)	195	195	3.91 (0.49)	3.91 (0.49)	0.00
Interest (matched)	193	193	3.15 (0.59)	3.15 (0.59)	0.00

Note. Data represent scale scores using a logit metric. *SD*s are the unadjusted student-level standard deviations. Treatment group includes 10 school clusters, and control group includes 17 school clusters. Knowledge assessment scores ranged from 0 to 20. All survey scales ranged from 1 to 5.
Source: Author calculation.

Playground Physics Impact on Students

The remainder of this section discusses how participation in the Playground Physics program influenced student knowledge of physics concepts, engagement in science class, perceived utility of physics, and interest in physics. We conducted confirmatory analyses to measure differences between treatment and control groups using a two-level, hierarchical linear model with students nested within schools. Means and differences were regression adjusted to account for student grade level and student performance on pretest measures. Impact results for each measure were calculated separately. The technical approach to the impact analysis is described in Appendix D.

After statistical adjustments to satisfy baseline equivalence, we did not observe any differences between students of treatment and control teachers for any of the outcome measures. The regression coefficients for the treatment effect for each outcome variable, along with descriptive statistics for these outcomes, by condition, are provided in Exhibit 24. Full tables describing all regression coefficients are provided in Appendix E.

Exhibit 24. Regression estimates for treatment effect and descriptive statistics for outcome measures, by condition

Outcome Variable	Coeff.	SE	Treatment			Control			*DID*
			Mean	*SD*	*N*	Mean	*SD*	*N*	
Knowledge assessment	0.50	0.82	8.52	3.80	224	8.20	3.78	485	0.08
Engagement in science class	0.27	0.17	3.74	0.48	195	3.64	0.71	195	0.24
Perceived utility of physics	-0.01	0.09	3.44	0.76	201	3.46	0.79	450	-0.04
Interest in physics	0.17	0.08	2.90	0.69	193	2.91	0.66	193	-0.02

Note. Data represent scale scores using a logit metric. *SD*s are unadjusted student-level *SD*s. Means are adjusted to model covariates. Treatment group includes 10 school clusters, and control group includes 17 school clusters. DID = difference in differences.
Source: Author calculation.

Section 7. Conclusions and Recommendations

Based on the findings in this report, AIR shares the following conclusions and recommendations.

Teachers and coaches participated in online CoPs less frequently than expected. Teacher and coach participation in their respective CoPs was substantially less frequent than the stated criterion of biweekly posting. Most teachers posted one to three times in total, with a large proportion of these posts being introductions they posted about the time of the professional development workshop. Furthermore, we observed few instances of teachers participating in the CoP while they were implementing the program. Similarly, there were several weeks in which coaches did not facilitate the CoP when teachers said they were implementing the program. Not surprisingly, teachers did not rate the CoP as highly supportive. Nevertheless, we did observe that teachers sought and received support from the CoP. For example, teachers requested assistance with technology challenges and discussed best practices for using the curriculum and the app.

The low CoP participation may have been the result of the small number of teachers participating in the program. NYSCI designed the CoP and coaching to scale up the support of teachers implementing the program in 30 schools statewide. Given the attrition of teachers from the program, only 14 teachers total implemented the program. With these teachers divided into two separate CoPs, in most weeks, three or fewer teachers were actively implementing the curriculum. Such a small number of participants may lack the critical mass to foster an online community. Whether the CoP model would have fostered more participation with a greater critical mass of teachers is unclear. NYSCI and NYSCATE provided coaching on demand, outside of the CoP format. We recommend that NYSCI and NYSCATE consider whether to formalize a plan for one-on-one coaching and specify whether this approach would replace the CoP in the future or exist alongside it.

Teachers perceived the professional development workshops as effective to varying degrees. Professional development and support comprised an initial training workshop (conducted synchronously and remotely) and an online CoP. Teacher ratings of the workshop's effectiveness ranged from *somewhat* to *very much so*. Teacher attendance met the criterion for fidelity. Two teachers commented about the timing of the training not lining up with their teaching of physics. Indeed, most teachers did not begin to implement the program until 2 to 6 months after the workshop. ***We recommend that NYSCI consider how to reduce the lag between the training and curriculum implementation.*** For example, hosting a refresher session on a monthly basis may be possible, for each teacher to attend just prior to their classroom implementation.

Teachers adapted the curriculum in several ways. A majority of teachers taught at least one full unit. However, in each unit, some teachers adapted the curriculum by teaching only a subset of lessons included in the app. Some teachers chose to combine Playground Physics with some or all of their regular physics curriculum, some teachers used only Playground Physics for certain units, and some teachers chose not to use Playground Physics at all for certain units. Finally, most teachers set aside the curriculum's introductory lesson and created their own lessons to introduce students and engage them in using the app. ***We recommend conducting further study of teachers' decisions about what aspects of the curriculum to implement and what aspects not to implement.*** Based on this information, NYSCI would be better informed to revise its workshops and coaching to support implementation. This information could also inform NYSCI's decision about criteria to consider as essential for implementation fidelity.

More than half of the teachers reported that remote learning posed a barrier to classroom implementation. Teachers who taught in remote or blended educational environments tended to implement fewer lessons from the Playground Physics curriculum.[13] Teacher comments suggest possible reasons. For example, teachers reported that students learning remotely encountered difficulties in conducting activities on their own and that blended learning environments reduced the amount of time available for in-person activities. ***We recommend that NYSCI consider which lessons and activities are feasible for remote or blended learning and whether adapting the curriculum for these environments is worthwhile.*** One critical factor is whether students learning remotely are still able to engage in the embodied learning that is a hypothesized mediator of the program's impact. Although the COVID-19 pandemic forced schools to adopt remote or blended learning this past year, many schools may choose to use these learning environments more-or-less comprehensively in the future. The curriculum materials can provide clearer guidance about how the program can be implemented in these environments.

Nearly half of teachers reported a problem with app compatibility, which they described as a moderate or major barrier. In addition, half of teachers recommended improvements to the app, such as fixing problems with recording and uploading videos. We understand that many of these challenges stemmed from technical problems with the Chrome OS app, which NYSCI has since retired. Some teachers noted ways the app could be made more accessible to students with special needs. There is a new web-based version of the Playground Physics app that a new cohort of teachers is using. ***We recommend that NYSCI explore whether the new version of the***

[13] Due to the small number of teachers in the treatment condition, we combined the categories of remote and blended learning environments in our analysis of educational environment (see Section 3).

app has ameliorated the technical challenges reported by the 2020–21 cohort. Finally, on the positive side, no teacher reported that student behavior or a lack of time in the regular curriculum posed a major barrier.

Most teachers reported that the program enhanced student learning and engagement but also recommended areas for improvement. Nearly all teachers stated that the program supported instruction in physics. When explaining their ratings, teachers praised the program's visualizations and hands-on activities. At the same time, more than half of teachers recommended changes to instructional materials to improve their quality and usability. Some teachers suggested decreasing the difficulty level of assignments for younger students and for students with special needs. Finally, although the curriculum is designed to help students connect their embodied experiences at play to abstract physics concepts, none of the teachers mentioned embodied learning as enhancing student learning. ***We recommend that NYSCI continue to investigate how the program enhances student learning and engagement.***

The current study did not find any demonstrable impact of program participation on physics knowledge or science-related attitudes. However, these findings should be considered in light of the context of the COVID-19 pandemic and the significant shifts in teaching and learning environments that the original design of Playground Physics did not account for or could have anticipated. In light of the previously observed positive impact of the program when implemented prior to pandemic (Margolin et al., 2020) Further research is necessary to determine the impact of Playground Physics on anticipated student outcomes. Teachers in the present study implemented the program in an unfamiliar educational environment, and students were equally forced into different and challenging learning settings. Moreover, more than half of schools in the treatment condition withdrew from the study, resulting in a relatively small sample. At the same time, the program implemented a train-the-trainer model. Future research can explore the role of these and other factors in moderating the program's impact.

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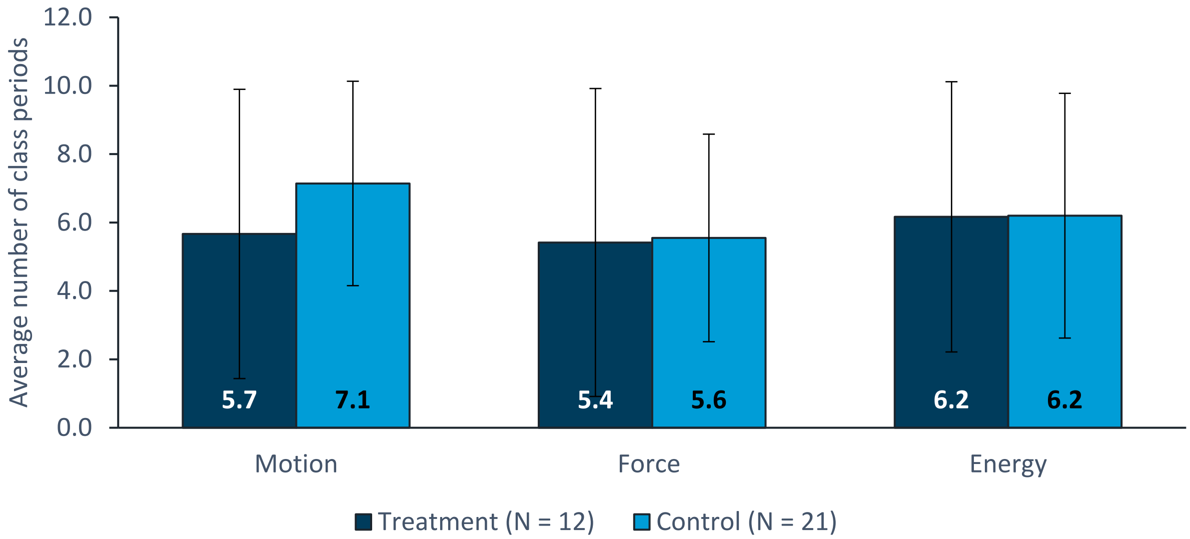
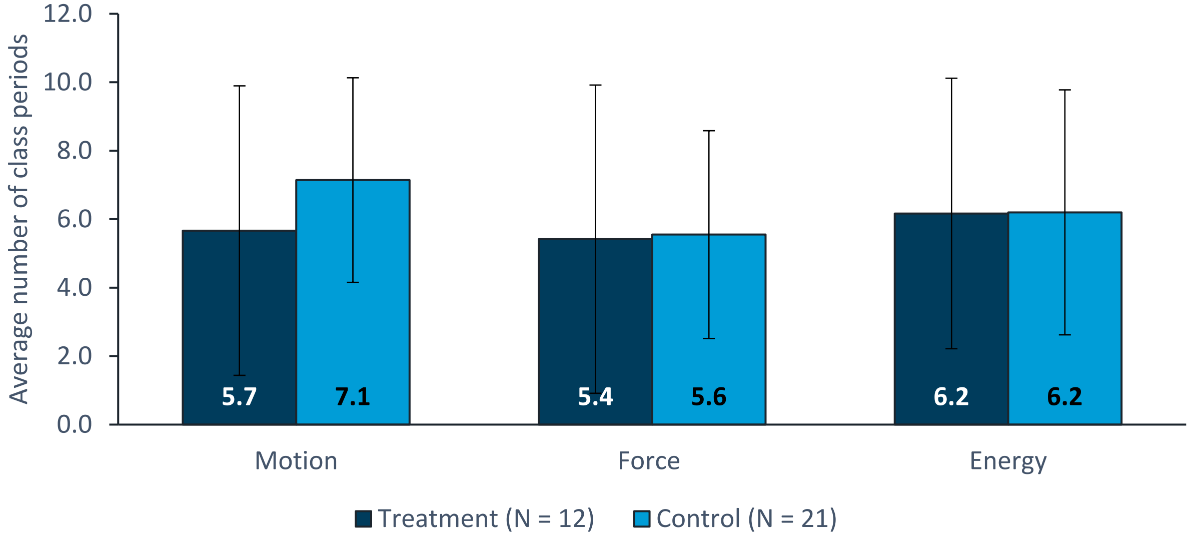
Appendix A: Comparing Treatment and Control Conditions

Exhibit A1. Teachers in both conditions spent a similar number of class periods on each instructional unit.



Note. Gray bars display the mean plus or minus the standard deviation. The survey item asked, "In total, how many class periods included lessons on motion (e.g., distance, direction, speed, velocity, acceleration) this school year? Include all class periods that incorporated a lesson on this topic, whether they involved Playground Physics or any other curriculum." Teachers are included even if they reported that they did not teach a given unit (0 class periods). The option "10 or more" is treated as 10 for the purpose of calculating averages.

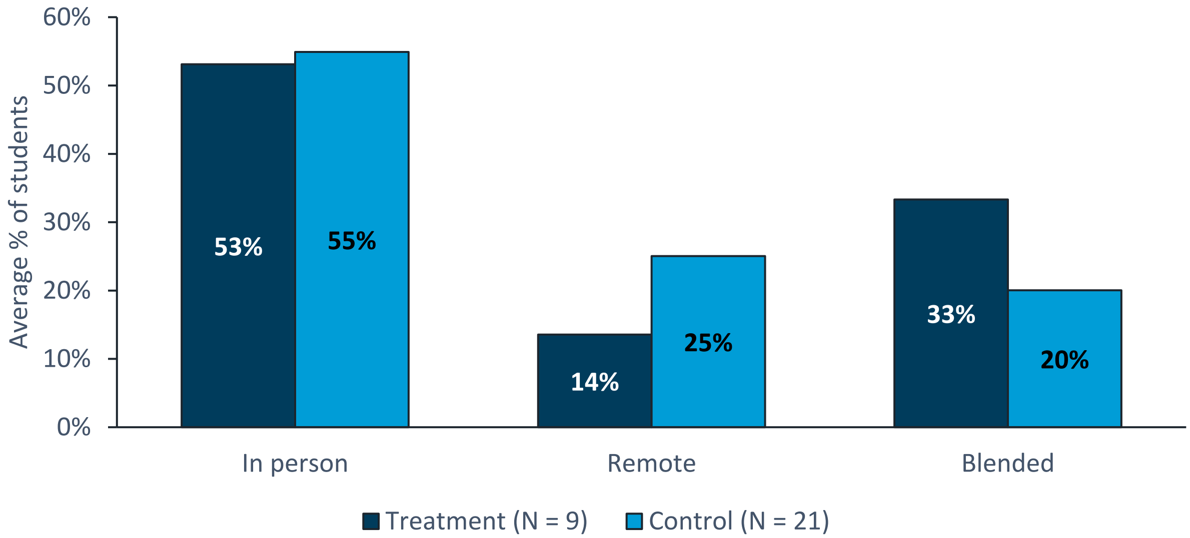
Exhibit A2. Teachers in both conditions spent a similar number of minutes on each instructional unit.



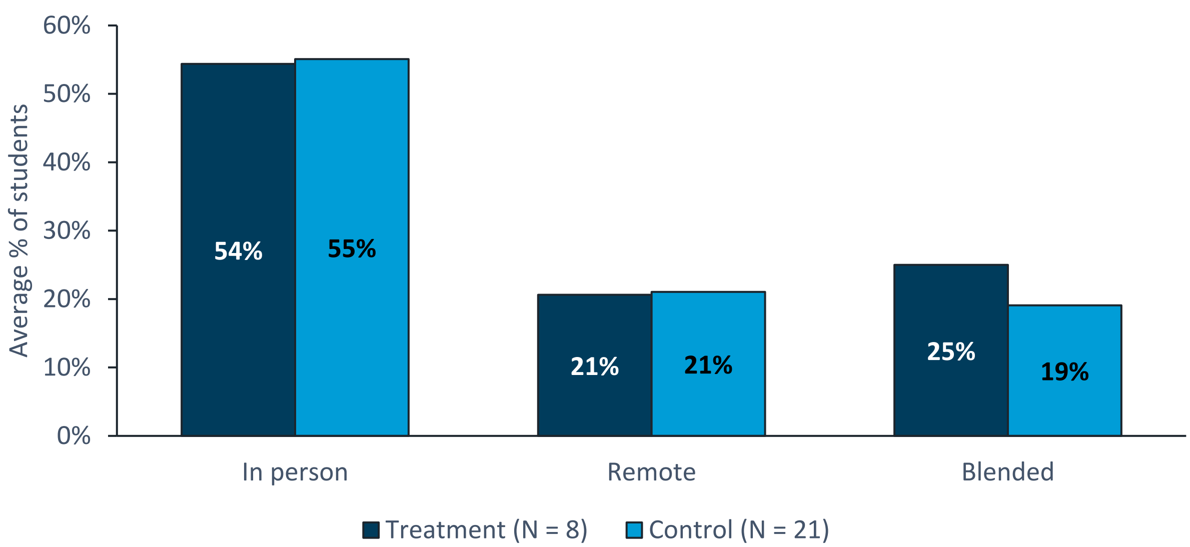
Note. Gray bars display the mean plus or minus the standard deviation. The number of minutes spent teaching each unit is calculated by multiplying the number of class periods spent on the unit by the number of minutes in each period. Teachers are included even if they reported that they did not teach a given unit (0 class periods).

Exhibit A3. Most students in both conditions learned each physics topic in person, except for energy among students in the treatment condition.

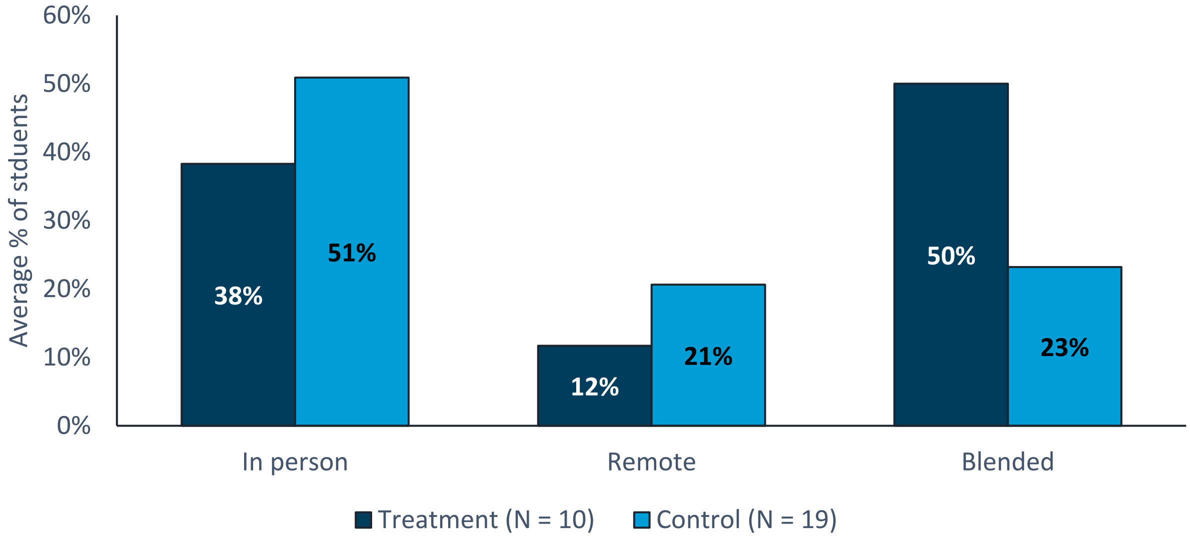
Panel A. Motion



Panel B. Force



Panel C. Energy



Note. The survey item asked, “What percentage of students typically participated in [motion, force, or energy] lessons in each of the following learning environments?” Teachers who reported that 0 lessons included the topic area were excluded.

Appendix B: Implementation of Playground Physics Lessons, by Learning Environment

Exhibit B1. Number of teachers implementing playground lessons in different learning environments

Lesson	In person	Remote	Blended	Did not teach this lesson	Total
Motion					
1.1—Playing Catch I	4	1	2	1	*8*
1.2—Fun With Motion	3	1	2	2	*8*
1.3—Playing Catch II	4	1	2	1	*8*
1.4—Playing Catch III	4	0	1	3	*8*
1.5—Data Match	3	1	1	3	*8*
1.6—Motion: Four Corners	3	0	3	2	*8*
1.7—Motion: Odd One Out	3	1	3	1	*8*
1.8—Home Run!	3	0	1	4	*8*
Force					
2.1—Jumping Rope I	4	0	2	0	*6*
2.2—Fun With Force	3	0	1	2	*6*
2.3—Jumping Rope II	4	0	2	0	*6*
2.4—Jumping Rope III	3	1	1	1	*6*
2.5—Force: Four Corners	3	1	2	0	*6*
2.6—Force: Odd One Out	3	0	2	1	*6*
2.7—Double Dutch!	3	1	1	1	*6*
Energy					
3.1—Swinging I	3	0	5	0	*8*
3.2—Fun With Energy	3	0	5	0	*8*
3.3—Swinging II	3	0	5	0	*8*
3.4—Swinging III	3	0	4	0	*7**
3.5—Energy: Four Corners	3	0	5	0	*8*
3.6—Energy: Odd One Out	3	0	5	0	*8*
3.7—Swinging Higher!	3	0	5	0	*8*

*One teacher did not respond to this item.

Appendix C: Responses to Open-Ended Survey Items

The following exhibits list all responses to open-ended survey items from a survey of 12 teachers in the treatment condition. The order of the responses in each table has been randomized.

Exhibit C1. "Please share feedback about how the professional development workshop and online community of practice could be improved."

I definitely felt prepared to teach the unit using the app and lessons. I really didn't have any questions or difficulty with the curriculum itself. My questions arose during the data collection (I think I just was worried . . . I wanted to make sure that all the students data was being collected.)
Schoology was difficult to keep up with due to the extra workload this year.
I thought the workshop was great! Participation in the online community of practice was more my fault than anything because I got wrapped up in doing in-person instruction and didn't network as well as I wanted to.
Our science and tech coaches really helped us in person to deliver the program to students.
"Single-device implementation" should be more than a teacher sharing their screen with the students. Could there be interactive PearDeck slides developed? Or a computer version of the app that doesn't need to be downloaded to an iPad and already has preloaded videos with it? This way we can avoid having to do the "single-device implementation."
I did the workshop in the fall. By the time I got to implementing the unit, I was rusty myself with how to use the app and the lessons. I'm not sure if there are different times of the year for this workshop, but a fall and spring session may be beneficial.
The app has a lot of potential. The workshop was informative and I didn't participate much with the Schoology community. However, I did use it to read comments and access some of the materials.
It would be great to meet in person. Due to the pandemic, we were not able to do this.
The workshop should be what you are gong to implement in the classroom. We were trained in one thing and had to teach another section of the program due to the time of the year. The program should be taught as a whole and not just a section.

Exhibit C2. "In what ways did Playground Physics enhance your instruction of [unit] concepts?"

Motion
The hands on activities
They were able to visualize the different components of motion, and could apply the vocabulary.
Playground Physics took the math out of the motion unit I usually teach because it graphed motion for students.
It gave them a good visual of what is happening with the kinetic and potential energy.
By allowing students to record and analyze their own data helped students develop a deeper understanding.
Students were able to personally relate to everyday activities.
It showed students a different way of looking at motion in real-world applications.
This was a better visual for the students to understand the energy and motion of an object
Ability to tie vocabulary to actual motion.
Force
Analyzing reaction forces, by visualizing them
Playground Physics creates the graphs students use to interpret forces.
It made students really think about the actions they make with simple activities.
It created a better visual of force of an object (for the students).
Energy
It gave the students a nice visual of the energy at work.
Analysis of changing KE and PE when position/speed changes
Playground Physics creates graphs that students can interpret to understand the concepts a little easier. Adding stickers to performances also creates a strong visual for students to connect concepts with experience.
The videos
We discussed potential and kinetic energy, mass, and speed.
Again, the visual aspect to the lessons were very helpful for the students to understand the concept.
My students struggle with energy, and the app really helped them identify and understand the different aspects of energy.

Exhibit C3. "Briefly explain why you decided not to use Playground Physics to teach [unit]."

Motion
Getting all students to receive the consent forms was a very time consuming process. If I recall correctly, we were also just beginning the trainings at the beginning of the year and the [district] never approved of the app download to the [district] iPads. Many obstacles that blocked our path.
Force
Force was taught in October. Playground Physics was introduced after.
Similar reasons as before.
Energy
Similar reasons as before.
Playground Physics was introduced after the energy lessons were taught.

Exhibit C4. Responses included in "Other" option of survey item, "Please rate the extent to which each of the following was a barrier to your implementation of Playground Physics."

The students that were only virtual did not all have a device to use with the app.
Consent forms with parents was another major barrier.
Difficulty covering all of the curriculum while using PP- primarily due to shortened week, also due to time required for PP, not enough time to focus on problem solving, etc. . . .
Having 19 8th grade students on the playground and keeping them on task is difficult.

Exhibit C5. "Please elaborate on your above response to describe how students engaged with Playground Physics lessons."

I don't think using the app made the students any "more" engaged then they would have been otherwise. They wanted to try it out and were excited but once they got into it, it was not as "exciting" as they thought it would be.
The students loved making the videos and annotating their motion. They told me that they were sad when the unit ended.
Because students had to create experiences that they could analyze they had little choice but to be engaged with lessons.
They really enjoyed coming up with their own ideas, asking questions, and then being able to test it out to find an answer.

The pandemic made it really challenging to get Chromebooks to students and get everyone engaged and to the same point before we could move on.
Kids responded well and were actively eager to find out what occurs during certain activities.
When it came to the outdoor activities, with the in person students, I gave the option of picking an activity they would like to complete. Once they picked I took them outside to complete the activity together as a group which was better/easier for them as opposed to them completing it by themselves.
The hybrid students did like doing the hands on pendulum and ball drop activities and plotting the points on the video. The students that were VLA had a much more difficult time doing the pendulum (swinging) activity at home. Not all students had what they needed for the ball drop as well.
Students were unable to use the app on their devices. Single use implementation was less interesting and interactive. Students were unable to manipulate parameters and make it their own.
The students completed all materials. It didn't matter what we used. They are a great group of students that love to learn.

Exhibit C6. "What advice would you give to New York Hall of Science (NYSCI) about how to improve the Playground Physics app or Teacher Guide?"

The reading was difficult for students in a self-contained classroom. The assessment was very difficult to comprehend. I would use 3 choices instead of 4 and think about the wording of the questions so they aren't too difficult for 6th graders.
Is there a way to bypass the consent forms until the end of the program? That way parents don't need to consent to sharing data until after data collection has been done and then only select parents decide if their student's data is shared with NYSCI?
Make the app bilingual Make the app more accessible to students with special needs (audio/video models) Talk to the DOE so that the app is already or easily installed on student devices.
The largest obstacle was that we were NOT using touch screen devices. Most videos had a meter stick in the viewpoint however it was still very difficult to estimate distance since we were not able to manipulate the start and end points.
1.) work out bugs in app (recording video directly in app) 2.) implement some multiple choice questions in maybe every other lesson as kids have a tendency to shut down with extended responses lesson after lesson. (Even if it is quick responses).
Re-format the writing assignments to support students organizing their ideas and thoughts as they construct explanations. For example, in the "Playing Catch I" assignment many questions are listed together for students to consider when they are playing catch. Perhaps breaking this down into writing prompts would help them to organize their thoughts better?

I think each lesson needs to come with a little more background information so teacher could turn that into a PowerPoint or presentation.
The app itself is not very user friendly. There are many "buttons" that the kids need to become familiar with in order to see all of the information you want them to see. Maneuvering around in the app was confusing for many of the kids. (especially when trying to deal with kids online at home)
Build in problem solving to the teacher guide (i.e. solving for acceleration using force screen, or distance or speed using motion screen)
For the app: the students should be allowed to upload videos from the iPads or whatever device they are using the app on; It's great that the app has its own videos, but just in case the app isn't working and they need to record, students should have the option to go back to the upload their own video. Teacher guide: For the force unit some of the items repeated. Having to answer the same questions over for a different activity is going to get boring for the students.
Hopefully we can schedule a Google Meet to express everything.
I really feel that this piloted program should have been in the springtime where all children would have been able to be outside on the playground, basketball and tennis courts. I think that doing now during the winter months was the right time to do so. If it was springtime, the students who might have a swing set in the backyard could have had an opportunity to make a video or participate like their counterparts during this pandemic. Therefore timing was an issue. Next, I feel that the slides presented in the student book on screen were difficult to view in certain parts. The coloring of the background and black typed information was so small and not very clear. The Thinking About Graphs worksheet was deceiving. The students had to talk about the 3 girls stomping on a top rocket. They are very small in the picture and almost of all of the students immediately looked at the larger rocket which was in clear view. Another issue I have is that the pages say recognizing energy at the top and were also confusing. Each page should have said beginning, middle, and end in recognizing energy. I truly do like this program and would like to see it used in the future, but changes need to be made to make it user friendly to students with special needs within a co-taught classroom. I am sure the same is true for our self-contained room. This app also should be licensed to Dell or Microsoft in order for teachers to use it on their computers. There was a lot of going back and forth between a Chromebook and our own district computers. We needed a technology coach to help us put the app onto the student's Chromebooks and had issues over several days. The video downloading was another issue as well. I wanted a meeting with the trainers or research institute to discuss these and other issues, but was told we had to do this survey. I think that was not right. If we are piloting a program, then we should have had another face to face meeting. I felt that if we did, then what we might have said may have lead to ideas to brainstorm or questions and answers to bounce off one another. I am very disappointed.

Appendix D: Technical Approach to the Impact Analysis

Baseline Difference Tests

Before testing for the impact of the Playground Physics program on student outcomes, we conducted baseline equivalence analyses to test for the equivalency of the intervention and comparison groups at baseline, as assessed with student pretest measures. Baseline equivalence with respect to pretest measures were evaluated by calculating standard mean difference, or effect sizes (Hedges' *g*), for the differences between students of treatment and control schools on each measure. Specifically, the student "pre-" survey and knowledge assessment for each of the domains of hypothesized impact (students' engagement and attitudes toward science and knowledge of science concepts) were used to assess baseline equivalence. The average scores on pretest measures were used to compare across treatment conditions. The effect sizes (Hedges' *g*) were calculated using the following formula:

$$\frac{u_t - u_c}{\sqrt{\frac{(n_t - 1)SD_t^2 + (n_c - 1)SD_c^2}{n_t + n_c - 2}}}$$

where u_t is the mean of students in the treatment condition and u_c is the mean of students in the comparison condition, n_t is the number of students in the treatment condition and n_c is the number of students in the comparison condition, SD_t is the standard deviation of students in the treatment condition and SD_c is the standard deviation of students in the comparison condition.

Following What Works Clearinghouse standards, for differences that were larger than 0.05 but smaller than 0.25 within each outcome domain, we included the pretest measures as covariates in the statistical models of program impact to minimize the influence of differences in student measures prior to participation in the study. For standard mean differences that were larger than 0.25, a one-to-one propensity score matching[14] technique was adopted to match students in the treatment condition with their most comparable students in the control condition using pretest measures.

Statistical Model Used to Test for the Program Impact

The analysis of the impact of Playground Physics on student outcomes was based off the simple cluster random assignment (schools randomly assigned to treatment or delayed treatment

[14] The propensity score is defined as the conditional probability of being assigned to the treatment condition given a set of observable covariates (Rosenbaum & Rubin, 1983). Propensity scores are commonly estimated by assuming a parametric model (e.g., a logistic regression model where a binary outcome that equals 1 for treatment group students and 0 for potential comparison group students is regressed on the observed covariates).

control condition). The main impact model was a mixed-effects regression model, with the following general form:

$$Y_{ij} = \beta_0 + \beta_1 \mathrm{PP}_j + \boldsymbol{\alpha}\mathbf{X}_{ij} + r_j + \varepsilon_{ij}$$

where Y_{ij} represented the outcomes of student *i* nested in school *j*. Due to the lack of student demographic data and the small sample of schools, the model did not include student demographic covariates or school characteristics. However, the model controlled for student pretest measure and grade level, represented by the covariate vector $\mathbf{X}_{ij}$. Random effect to account for variation due to schools (r_j) is included as well, along with a student error term (ε_{ij}). The treatment effect is measured by the coefficient β_1 for the treatment indicator (PP_j).

Appendix E. Regression Coefficients

This appendix includes tables describing all regression coefficients, by outcome.

Exhibit E1. Regression coefficients and standard errors from the physics knowledge assessment analysis

Predictor/covariate	Physics Knowledge Assessment	
	Coefficient	Standard error
Playground Physics	0.501	0.815
Pretest score	0.399***	0.056
Grade 6 reference		
Grade 7	1.841*	0.829
Grade 8	0.172	0.891
Constant	4.107**	1.464
Random effects	**Standard deviation**	**Variance component**
School intercept	1.499	0.335
Residual	3.301***	0.107
N	503	

* Significant at p < .05; ** significant at p < .01; *** significant at p < .001.
Source: Author analysis of data.

Exhibit E2. Regression coefficients and standard errors from the perceived utility of physics analysis

Predictor/covariate	Perceived Utility of Physics	
	Coefficient	Standard error
Playground Physics	-0.010	0.085
Pretest score	0.542***	0.046
Grade 6 reference		
Grade 7	0.027	0.092
Grade 8	-0.067	0.102
Constant	1.488***	0.225
Random effects	**Standard deviation**	**Variance component**
School intercept	0.060**	0.063
Residual	0.725***	0.023
N	524	

* Significant at *p* < .05; ** significant at *p* < .01; *** significant at *p* < .001.
Source: Author analysis of data.

Exhibit E3. Regression coefficients and standard errors from the student engagement analysis

Predictor/covariate	Student Engagement	
	Coefficient	Standard error
Playground Physics	0.268	0.169
Pretest score	0.512***	0.061
Grade 6 reference		
Grade 7	0.199	0.148
Grade 8	0.256	0.168
Constant	1.342***	0.290
Random effects	**Standard deviation**	**Variance component**
School intercept	0.326***	0.063
Residual	0.471***	0.020
N	302	

* Significant at $p < .05$; ** significant at $p < .01$; *** significant at $p < .001$.
Source: Author analysis of data.

Exhibit E4. Regression coefficients and standard errors from the interest in science analysis

Predictor/covariate	Interest in Science	
	Coefficient	Standard error
Playground Physics	0.165*	0.079
Pretest score	0.506***	0.064
Grade 6 reference		
Grade 7	0.106	0.091
Grade 8	0.292*	0.114
Constant	1.084***	0.232
Random effects	**Standard deviation**	**Variance component**
School intercept	< 0.001***	< 0.001
Residual	0.612***	0.026
N	284	

* Significant at $p < .05$; ** significant at $p < .01$; *** significant at $p < .001$.
Source: Author analysis of data.

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