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Playground Physics Implementation Study

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Executive Summary

Playground Physics is a technology-based program designed by New York Hall of Science (NYSCI) to support middle school students' science engagement and learning. The program includes professional development, the Playground Physics app, and a curriculum aligned with New York State Learning Standards, Common Core State Standards, and the Next Generation Science Standards. The curriculum was designed to fit teachers' personal instructional preferences, and the iOS app allows students to record and review videos through three "lenses": motion, force (Newton's third law), and energy. The program is designed to facilitate teacher instruction and to have a positive impact on student engagement in science. Increases in student engagement are expected to moderate longitudinal student attitudes toward science and learning of physics concepts.

This purpose of this report is to provide NYSCI timely feedback on (1) Playground Physics program implementation and implementation fidelity during the 2014–15 academic year and (2) examine changes in student affect and knowledge of key physics concepts as a result of participating in Playground Physics.

The final implementation fidelity and student outcomes sample included data from 18 teachers from 11 schools. In total, 543 students were included in the final analytic sample. All 18 teachers in the final sample were provided with Playground Physics program professional development and materials. The 2014–15 study does not include a control condition.

Program Fidelity of Implementation and Use

NYSCI identified three components of Playground Physics implementation fidelity: professional development, materials, and enactment of Playground Physics. Benchmarks for high fidelity were set for each component. To reach high fidelity rating on professional development, NYSCI was required to deliver all three days of professional development, and 81 percent of all teachers needed to attend all three days of professional development. To achieve a high rating for materials, 95 percent or more of teachers needed to receive all three materials: app, curriculum, and two or more iPads. In addition, to achieve high component fidelity ratings on enactment of Playground Physics, 81 percent of teachers were expected to use Playground Physics in at least seven class periods and cover all three physics content areas (energy, force, motion) using at least one instructional strategy per content area (i.e., single-device approach, multiple-device approach, or science investigation).

During the 2013–14 school year, NYSCI and the majority of participating teachers were not able to attain high component fidelity ratings on any of the three component fidelity measures.

In addition, data on teacher and student use of Playground Physics in classroom was collected using a teacher survey. Overall, the survey findings indicated that the app was heavily used by students during instruction and teachers most commonly reported supplementing Playground Physics with their regular curriculum in each of the three content areas: energy, motion, and force.

Reactions to Playground Physics

The teacher survey was also used to capture information on teacher and student reactions to and use of the Playground Physics program during the 2014–15 school year. Most teachers believed professional development prepared them to use the Playground Physics program moderately or very well. Furthermore, the majority of teachers believed Playground Physics was moderately or very educationally effective for teaching each of the content areas and would use the program in the future.

Student Outcomes

Student affect and knowledge of key physics concepts were measured at two points in time: once prior to teacher implementation of Playground Physics (December 2014) and once at the end of the school year when Playground Physics implementation was complete (May 2015). The student affect survey captured data on the following constructs: student engagement in science class, overall attitudes toward science, intrinsic motivation and educational and career plans relevant to science, and knowledge of standards-aligned science content. The knowledge assessment included 20 multiple-choice questions aligned to four New York science standards related to the content covered in the Playground Physics program.

For the student affect analysis, Rasch-derived scale scores were modeled using a Hierarchical Linear Model approach. Results indicated that student engagement in science and attitudes toward science (Science self-concept and Interest in science) were less positive at the end of the school year compared to the beginning of the school year. No differences were noted for student motivation and educational and career aspirations.

A paired sample *t*-test was used to investigate the difference in the student knowledge assessment scores between the two administrations. Students achieved higher score at the end of the year, and the difference was statistically significant. Knowledge assessments results should be interpreted with caution. Because there was not a control group in the implementation study, it is unclear whether teacher use of Playground Physics in whole or as a supplement to their regular curriculum would lead to greater student engagement and learning gains than those teachers who would have used only their own traditional instruction on energy, force, and motion with students.

Chapter 1: Playground Physics Overview

The New York Hall of Science (NYSCI) received a 2011 i3 Development Grant to create Playground Physics, a technology-based application and accompanying curriculum designed to support middle school students' learning. It is designed to have a positive impact on student engagement and attitudes toward science and to foster deeper learning of physics concepts.

American Institutes for Research (AIR), an independent, nonprofit, nonpartisan organization, was selected to evaluate NYSCI Playground Physics program. The evaluation of the Playground Physics program includes an implementation study during the 2014–15 school year and an impact study during the 2015–16 school year. This report will focus on results of the 2014–15 implementation study.

The Playground Physics implementation study formatively evaluated what Playground Physics implementation looked like in participating classrooms, teacher and student reactions to the program, and changes in student affect and knowledge of key physics concepts as a result of participating in the Playground Physics program. Teacher surveys supplemented with formative data collected from teacher interviews and classroom observation in February 2015 (See Preliminary Findings From SciPlay Classroom Observations and Interviews report) were used to understand variations in implementation and teacher and student reactions to Playground Physics. Pre- and posttest student surveys and knowledge assessments were used to capture changes in student engagement in science class, attitudes toward science, and physics knowledge before and after participating in Playground Physics. The implementation study included 18 teachers and 543 students.

The remainder of Chapter 1 describes the Playground Physics program and logic model in greater detail. Chapter 2 provides an overview of the sample, instruments, and analytic methods employed to conduct the Playground Physics evaluation. Chapter 3 presents finding on developer and teacher implementation of Playground Physics. Chapter 4 examines changes in student affect and knowledge of key physics concepts as a result of participating in Playground Physics using a pre- and posttest sample design, and Chapter 5 provides a high level discussion of the results of this evaluation and recommendations for program improvement.

Playground Physics Program and Logic Model

NYSCI developed Playground Physics to improve student engagement by using technologies that support students' engagement in science class, which in turn was expected to have a positive impact on student attitudes toward science and deepen student learning. Following we describe the resources, inputs, and outcomes of the Playground Physics logic model. Figure 1 provides a graphic depiction of the Playground Physics logic model.

Resources

During the 2014–15 academic year, NYSCI provided 18 participating middle school science teachers from the New York City region with professional development and Playground Physics materials. Materials included an app and curriculum aligned with New York State Learning Standards, Common Core State Standards, and the Next Generation Science Standards. The iOS-based app allows students to record and review videos through three "lenses," also referred to as content areas, that highlight the underlying physics principles of motion, force (Newton's third law), and energy.

Professional Development. NYSCI developed and delivered professional development for the Playground Physics. Professional development consisted of three sessions: two afterschool sessions of about 3.5 hours each and one weekend session lasting approximately 6.5 hours. NYSCI offered two options per session.[1] Each teacher was expected to participate in all three professional development sessions. During these professional development sessions, teachers were taught how to use the Playground Physics app and curriculum and were afforded the opportunity to practice using these materials with other science teachers who attended their sessions.

Playground Physics iOS App. The Playground Physics app allowed students to record videos of a person or object's movement. Once a video was recorded, students could open a recording and use a tracking feature to follow a person's or object's motion on the screen. Following recording and tracking the motion of a person or object, students could explore how physics exist in their everyday play experiences. In the motion lens, students examined how distance, speed, and direction change when things move. In the energy lens, students explored a person's or object's potential and kinetic energy, and in the force lens, students used annotation stickers to identify equal and opposite forces in their recorded performance.

Playground Physics Curriculum. The Playground Physics curriculum could be taught through three instructional approaches: single device, multiple device, and science investigation. According to the NYSCI, the single-device instructional approach is teacher directed and thus involves only a single iPad device. The multiple-device approach is so named because it involved teams of students each with their own device. This approach was intended to support inquiry-oriented instruction. Long-Term Science Investigation (LTSI) mirrored a traditional scientific method instructional approach. The scientific method was designed to help students learn through structured experimentation. In the scientific method, the experimenter must identify a question or problem, develop a hypothesis, document experimental procedure, test the hypothesis, review the data, and state their conclusion. NYSCI expected teachers to vary in the extent to which they use inquiry or investigative approaches. By offering these three instructional approaches, teachers could choose the instructional approach to which they were most accustomed.

Playground Physics curriculum units were designed to be flexibly integrated into teacher instruction. Teachers could use the Playground Physics curriculum to replace or supplement curriculum they used in past instruction. More so, teachers could use one or more of the program's instructional strategy to teach energy, force, and motion throughout the school year. Each instructional approach includes a series of activities to help facilitate instruction. See Appendix A for single- and multiple-device as well as LTSI curriculum activities.

[1] Session 1: 12/9/2014 or 12/10/2014; session 2: 12/13/2014 or 12/14/2014; session 3: 12/15/2014 or 12/16/2014

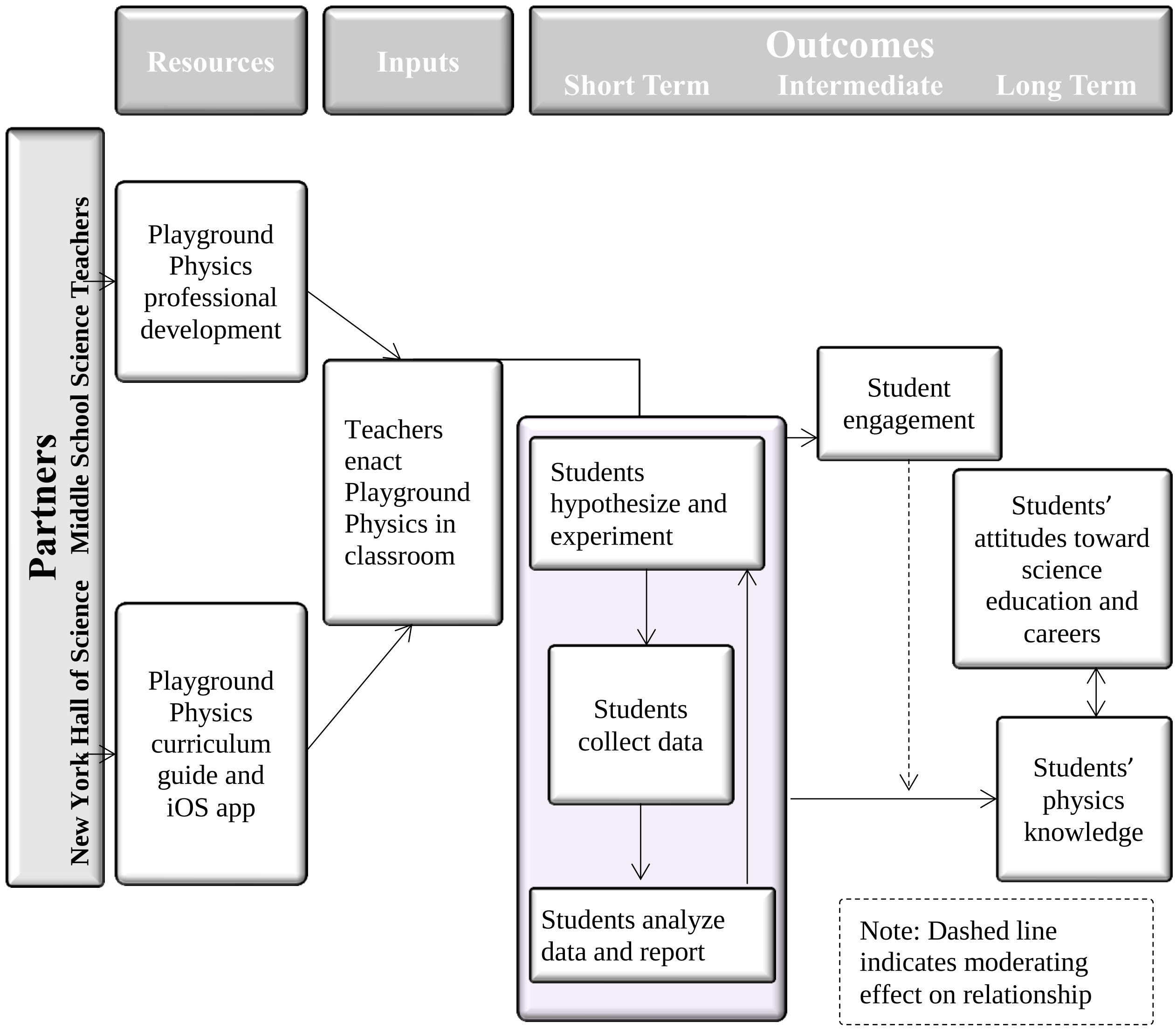
Inputs

Each teacher was expected to enact the Playground Physics program in their respective classrooms. Teachers were expected to cover all three physics content areas (energy, force, and motion) using at least one instructional strategy (single, multiple, or LTSI) per content area. In addition, teachers were to use the Playground Physics curriculum and app in a minimum of seven class periods. How many class periods were used for each concept was left to the discretion of the participating teachers.

Outcomes

The Playground Physics curriculum integrated the elements of informal learning that promote student engagement and elements of formal, inquiry-based learning that lead to deeper understanding of scientific concepts. Informal science environments have been shown to have a positive impact on aspects of students' science affect, including intrinsic motivation (Bell, Lewenstein, Shouse, & Feder, 2009; Zuckerman, Porac, Lathin, Smith, & Deci, 1978) and engagement (Tisdal, 2004), which evoke longer term attitudinal changes, such as interest in science. We hypothesize that greater engagement in science lessons would reinforce attitudinal changes and lead to deeper understanding of science concepts. Attitudinal changes include improved science self-concept, interest in science, and motivation and interest in pursuing academic and career opportunities in science.

Figure 1. Playground Physics Logic Model



Chapter 2: Sample and Data Sources

In this chapter, we present the sample and data sources used to evaluate Playground Physics fidelity of implementation and use, teacher and student reactions to the program, and changes in student affect and knowledge of key physics concepts as a result of participating in the Playground Physics program.

Sample

Twenty-two teachers from 15 New York area schools were recruited by the NYSCI to participate in the 2014–15 Playground Physics implementation study. Participating teachers were required to teach sixth, seventh, or eighth grade and agree to teach energy, force, and motion during the school year. All teachers participating in the study received the Playground Physics program in December 2014.

Of the 22 teachers recruited for the study, two teachers failed to obtain any student assent and parent consent information. An additional two teachers left the study midyear. The teachers who left the study failed to share student posttest knowledge assessment data and complete measures used to assess implementation fidelity (teacher survey). As a result, the two teachers who failed to obtain consent and the two teachers who left the study were removed from analytic sample. The final sample included 18 teachers.

Fidelity of Implementation and Student Outcomes Sample

The final fidelity of implementation and student outcomes sample included data from 18 teachers from 11 schools. Nine of the 11 schools were in the New York City region, and two schools were from the greater New York area. Class rosters provided by these teachers identified 1,108 potential student participants. Of these 1,108 students identified, 631 provided both student assent and parent consent to participate in the study. Four of the 631 students left the study midyear because they either changed classes or moved to another school. Eighty-four students did not complete all four pre- and posttest tasks (surveys and assessments) and were excluded as well. In total, 543 students were included in the final analytic sample.

Teacher and Student Reactions to Playground Physics Sample

In February 2015, AIR conducted classroom observations and teacher interviews midyear. Findings from these data sources were provided to NYSCI in April 2015 and provided formative feedback on program implementation during the 2014–15 school year. Because classroom observations and interviews were conducted with a subset of five participating teachers, it is unclear how representative the feedback gained was to overall program implementation.

To better understand program implementation, AIR administered a teacher survey to all participating teachers at the end of the 2014–15 school year. The 18 teachers who met study requirements and the two teachers who received and used Playground Physics materials but failed to attain student assent or parent consent were included in the teacher survey analysis. The two teachers who did not obtain student assent or parent consent were included in the survey analysis because they offered useful formative feedback on how the program was received in their classrooms.

Sample Characteristics

This section describes the characteristics of teachers and classrooms participating in the 2014–15 implementation study.

Teacher Characteristics

The 18 teachers who met study criteria during the 2014–15 school year varied in both the number of years they have been teaching in general and in science specifically. Teacher general instructional experience ranges from 1 to 22 with average of 12.2 years of general experience. Teacher science instructional experience range from 1 to 16 years with an average of 9.4 years of science instructional experience.

All 18 participating teachers reported earning their masters degrees. Teachers were asked to report subjects for any degree earned (e.g., bachelor, master, doctorate). Subjects included both science and non-science degrees. The most commonly reported degree subject was other education followed in frequency by elementary education and science education. Overall, about half (47.5 percent) of all reported degrees were related to science. Similarly, 16 (47.1 percent) teachers reported science-based certifications, and 18 (52.9 percent) reported non-science certifications. Tables 1 and 2 identify teacher reported degree subjects and certifications.

Table 1. Playground Physics Teacher Degree Subjects

Degree Subjects[a]	Frequency	Percent
Science	19	47.5%
Biology or life sciences	6	15.0%
Chemistry	4	10.0%
Earth and space sciences	0	0.0%
Physics	1	2.5%
Other science	1	2.5%
Science education (any science discipline)	7	17.5%
Non-science	21	52.5%
Mathematics or mathematics education	0	0.0%
Elementary education	7	17.5%
Other education	8	20.0%
Other (please specify) Communications (BA) with minors in history, English literature, generalist 5–9, special education, psychology, Spanish	6	15.0%
Total	**40**	**100%**

[a] Teachers could report more than one subject.
Source: Teacher Survey.

Table 2. Playground Physics Teacher Certifications

Certifications[a]	Frequency	Percent
Science certifications[b]	16	47.1%
Non-science certifications[c]	18	52.9%
Total	**34**	**100%**

[a] Teachers could report more than one certification.
[b] Science certifications include biology, chemistry, earth science, general science, and physics.
[c] Other disciplines include childhood education, education technology, English, gifted education, literacy, mathematics, middle childhood education, secondary education, special education, speech and language disabilities, students with disabilities, technology education, elementary education, and generalist.

Source: Teacher Survey.

Classroom Characteristics

As stated previously, 543 students were included in the final implementation fidelity and student outcomes analytic sample. The 18 teachers taught a total of 45 classes; twelve (26.7 percent) of the 45 classes were sixth grade classes, 14 (31.1 percent) were 7th grade classes, 17 (37.8 percent) were eighth grade classes and two (4.4 percent) were mixed 6 and 7th grade classes. .[2] The number of classes taught by each teacher ranged from one to five. Within each class, the number of students ranged from two to 28 with mean of 12.1 students per class, median of 11, and mode of 10 students. The total number of students per teacher ranged from five to 80 with a mean of 30.2 students per teacher, median of 22.5, and mode of 22.0.

Baseline Equivalence

The study this year does not include baseline equivalence analysis because all study participants received treatment. There is no control condition against which to compare students and teachers.

Evaluation Data Sources

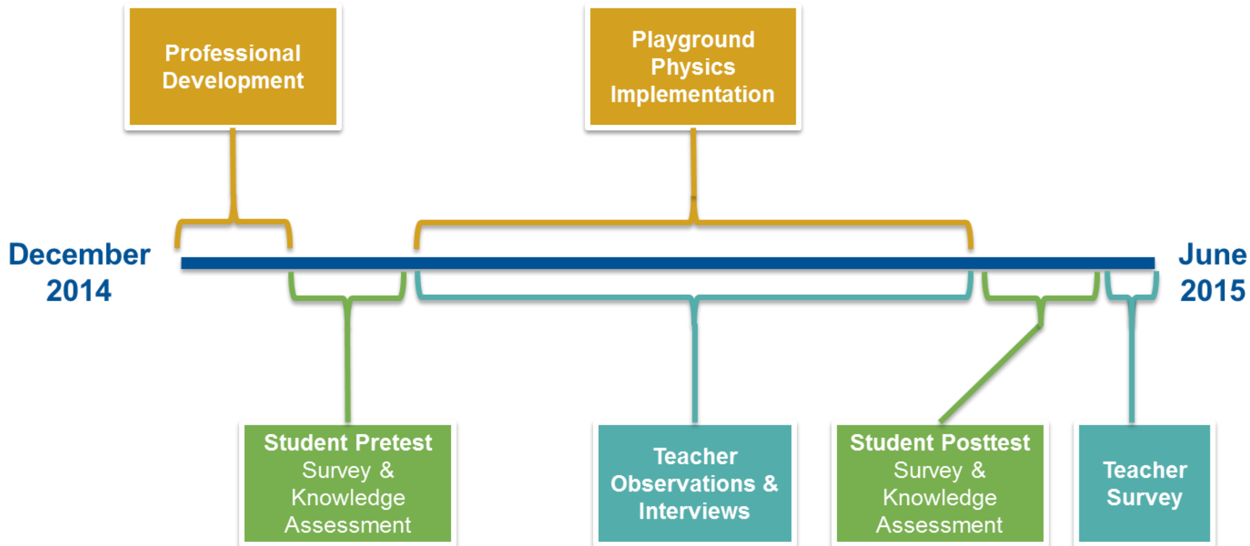
This section summarizes the data sources used for the 2014–15 study. Implementation data collected for this study included professional development delivery and attendance records and teacher surveys. Student outcome measures include student affect survey and knowledge assessment.

The data collection timeline for the implementation study spanned most of the 2014–15 school year. NYSCI provided teachers with professional development and materials at the beginning of the school year. Teachers were encouraged to use the Playground Physics program following participation in professional development. Teachers could use the program at any point in the school year. Student outcome evaluation instruments were administered at the beginning and end

[2] Teachers could teach more than one grade.

of school year. This was done to capture changes in student affect and learning prior to program implementation and at the end of the school year. Figure 2 provides a visual depiction of the Playground Physics program implementation and evaluation timeline.

Figure 2. Playground Physics Program Implementation and Evaluation Timeline



Fidelity of Implementation and Reaction to the Program Data Sources

NYSCI was asked to identify the critical components needed to successfully implement Playground Physics in classrooms. According to NYSCI, it was critical for the program to meet the following program implementation requirements: teacher participation in professional development, delivery of program materials by NYSCI, and teacher enactment Playground Physics in classrooms. These three components were the formal criteria used to assess Playground Physics fidelity of implementation during the 2014–15 school year. Details of the criteria used to determine fidelity of implementation will be described in Chapter 3. NYSCI was also interested in understanding how Playground Physics was used in classrooms and how students and teachers reacted to the program. Following, we provide more detail on the instruments used to capture high fidelity of implementation as well as teacher and student use of and reactions to the Playground Physics program.

- **Professional development delivery and attendance records.** AIR requested professional development delivery and teacher attendance records from NYSCI. Professional development consisted of three sessions; two were afterschool sessions of about 3.5 hours each, and one was a weekend session lasting approximately 6.5 hours. NYSCI offered two options per session.[3] NYSCI provided attendance sheets that identified which teachers participated in each of these sessions.
- **Teacher surveys.** Teacher surveys were used to capture information to examine program fidelity of implementation and use as well as teacher and student reactions to the

[3] Session 1: 12/9/2014 or 12/10/2014; session 2: 12/13/2014 or 12/14/2014; session 3: 12/15/2014 or 12/16/2014

program. We administered a survey to participating teachers using a Web-based platform in spring 2015 (April/May). In cases where the teacher had only one class participating in the study, teachers were asked to report on the activities covered by that group. If a teacher used Playground Physics in more than one classroom, they were asked to report on activities with respect to the class that was scheduled second during the school day. See Appendix B for teacher survey instrument.

- **Fidelity and use questions.** Teachers were asked to indicate their level of implementation of the Playground Physics. Specifically, they were asked whether they were provided with Playground Physics materials (app, curriculum, and two iPads), the number of classroom sessions in which Playground Physics was used, and the number of content areas they covered using the program. To minimize reporting burden, teachers were only asked to report on the second classroom to which they provided instruction. Teachers were also asked to report on how they used Playground Physics in their classrooms.
- **Program reaction questions.** Teachers were asked to comment on the quality of professional development, alignment of Playground Physics to teacher instructional approach and student educational level, as well as the facilitators and barriers of Playground Physics.

Student Outcome Instruments

Playground Physics curriculum integrates the elements of informal learning that promote student engagement and elements of formal, inquiry-based learning that lead to deeper understanding of scientific concepts. By increasing engagement in science class, NYSCI anticipates student attitudes toward science and learning of physics concepts to increase. To understand how student affect and learning changed as a result of participating in the Playground Physics program, data were captured using a student affect survey and knowledge assessment.

All students who assented and had parental consent to participate in Playground Physics were given the paper-and-pencil survey and knowledge assessment at two points in time: once prior to teacher implementation of Playground Physics (December 2014) and once at the end of the school year when Playground Physics implementation was complete (May 2015). See Appendix C for student affect survey and knowledge assessment. Following, we provide more detail on the instruments used to assess student outcomes.

Pre- and Posttest Student Affect Survey. Changes in students' affect were assessed by a written pre- and posttest survey administered in December 2014 and April 2015. The student affect survey included forced-choice questions related to the following four constructs: engagement in science class, attitudes toward science, intrinsic motivation, and educational aspirations. The pre- and posttest student affect survey included the same questions.

- **Science engagement.** According to Shernoff and Vandell (2007) engagement is defined as "the simultaneous experience of concentration, enjoyment, and interest" (p. 891). Similar to a survey developed by Shernoff and Vandell, the engagement items selected for this study include 16 questions that addressed concentration, enjoyment, and interest. Specifically, eight questions focused on concentration, four focused on enjoyment, and four focused on interest. These items were adapted from the following surveys:

Consortium on Chicago School Research (2011), Engagement Versus Disaffection With Learning Survey (Skinner, Furrer, Marchand, & Kindermann, 2008), and Tinio's Academic Engagement Scale for grade-school students (Tinio, 2009). The items asked students to rate their agreement with statements such as, "In science class I actively participated," "in science class, I enjoyed working with my classmates," and "In science class I liked the ways we learned things."

- **Intrinsic motivation.** Student intrinsic motivation was measured through five forced-choice items, using a 4-point agree-disagree scale. These items were adapted from an intrinsic motivation scale developed by Elliot and Church (1997) and Motivated Strategies for Learning Questionnaire developed by Pintrich and DeGroot (1990). The items ask students to rate their agreement with statements such as, "I wanted to learn as much as possible from this class."
- **Attitudes toward science survey**. To understand student attitudes toward science, two scales were developed: interest in science and science self-concept. Both scales were measured through forced-choice items, using a 4-point agree-disagree scale. Student interest in science items were adapted from Attitudes Toward Science in School Assessment (Germann, 1988), Test of Science-Related Attitudes (Fraser, 1978), and Kanter and Konstantopoulos (2010). These 11 questions examine global sentiments regarding science learning. The Marsh (1990) scale was used to measure science self-concept. These six questions detail student beliefs on their ability to complete science task. Representative items from these scales are "I like learning about science" and "I get good grades in science."
- **Educational aspirations**. To measure students' educational and occupational plans in the student survey, we adapted questions identified by Eccles, Vida, & Barber (2004) to create a 4-point scale examining middle school student future science plans. The five topics covered will include likelihood of college attendance, selection of science coursework in college, major in science in college, desire to obtain science occupation, and likelihood of seeking a science-related job.

Student Science Knowledge Assessment. Students' physics content learning was assessed by a written pre- and posttest knowledge assessment administered in December 2014 and April 2015. The assessment consisted of items from multiple sources, including publically available state assessment items (New York, Massachusetts, Illinois, and California) and research-based instruments (American Association for the Advancement of Science, n.d.; Hestenes,Wells, & Swackhamer, 1992; Mozart, n.d.). The pre- and posttest knowledge assessments each had 20 items, of which 10 were overlapping. Items were selected based on their broad alignment to the following New York State Learning Standards:

- 4.1c (energy): Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Energy, in the form of heat, is almost always one of the products of energy transformations.
- 4.1e (energy): Energy can be considered to be either kinetic energy, which is the energy of motion, or potential energy, which depends on relative position.

- 5.1b (motion): The motion of an object can be described by its position, direction of motion, and speed. The position or direction of motion of an object can be changed by pushing or pulling.
- 5.1e (force): For every action there is an equal and opposite reaction.

In total, four of the 20 questions on both the pre- and posttest knowledge assessment focused on standard 4.1c, seven questions focused on standard 4.1e, four questions focused on standard 5.1b, and five focused on standard 5.1e.

Internal Consistency of Student Outcomes Instruments

Internal consistency was examined to ensure that items within the same scale measuring the same general construct would produce similar scores. Rasch analysis (Wright & Masters, 1982) was employed to ensure an internal consistency rating of 0.5. Table 3 describes the internal consistency of the student outcome instruments.

Table 3. Student Outcome Instrument Reliability and Internal Consistency

Instruments	Internal Consistency (Cronbach's Alpha)
Knowledge Assessment	
Pretest	0.49
Posttest	0.82
Student Affect Survey[a]	
Engagement (concentration, enjoyment, and interest)	0.90
Science self-concept	0.72
Interest in science	0.92
Intrinsic motivation	0.88
Educational aspirations	0.85

[a] Data from both pre- and posttest student affect surveys were combined to examine reliability and internal consistency.

Internal consistency ratings surpassed the minimum 0.5 rating. In fact, Chronbach's alphas for survey scales ranged from 0.72 to 0.92 and were reported as having good to excellent internal consistency. The pretest knowledge assessment was reported as having poor levels of internal consistency ($\alpha = 0.53$) and posttest knowledge assessment was reported as having good levels of internal consistency ($\alpha = 0.77$). It is suspected that the internal consistency of the pretest knowledge assessment could not be accurately measured because students had little to no exposure to physics instruction. The items were likely more difficult than the student's ability level during the time of pretest administration.

Chapter 3: Fidelity of Implementation and Use

In this chapter, we present Playground Physics implementation findings. Implementation is examined two ways. The first analysis, fidelity of implementation, examines how well the program developers and participating study teachers implement the program as designed. Components that have been identified by NYSCI as being critical to program implementation including professional development, provision of program materials and teacher enactment of the program. The second analysis provides a more detailed look at how Playground Physics was used in classrooms. This information is intended to provide the developers with formative feedback that may be used to refine the program in the future.

The fidelity of implementation and use study addresses the following questions:

1. To what extent were Playground Physics components implemented with high fidelity?
2. How was Playground Physics used in implementing classrooms?

Overall, NYSCI and the majority of participating teachers were not able to attain high component fidelity ratings on any of the three component fidelity measures. In addition, data on teacher and student use of Playground Physics in classroom indicated that the app was heavily used by students during instruction and teachers most commonly reported supplementing Playground Physics with their regular curriculum in each of the three content areas: energy, motion, and force.

Fidelity of Implementation Evaluation Criteria

NYSCI identified three critical components for fidelity of implementation: professional development, materials, and enactment of Playground Physics. Nested within each component are indicators that are combined together to form the component measures. For each set of indicator and component, NYSCI identified the criteria for low, adequate, and high fidelity.[4] Table 4 provides the indicators and components used to examine program implementation fidelity.

To achieve high fidelity on the professional development component, NYSCI was expected to deliver 100 percent of all sessions offered, and at least 81 percent of all teachers participating in the study were expected to complete three sessions. The indicators for the professional development component include:

- **Delivery of professional development.** NYSCI was expected to offer three professional development sessions to teachers: two evening sessions and one weekend session. NYSCI offered two options per session.[5] To attain high fidelity on this professional development indicator, NYSCI needed to hold all six professional development sessions offered to teachers. Provision of five or fewer sessions was considered low fidelity.

- **Attendance of professional development.** Teachers were expected to attend three professional development sessions: two weekday evening sessions and one weekend session. To attain high fidelity on this indicator, teachers needed to attend all three sessions. To attain adequate fidelity, teachers needed to participate in two sessions. Participation in one or fewer sessions resulted in a low indicator rating.

To attain high fidelity on the material component, 95 percent of all teachers needed to receive the Playground Physics app, curriculum, and two iPads. The indicator for the materials component include:

- **Receipt of Playground Physics materials.** To attain high fidelity of this indicator, NYSCI needed to provide all three components—app, curriculum, and two iPads. Delivery of two or fewer materials earned a low fidelity rating.

To attain high fidelity on the enactment of Playground Physics component, 81 percent or more of all participating teachers had to use Playground Physics in seven or more class periods and teach the three content areas (energy, force, motion) using one of the three instructional strategies (single, multiple, LSTI) per content area. The indicators for the enactment of Playground Physics component include the following:

- **Use of Playground Physics.** To attain high fidelity of this indicator, teachers were expected to use Playground Physics (app, curriculum, and iPads) as part of classroom instruction in seven or more class periods for implementation. To attain adequate fidelity of this indicator, teachers were expected to use the program in four to six class periods. Use of Playground Physics in three or fewer class periods resulted in a low indicator rating for fidelity.
- **Delivery of Playground Physics content area instruction.** To attain high fidelity of this indicator, teachers were expected to use the Playground Physics curriculum when they provided instruction on all three physics content areas (energy, force, motion) using at least one Playground Physics instructional strategy (single, multiple, LSTI) per content area. If teachers covered two or fewer physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area they were rated as having low indicator rating for fidelity.

Table 4. Playground Physics Indicator and Component Measures of Fidelity

Indicator	Operational Definition	Data Collection	Criteria Indicator Fidelity	Criteria for High Component Fidelity
Professional Development				
NYSCI delivery Playground Physics professional development	Deliver three days of professional development to teachers	Developer attendance records	**Low:** Delivery of two or fewer sessions **Adequate:** N/A **High:** Delivery of three sessions	NYSCI delivery of all three days of professional development, and 81 percent of all teachers attend all three days of

Indicator	Operational Definition	Data Collection	Criteria Indicator Fidelity	Criteria for High Component Fidelity
Teacher attendance of Playground Physics professional development	Attend three professional development sessions (two after school and one weekend)	Developer attendance records	**Low:** Attendance of one or fewer professional development sessions **Adequate:** Attendance of two professional development sessions **High:** Attendance of all three professional development sessions	professional development.
Materials				
Teacher receipt of Playground Physics materials	Teacher provided with each of the following: 1. App 2. Curriculum 3. Two iPads	Teacher survey	**Low:** Teacher receipt of two or fewer materials **Adequate:** N/A **High:** Teacher receipt of all three materials	Ninety-five percent or more teachers receive all three materials: app, curriculum, and two iPads.
Enactment of Playground Physics				
Teacher usage of Playground Physics	Number of days Playground Physics app and curriculum were used	Teacher survey	**Low:** Use Playground Physics in three or fewer class periods **Adequate:** Use Playground Physics in four to six class periods **High:** Use Playground Physics in seven or more class periods	Eighty-one percent of teachers use Playground Physics in at least seven periods and cover all three physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area.
Teacher delivery of Playground Physics instruction	Number of Playground Physics content areas introduced to students	Teacher survey	**Low:** Teacher covers two or fewer physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area. **Adequate:** N/A **High:** Teacher covers all three physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area.	

Fidelity of Implementation and Use Results

In this section we present Playground Physics fidelity of implementation and use findings. Data from 20 teacher surveys and professional development delivery and attendance records were coded and analyzed using Stata 13 software. Open-ended responses were coded by a single AIR staff member and analyzed using Dedoose 5.3.12 software.

To what extent were Playground Physics components implemented with high fidelity?

To examine fidelity of implementation, Playground Physics indicators were combined to create a composite score for professional development, materials, and enactment of Playground Physics. Table 5 and 6 provide Playground Physics indicators and component fidelity ratings. See Appendix D for more information on how indicator and component fidelity scores were calculated.

Professional development. The professional development component metric included two indicators: NYSCI delivery of Playground Physics professional development and teacher attendance of Playground Physics professional development. NYSCI professional development attendance records indicated all six planned sessions were administered by NYSCI; therefore, professional development was delivered with high fidelity, 14 (77.8 percent) of 18 teachers attended all three sessions and four (22.2 percent) attended two sessions. Because the criterion for this indicator was NYSCI delivery of all three days of professional development and for at least 81 percent of teachers to complete all three sessions, implementation of the professional development component did not meet the high fidelity criterion.

Materials. Sixteen (88.9 percent) of the 18 participating teachers stated they received all three program materials (the Playground Physics app, curriculum, and two iPads). The implementation of this component narrowly missed the high fidelity of implementation criterion of 95 percent of teachers receiving all materials.

Enactment of Playground Physics. The enactment of Playground Physics component metric included two indicators: teacher use of Playground Physics and teacher delivery of Playground Physics instruction. Of the 18 participating teachers, 14 (77.8 percent) used Playground Physics during seven or more class periods and met the criterion for high indicator implementation fidelity. Two (11.1 percent) teachers used Playground Physics for four to six class periods, meeting the criterion for adequate indicator implementation fidelity. Two (11.1 percent) teachers used Playground Physics in three or fewer classes, indicating low indicator fidelity of implementation.

To attain high indicator ratings on teacher delivery of Playground Physics instruction, teachers needed to covers all three physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area. In total, 14 (77.8 percent) teachers met this criterion. The remaining four (22.2 percent) teachers covered two or fewer physics content areas using at least one instructional strategy per content area, indicating low indicator fidelity of implementation. Only twelve (66.7 percent) of the 18 teachers had high fidelity for both indicators of Playground Physics enactment. Therefore, teachers did not meet the component criterion for high fidelity of implementation, which was for 81 percent or more teachers use Playground Physics in at least seven periods and covers all three physics content using at least one instructional strategy per content area.

Table 5. Playground Physics Indicator Fidelity Ratings

Program Indicators	Indicator Rating Criteria	Frequency	Percent
		All teachers (N = 18)	
Professional Development			
NYSCI delivery Playground Physics Professional Development	**Low:** Delivery of two or fewer sessions	0	0.0%
	High: Delivery of three sessions	18	100%
Teacher attendance of Playground Physics Professional Development	**Low:** Attendance of one or fewer professional development sessions	0	0.0%
	Adequate: Attendance of two professional development sessions	4	22.2%
	High: Attendance of all three professional development sessions	14	77.8%
Materials			
Teacher receipt Playground Physics materials	**Low:** Teacher receipt of two or fewer materials	2	11.1%
	High: Teacher receipt of all three materials	16	88.9%
Enactment of Playground Physics			
Teacher usage of Playground Physics	**Low:** Use Playground Physics in three or fewer class periods	2	11.1%
	Adequate: Use Playground Physics in four to six class periods	2	11.1%
	High: Use Playground Physics in seven or more class periods	14	77.8%
Teacher delivery of Playground Physics Instruction	**Low:** Teacher covers two or fewer physics content areas (energy, force, motion) using at least one instructional strategy (single, multiple, LTSI) per content area.	4	22.2%
	High: Teacher covers all three physics content areas (energy, force, motion) using at least one instructional strategy (single, multi, LTSI) per content area.	14	77.8%

Table 6. Playground Physics Component High Fidelity Ratings

Program Indicators	Criteria for High Component Implementation	Frequency	Percent	Met Criterion?
		All teachers (*N* = 18)		
Playground Physics professional development	NYSCI delivery of all three days of professional development, and 81 percent of all teachers attended all three days of professional development.	4 14	22.2% 77.8%	No
Playground Physics materials	Ninety-five percent or more teachers receive all three materials: app, curriculum and two iPads.	2 16	11.1% 88.9%	No
Enactment of Playground Physics	Eighty-one percent of teachers use Playground Physics in at least seven periods and covers all three physics content areas (energy, force, motion) using at least one instructional strategy (single, multi, LTSI) per content area.	6 12	33.3% 66.7%	No

How Was the Playground Physics Program Used in Implementation Classrooms?

Program use was examined for each content area: energy, motion, and force. For each content area, we calculated how many class periods used Playground Physics, how much regular (non-Playground Physics) energy curriculum was used, what program instructional approaches were used, and what percentage of the class used the app during the unit.

During the 2014-15 school year, 17 (85.0 percent) of 20 teachers who completed the teacher survey reported using Playground Physics as part of their energy instruction, 17 (85.0 percent) teachers reported using Playground Physics as part of their motion instruction, and 19 (95.0) teachers reported using Playground Physics as part of their force instruction.

Teachers most commonly reported using 10 or more class periods during the school year to teach energy. There was much variability in the number of classes used during the school year to teach motion and force. For example, during motion instruction, four teachers reported using four class periods, three teachers reported two classes, and another three reported 10 or more class periods. Table 7.a. and 7.b. provide the frequency of class periods used to teach energy, motion, and force in general and using the Playground Physics program.

Table 7.a. Frequency of Classroom Periods Used to Teach Energy, Motion, and Force in General

Number of Class Periods	Energy		Motion		Force	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	1	5.0%	1	5.0%	1	5.0%
1–3	3	15.0%	4	20.0%	4	20.0%
4–6	6	30.0%	8	40.0%	8	40.0%

7–9	2	10.0%	4	20.0%	4	20.0%
10 or more	8	40.0 %	3	15.0%	3	15.0%
Total	**20**	**100%**	**20**	**100%**	**20**	**100%**

Note: Frequency based on all 18 teacher who met study requirements and the two teachers who used the program but failed to attain student contest to participate in evaluation components of this study.

Source: Teacher Survey.

Table 7.b. Frequency of Classroom Periods in which Playground Physics was Used to Teach Energy, Motion, and Force

Number of Class Periods	Energy		Motion		Force	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	0	0.0%	0	0.0%	0	0.0%
1–3	5	29.4%	7	41.1%	9	47.4%
4–6	6	35.3%	8	47.0%	9	47.4%
7–9	3	17.6%	2	11.8%	1	5.3%
10 or more	3	17.6%	0	0.0%	0	0.0%
Total	**17**	**100%**	**17**	**100%**	**19**	**100%**

Note: Frequency based solely on those teachers reported using Playground Physics in energy, motion or force instruction.
Source: Teacher Survey.

On average, teachers used Playground Physics in 74.0 percent of energy class periods, 69.0 percent of motion class periods, and 67.0 percent of force class periods. Table 8 summarizes proportion of class periods that use of Playground Physics as part of content area instruction

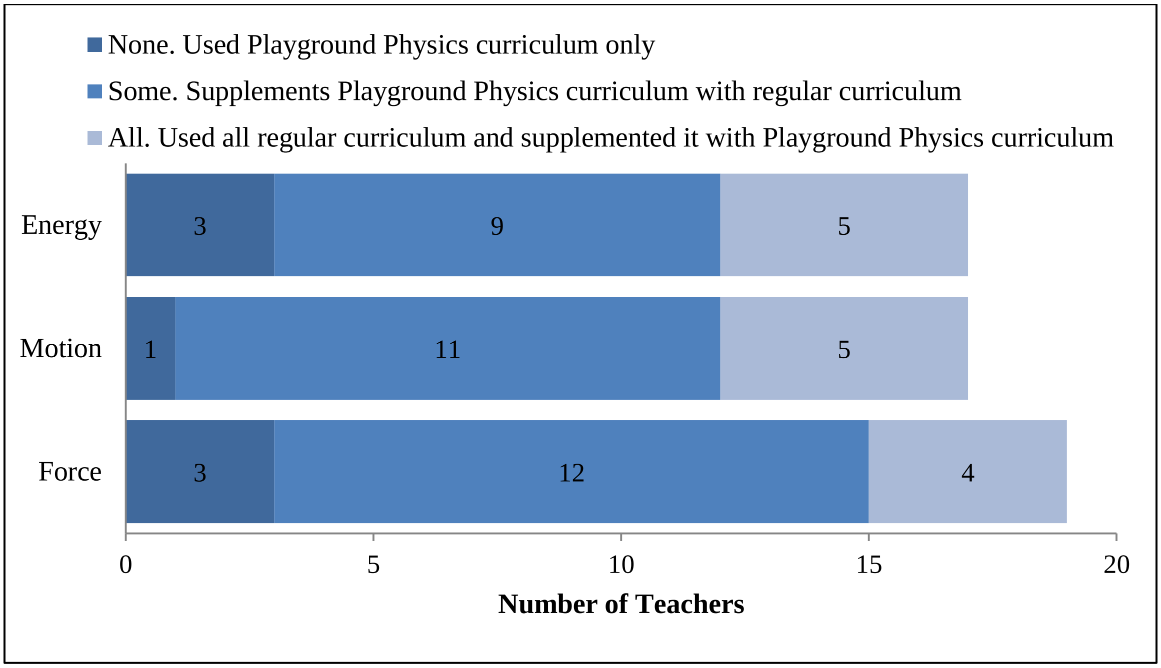
Table 8. Proportion of Class Periods That Used Playground Physics as Part of Content Area Instruction

Content Area	Teachers	Mean	Standard Dev.	Min	Max
Energy	17	0.74	0.26	0.25	1
Motion	17	0.69	0.28	0.2	1
Force	19	0.67	0.23	0.33	1

Source: Teacher Survey.

In addition, most teachers supplemented the Playground Physics curriculum with their regular curriculum. Three (17.6 percent) of the 17 teachers who used Playground Physics stated using only the program to teach energy, nine (52.9 percent) teachers stated that they supplemented the program curriculum with some materials and activities from their regular energy curriculum, and five (29.4 percent) teachers stated using their entire regular energy curriculum and supplementing it with Playground Physics. Similarly, one (5.9 percent) of 17 teacher stated using only Playground Physics to teach motion, 11 (64.7 percent) teachers stated that they supplemented the program curriculum with some materials and activities from their regular motion curriculum, and five (29.4 percent) teachers stated using their entire regular motion curriculum and supplementing it with Playground Physics. Three (15.8 percent) of 19 teachers stated using only Playground Physics to teach force, 12 (63.2 percent) teachers stated that they supplemented the program curriculum with some materials and activities from their regular force curriculum, and four (21.0 percent) teachers stated using their entire regular force curriculum and supplemented it with Playground Physics. Figure 3 provides the frequency of teacher's use of their regular energy, motion, and force curriculum versus Playground Physics curriculum.

Figure 3. Teacher Use of Regular versus Playground Physics Curriculum



Source: Teacher Survey.

Teachers were expected to use at least one of the following instructional approaches to teach energy, motion, and force[6]: single device, multiple device, or LTSI. For energy, 10 (58.8 percent) of 17 teachers reported using one instructional approach, and seven (41.2 percent) reported using more than one instructional approach. For motion, eight (47.0 percent) of 17 teachers reported using one instructional approach, and eight (47.0 percent) reported using more than one instructional approach.[7] For force, 14 (73.7 percent) of 19 teachers reported using one instructional approach, and five (26.3 percent) reported using more than one instructional approach. Table 9 provides the number of instructional strategies used during energy, motion, and force instruction.

[6] LTSI was not an instructional option for force instruction.
[7] On individual who reported using the motion instructional strategy chose not to answer this question.

Table 9. Number of Instructional Strategies Used During Energy, Motion and Force Instruction.

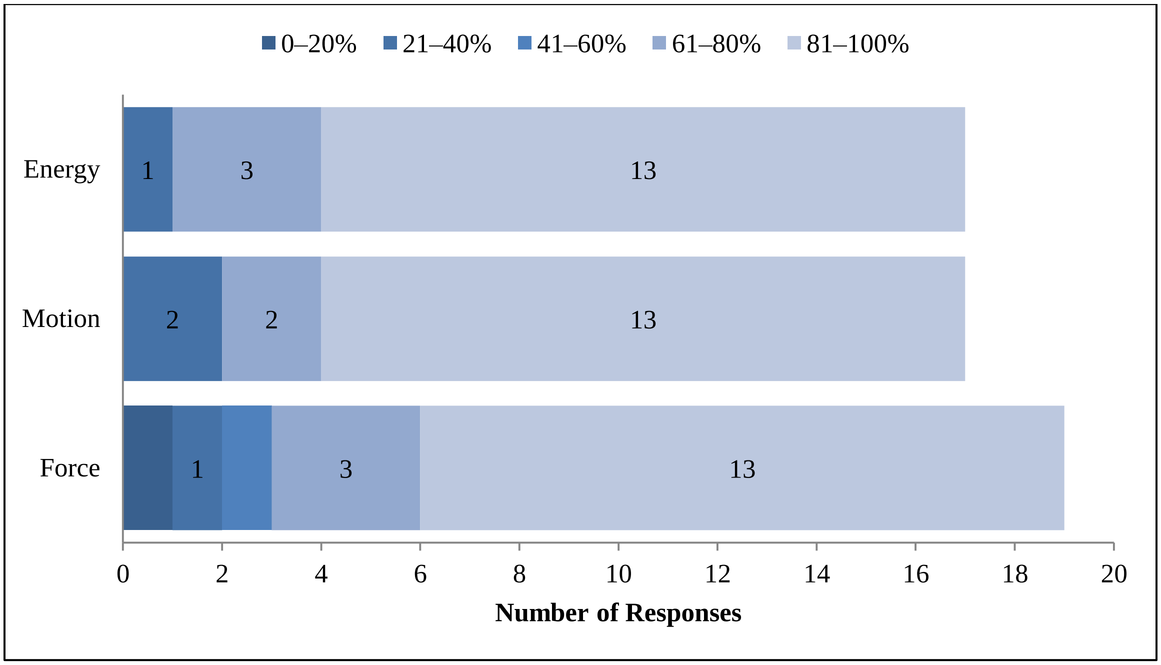
Instructional Strategy	Energy		Motion		Force	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Single Instructional Strategy						
Single	1	5.9%	0	0.0.%	3	15.8%
Multiple	8	47.1%	6	37.5%	11	57.9%
LTSI	1	5.9%	2	12.5%	—	—
Single instructional strategy total	10	58.8%	8	50.0%	14	73.7%
Multiple Instructional Strategies						
Single and multiple	3	17.7%	4	25.0%	5	26.3%
Single and LTSI	0	0.0%	0	0.0%	—	—
Multiple and LTSI	2	11.7%	2	12.5%	—	—
Single, multiple, and LTSI	2	11.7%	2	12.5%	—	—
Multiple instructional strategy total	7	41.2%	8	50.0%	5	26.3%
Grand Total	**17**	**100%**	**16[a]**	**100%**	**19**	**100%**

[q] Although 17 teachers indicated that they taught motion using Playground Physics, one teacher chose not to respond to the question associated to instructional strategies.

Source: Teacher Survey.

Teachers were also asked what percentage of students in the class used the Playground Physics app during the energy, motion, and force unit. For energy, one (5.9 percent) of 17 teacher reported 21 percent to 40 percent of the class used the app; three (17.6 percent) teachers reported 61 percent to 80 percent of the class used the app; and 13 (76.5 percent) teachers reported 81 percent to 100 percent of the class used the app. For motion, two (11.8 percent) of 17 teachers reported 21 percent to 40 percent of the class used the app; two teachers (11.8 percent) reported 61 percent to 80 percent of the class used the app; and 13 (76.8 percent) teachers reported 81 percent to 100 percent of the class used the app. Similarly, for force, 1 percent to 20 percent, 21 percent to 40 percent, and 41 per cent to 60 percent were reported by one (5.3 percent) of 19 teacher each, while 16 (84.2 percent) teachers reported 61 percent to 80 percent or 81 percent to 100 percent of the class used the app. Figure 4 offers the proportion of class use of the Playground Physics app during energy, motion, and force instruction.

Figure 4. Proportion of Class Use of the Playground Physics App During Energy, Motion, and Force Instruction



Source: Teacher Survey.

Summary of Fidelity of Implementation and Use and Limitations

During the 2014–15 school year, NYSCI and the majority of participating teachers exhibited high fidelity ratings on individual indicators. However, reaching high component fidelity was a challenge. Only 67 percent of teachers met component criteria for a high rating on enactment of Playground Physics. Professional development and materials appeared to be an area of promise. Although neither of these components was rated as high, the percentage of teachers needed to meet the "high" component rating was close to the component benchmarks set. For example, in the case of professional development, the benchmark set was NYSCI provision and teacher participating in all three professional development sessions. Fifteen teachers needed to meet this benchmark in order for the professional development component to be rated as high. Participating teachers came close with 14 individuals meeting the high component rating criteria.

There are several limitations to the fidelity findings. The findings do not address reasons for the observed variation in the extent to which teachers implemented program components. Moreover, it is possible that the criteria for fidelity, as now defined, are too stringent. Most of the indicators have criteria for high levels of fidelity. It is possible that these criteria should be further articulated to describe adequate as well as high levels of fidelity.

Implementing teachers most commonly reported supplementing Playground Physics with their regular curriculum in each of the three content areas: energy, motion, and force. On average, teachers used Playground Physics in 74 percent of energy class periods, 69 percent of motion class periods and 67 percent of force class periods. Teachers used a mix of instructional approaches to teacher energy, motion and force. Several teachers reported using more than one instructional approach to teach a concept. However, the multi-device instructional approach was the single most commonly reported strategy used to teach energy, motion and force. This may have occurred, in part, because teachers were given multiple iPads to use in their classrooms.

Chapter 4: Teacher and Student Reactions to Playground Physics

This section provides descriptive findings on teacher and student reactions to and use of the Playground Physics program using data collected through the teacher surveys during the 2014–15 school year. To supplement these findings classroom observations of program use and teacher interview data has been included where appropriate.

This chapter will address the following three questions:

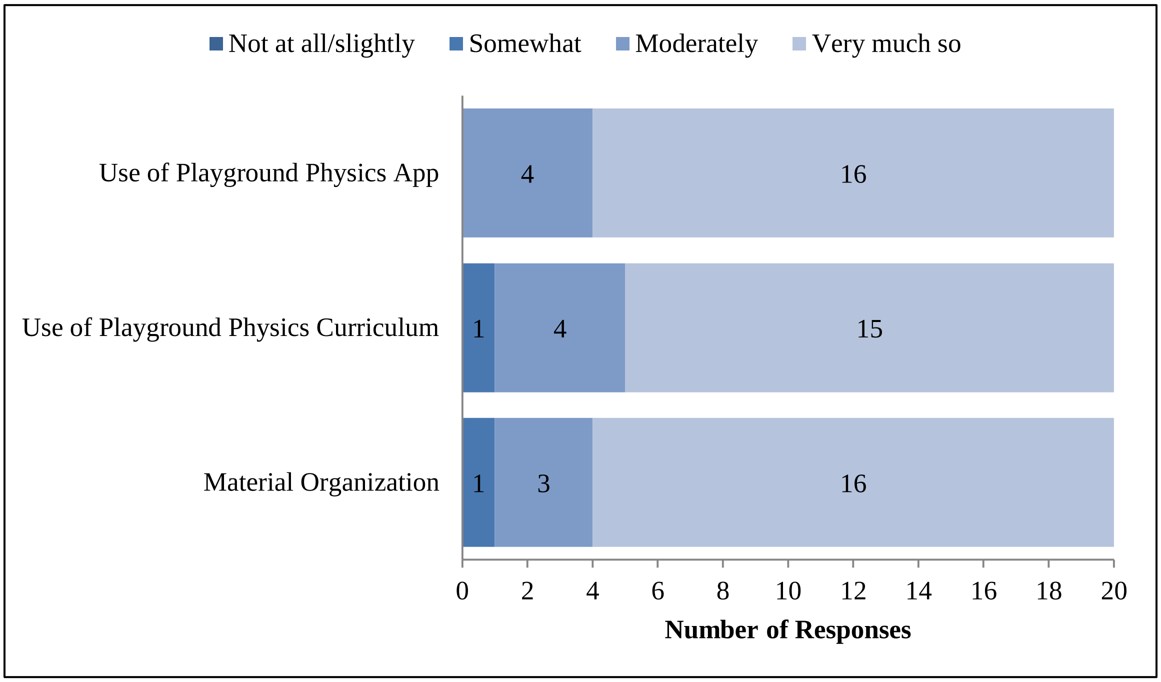
1. How well did professional development prepare teachers to implement Playground Physics?
2. How did teacher and student respond to Playground Physics program?
3. What were the facilitators and barriers of Playground Physics use?

Generally, it was found that most teachers believed professional development prepared them to use the Playground Physics program moderately or very well. More so, teachers would use the program in the future, believed the program was equally or more engaging than conventional lessons and was moderately or very educationally effective for teaching each of the three content areas. Overall, teachers reported Playground Physics facilitate student learning and classroom engagement. Technological issues and revision to curriculum materials were the most commonly noted barriers.

How Well Did Professional Development Prepare Teachers to Implement Playground Physics?

In the teacher survey, 19 (95 percent) of 20 teachers reported that Playground Physics materials were moderately or very well organized. Only one teacher did not feel that materials were organized in a useful manner. When teachers were asked if NYSCI's professional development prepared them to teach the Playground Physics curriculum, one (5.0 percent) teacher stated it had prepared them somewhat, four (20.0 percent) teachers reported it prepared them moderately, and 15 (75.0 percent) reported it prepared them very much so. Similarly, four (20.0 percent) teachers reported that professional development prepared them moderately, and 16 (80.0 percent) reported it prepared them very much so to use the Playground Physics app. Figure 5 detail teacher belief of Playground Physics material organization and preparation.

Figure 5. Playground Physics Professional Development Material Organization and Preparation



Source: Teacher Survey.

Likewise, teachers reported high regard for the Playground Physics professional development in teacher interviews. All five teachers[8] interviewed stated that NYSCI sufficiently prepared them to implement Playground Physics, professional development was paced well, and the quality of materials was good. When asked about the quality of ongoing support during implementation, all five described NYSCI as responsive.

In the teacher survey, teachers were asked how NYSCI could improve professional development. Ten teachers offered 12 comments; the following were the major categories of recommendations:

- **Allow more time for teacher collaboration** (3 comments). Two teachers mentioned wanting more time to discuss ways of integrating the program with their regular curriculum, and another mentioned wanting to have another session later in the year to review concepts and share experiences using the program.
- **More developer support during the school year** (4 comments). Some teachers mentioned that it was difficult to remember everything that was covered during professional development and would like to have NYSCI reteach content in a school setting, offer a refresher course midyear, support a blog for teachers, and have general in-school support during implementation.

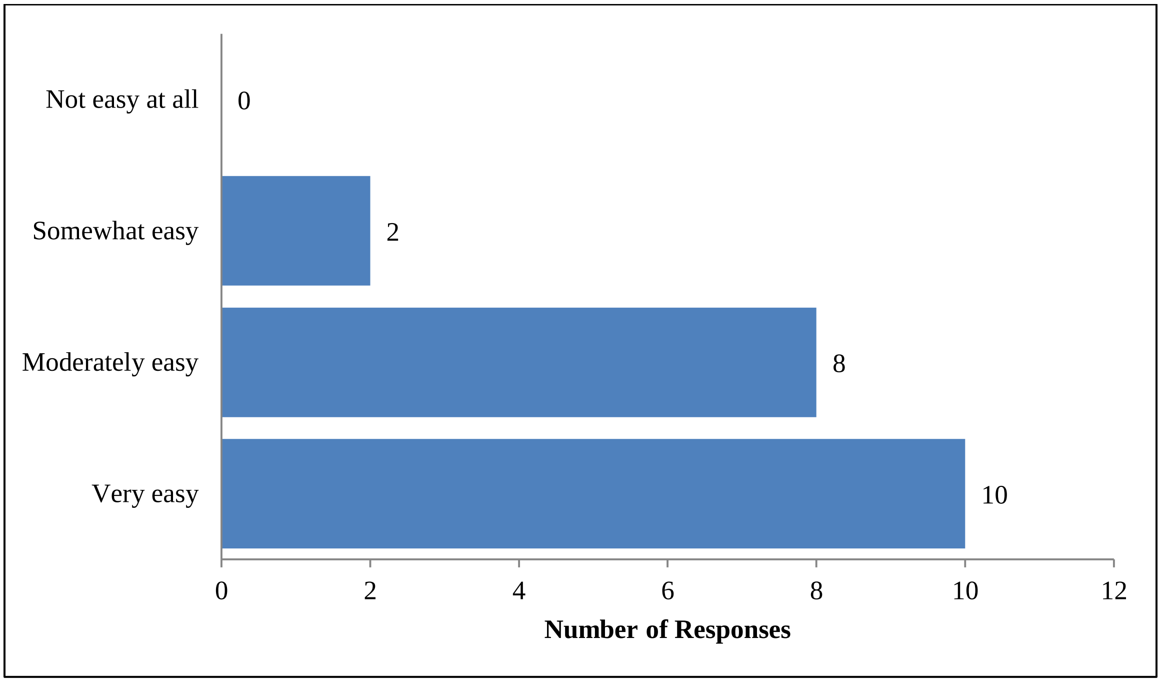
[8] The sample selected for classroom observations and interviews was purposive. Teachers who indicated that they were implementing Playground Physics during the second week of February 2015, intended to have one physics lens (motion, force, or energy) completed and as much as possible, taught eighth grade were targeted.

- **More time to practice using the program** (4 comments). Specifically these teachers mentioned that they would have liked more time to play with the app.

How Did Teachers and Students Respond to Playground Physics Program?

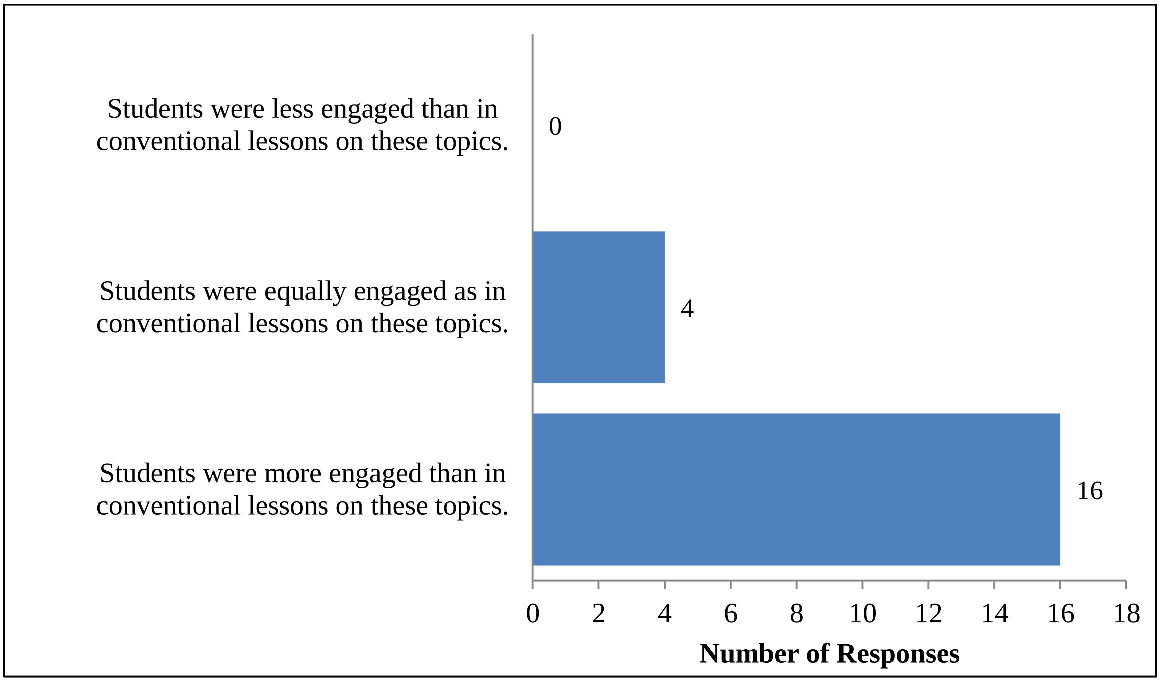
Eighteen (90 percent) teachers reported students found the Playground Physics moderately or very easy to use. In addition, according to participating teachers, all classes were equally or more engaged in Playground Physics lessons compared to conventional lessons on these topics. Similarly, during classroom observations, the observer noted that 6 (75 percent) of 8 classrooms exhibited between 61 percent and 100 percent of students focused on the academic task**.** Figures 6 and 7 provide the frequency of class ease of use of the program app and engagement in the program lessons.

Figure 6. Class Ease of Use of the Playground Physics App



Source: Teacher Survey.

Figure 7. Class Engagement in Playground Physics Compared to Conventional Lessons

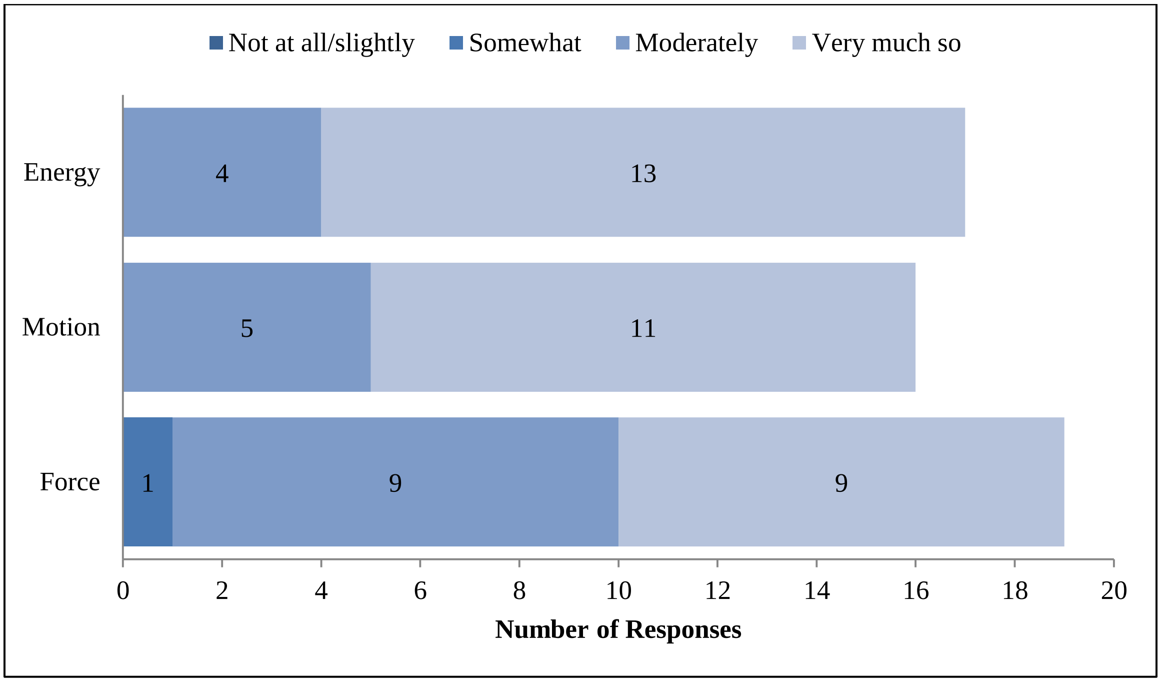


Source: Teacher Survey.

All 17 (100 percent) of participating teachers who indicated using Playground Physics to teach energy believed Playground Physics was moderately or very educationally effective for teaching energy. Likewise, all 17 (100 percent) teachers who indicated using Playground Physics to teach motion believed Playground Physics was moderately or very educationally effective for teaching motion. Eighteen (94.7 percent) of the 19 teachers who used Playground Physics to provide force instruction believed Playground Physics was moderately or very educationally effective for teaching force, while one (5.3 percent) teacher believed it was only somewhat effective. Figure 8 provides the number of teachers who believe Playground Physics is educationally effective by content area.

Moreover, all 17 (100.0 percent) teachers would use the program with no or some changes the next time they taught energy and motion. Seventeen (89.5 percent) of the 19 teachers who taught force using Playground Physics would use the program with no or some changes the next time they taught force, and two (10.5 percent) teachers might consider using Playground Physics to teach force in the future.

Figure 8. Number of Teachers Who Believe Playground Physics Is Educationally Effective

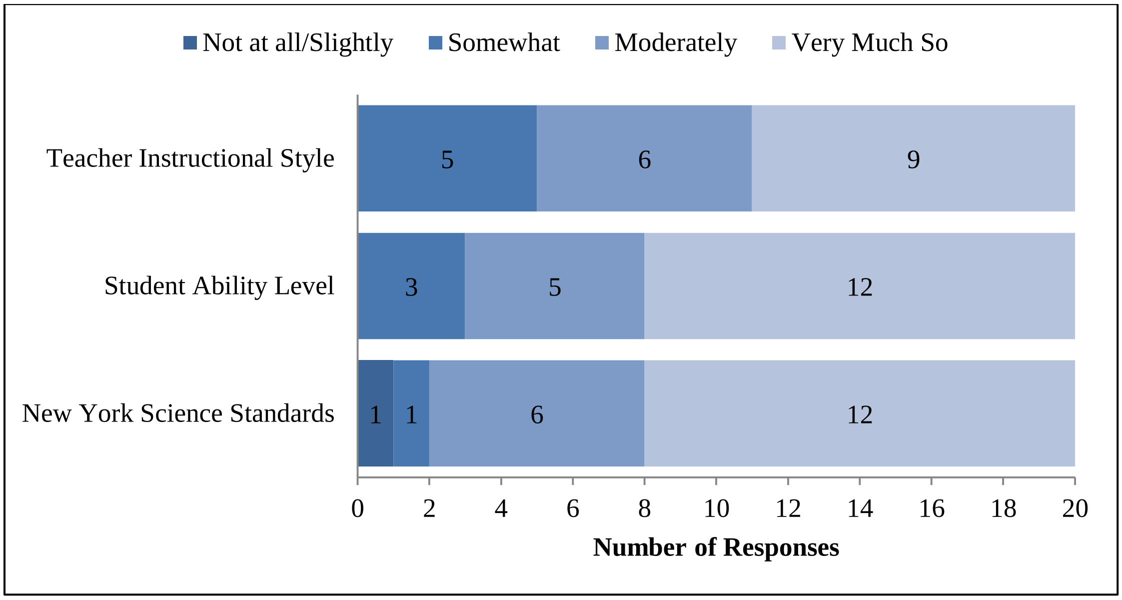


Source: Teacher Survey.

Teacher interview data collected in February 2015 corroborated much of what was reported on student and teacher reactions to the program. The five teachers who participated in interviews reported that they believed Playground Physics was a useful instructional tool, engaged students in classroom instruction, and was effective for students of diverse ability levels. For example, one teacher noted that students were "excited" to use the tablets and another teacher stated that students were "all into … adding special effects." One teacher stated Playground Physics, "…really adds to their [student's] conceptual knowledge of …motion, force, energy. It… really expands on the discussion component of our class…" and another teacher appreciated that Playground Physics was modifiable to suit student needs, and provided "multiple points of entry" for students to connect with content (e.g., records, manipulating data in real time, and written tasks).

When asked if Playground Physics aligned to teacher instructional style, five (25.0 percent) of 20 teachers reported it matched somewhat, six (30.0 percent) reported it matched moderately, and nine reported (45.0 percent) in matched very much so. Three (15.0 percent) teachers reported that Playground Physics somewhat aligned to student's ability level, whereas 17 (85.0 percent) reported that it moderately or very much so aligned to student ability level. Similarly, two teachers (10.0 percent) reported that Playground Physics not at all/slightly or somewhat aligned to New York science standards while 18 (90.0 percent) teachers believe the program moderately or very much so aligned to New York science standards. Figure 9 details the frequency of Playground Physics curriculum matching teacher instructional style, student ability level, and New York science standards.

Figure 9. Playground Physics Curriculum Alignment to Teacher Instructional Style, Student Ability Level, and New York Science Standards



Source: Teacher Survey.

What Aspects of Playground Physics Worked Well and What did Not?

Teachers were asked to comment on what aspects of Playground Physics worked well and poorly. Eighteen teachers mentioned 28 aspects of the program that worked well. The 28 comments centered on the following four themes:

- **Student learning through app technology** (9 comments). Teachers stated that the app made concepts visual, assisted student investigation and explanation of the concepts they were seeing, and helped students see relationships between different concepts.
- **Student engagement** (7 comments). Several teachers mentioned that students were more engaged when using the app or participating in curriculum activities. One teacher mentioned that students were more motivated to learn, while another teacher stated that his/her students were asking more inquiry-based questions based on their participation in Playground Physics.
- **Hands-on experience** (3 comments). These teachers mentioned that they appreciated the hands-on experience afforded to students by using the app.
- **Specific features of the Playground Physics program** (9 comments). Three teachers mentioned liking the video capabilities of the app. One teacher stated that he/she liked that the app calculated the formulas for their students, while another like the special effects in the app. Four teachers mentioned that certain activities worked well. Specifically, these teachers mentioned the following activities: Agree/Disagree, Odd One Out, Bingo, and the LTSI instructional tools.

Seventeen teachers made 19comments about aspects of the program that did not work well. The comments centered on the following four themes:

- **Technology access or use** (7 comments). Four teachers mentioned that there were glitches with the iPads or app that resulted in them not being able to use those materials. One teacher mentioned that they did not feel like they had enough iPads for their class, and another mentioned that it was challenging to save and collect student work. Although not a program issue, one teacher also mentioned that it was difficult for them to connect wirelessly.
- **Functionality of the app** (4 comments). Two teachers stated that the placement of path dots was not as accurate as they would have wanted. One teacher thought that the force and motion lenses were too similar, and another teacher thought that the visuals in the app were too complicated for students with special needs.
- **Add curriculum materials** (6 comments). One teacher did not like the Odd One Out activity, while another teacher thought that the single- and multiple-device Bingo activity were too similar. In addition, one teacher thought that there was insufficient background information on the content areas, and another teacher stated that there was insufficient content on energy transformation. A teacher also mentioned that curriculum images were hard to see and read when materials were copied for students.
- **Time with the app** (2 comments). Specifically, two teachers commented that they would like to have had more time to play with or use the app in their classroom.

. These four themes were similar to the challenges noted by the five teachers interviewed in February 2015 (as reported in the Preliminary Findings From SciPlay Classroom Observations and Interviews report.). In addition, the interview data indicated that teachers encountered challenges related to lack of physical space (in classroom or outside) and management of student behavior. The need for more space and student behavior were not identified as issues in the teacher survey responses.

In the teacher survey, teachers were given the opportunity to provide additional advice. The comments provided were often recommendations for improving the Playground Physics program. Recommendations centered on improving technology access or use, functionality of the app, curriculum content, and developer support. Table 10 lists the recommendations offered by participating teachers.

Table 10. Recommendations for Program Improvement Mentioned by Teachers in Survey Responses (*N* = 18)

Recommendations	Frequency (Number of Comments)	Percent
Technology Access or Use		
Address iPad and app malfunctions	1	7.1%
Wireless connectivity	1	7.1%
Functionality of App		
Increase accuracy of dots on path	2	14.3%
Add formulas to app	1	7.1%

Allow videos to be renamed	1	7.1%
Simplify app visuals for students with special needs	1	7.1%
Curriculum		
Add content intro or background information	1	7.1%
Add more activities	1	7.1%
Expand to other content areas	2	14.3%
Developer Support		
Provide more teacher support throughout the school year (e.g., midyear refresher course, tutorials)	1	7.1%
Teacher communication opportunities (e.g., blogs)	1	7.1%
Allow classes more time with iPads	1	7.1%
Total	**14**	**100%**

Note: Teachers could report more than one recommendation.Recommendations provided in the teacher survey were consistent with those provided in the teacher interviews. Three teachers recommended that NYSCI focus on addressing the iPad device quality and missing app functionality challenges. For example, one teacher specified that the quality of the camera could be improved so that students could take clearer videos. Another teacher stated that she would like students to be able to add points to each motion path out of sequence. In addition, five comments related to adding more content to the Playground Physics curriculum. Specifically, one teacher would like to see more background information on the physics content areas included in curriculum. Two teachers stated they would like more content areas developed for the app, and two teachers remarked that they would like to see more options for activities such as one that would require students to produce some type of written work (e.g., reflection exercise).

Summary of Reactions to Playground Physics

Unlike the classroom observations and teacher interviews that were completed with a subset of the teachers participating in this study, the teacher survey data collected allowed all teachers participating in the study an opportunity to voice their opinion on the Playground Physics program.

Overall, the survey findings were similar to what was noted in the classroom observations and teacher interviews. Nearly all teachers believed professional development prepared them to use the Playground Physics program moderately or very well. The app was heavily used by students during instruction by 61 percent to100 percent of the classes participating in the study, and teachers most commonly reported supplementing Playground Physics with their regular curriculum in each of the three content areas: energy, motion, and force. This was also heavily supported in the classroom observations, in which the observer noted that teacher instruction was typically student centered, students were focused on Playground Physics academic tasks and appeared highly engaged with using the video features of the app. Most teachers believed Playground Physics aligned to their instructional style, student's ability level, and New York science standards moderately or very much so. Furthermore, the majority of teachers believed

Playground Physics was moderately or very educationally effective for teaching each of the content areas and would use the program in the future.

Chapter 5: Student Outcomes

This chapter examines whether student engagement and knowledge of physics concepts changed as a result of participating in the Playground Physics program. NYSCI believes student engagement can help encourage changes in more global student attitudes toward science, intrinsic motivation, and educational aspirations as well as student learning of science concepts.

1. How does participation in Playground Physics influence middle school students' affect?
2. How does participation in Playground Physics influence middle school students' knowledge of physics concepts?

For the student affect analysis, results indicated that student engagement in science and attitudes toward science (Science self-concept and Interest in science) were less positive at the end of the school year compared to the beginning of the school year. No differences were noted for student motivation and educational and career aspirations. A paired sample *t*-test showed that students achieved higher score on the knowledge assessment at the end of the year compared to the beginning of the year, and the difference was statistically significant.[9]

How Does Participation in Playground Physics Influence Middle School Students' Affect?

To examine changes in student affect (Engagement in science classrooms, Attitudes toward science: science self-concept, Attitudes toward science: Interest in science, Intrinsic motivation and Educational aspirations) between pre- and posttest survey administration, Rasch-derived scale scores were modeled using a Hierarchical Linear Model (HLM) approach. First, the Rasch model for ordered categories (Andrich, 1978; Rasch, 1980; Wright & Masters, 1982) was used to produce two sets of individual scale scores for the student survey for each respondent.[10] Scores were equated over time (Wright, 1996) to ensure that the two sets of scale scores were comparable. Next, scale scores were modeled using an HLM approach to account for the nesting data structure with time points (pre- and posttest) nested in students nested in teachers. The student-level covariate was the school where students are from,[11] and teacher-level covariates include teaching experience, teaching experience in science, and the number of class periods the science topics of energy, motion and force were taught using the Playground Physics app or curriculum were included in the analysis model. Please see Appendix E for more detail about the HLM model.

Table 11 shows the student survey scale scores for the five survey constructs at pre- and posttest administration. Students exhibited higher engagement at pretest than at posttest. The difference

[9] Results should be interpreted with caution given there was not a control group in the implementation study.
[10] Survey items 4, 22, 25, 30, and 33 were reverse coded for the scaling.
[11] With the small number of schools in the study, AIR will include school as a covariate in the model. If data are available, other student level covariates, such as gender, race/ethnicity, free or reduced-price lunch participation, special educational status, English language proficiency, and school-level covariates, such as school enrollment, school level (e.g., elementary, middle, high school), percentage of students eligible for free or reduced-price lunch students, percentage special education students, and percentage English language learners, will also be included in the model.

between these two time points was significant and indicated there has been a change in student engagement in science. At the end of the school year, there was a reduction in positive student engagement in science.

Similarly, the two subscales of student attitudes toward science (science self-concept and interest in science) exhibited higher scores in pretest administration. The difference between these two time points is significant for each scale and indicated that there has been a reduction in positive student attitudes toward science at the end of the academic year.

There were no significant changes in student intrinsic motivation and educational aspirations. Student responses to these scales were similar at both pre- and posttest administration.

Table 11. Student Survey Construct Scale Scores, Pre- and Posttest Administrations

Constructs	Pre			Post			Pre-Post Comparison		
	Mean	Min	Max	Mean	Min	Max	Estimate	Std. Error	No. of Observations
Engagement in science	1.88	-1.44	6.47	1.79	-3.28	6.47	–0.320**	0.065	912
Attitude toward science: Science self-concept	1.46	-2.62	5.6	1.00	-2.13	3.38	–0.723**	0.058	916
Attitude toward Science: Interest in science	1.39	-5.11	6.85	1.36	-6.39	6.85	–0.302**	0.077	915
Intrinsic motivation	2.81	-5.81	6.83	2.80	-5.81	6.83	–0.201	0.112	913
Educational aspiration	0.96	-3.64	5.47	1.16	-6.7	5.47	0.003	0.078	911

Note: ** $p<0.01$

How does participation in Playground Physics influence middle school students' knowledge of physics concepts?

In addition to engagement in science facilitating changes in affect, changes in student engagement as a result of participating in the Playground Physics program was expected to increase student learning of key physics concepts of energy, force, and motion. The knowledge assessment questions were designed to align with four New York standards related to these content areas.

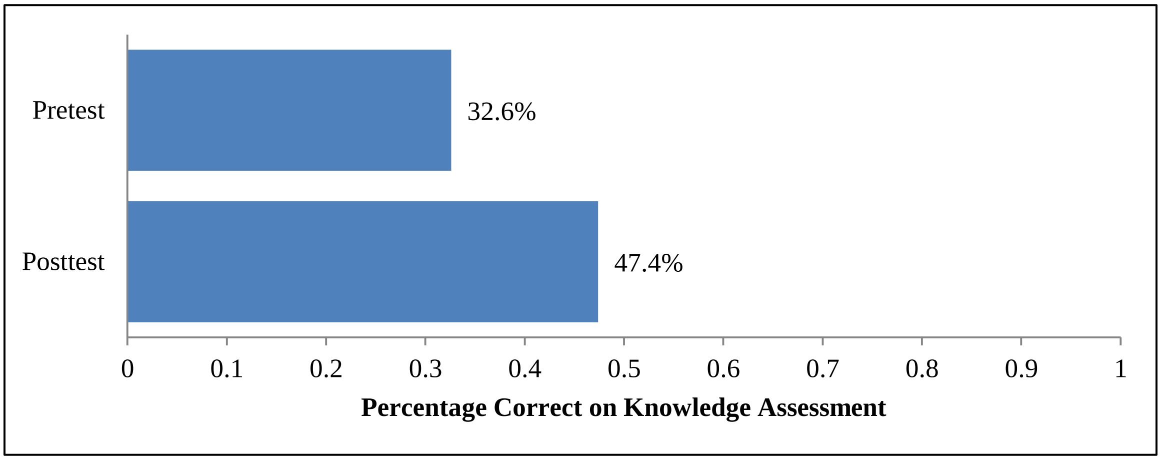
Student knowledge assessment scores at pre- and posttest administrations were generated by summing the number of items student answered correctly. A paired sample *t*-test was designed to investigate the difference in the student knowledge assessment score between pre- and posttest administrations. Only students who responded to both student survey and knowledge assessment at both pre- and posttest administrations were included in the analysis. This was done so student affect and knowledge of physics results reflected the same sample and to facilitate discussion of how well results fit NYSCI's theory of action for the Playground Physics program.

The pre- and posttest knowledge assessment contained 10 common questions and 10 questions that differed. This model was selected because there were a limited selection of publically available items. In addition to the paired sample t-test, student responses to both questions that were the same and different on the pre- and post- knowledge assessment were analyzed descriptively at the item level allowing forthe investigation the difference in the distributions of the correct (or wrong) answers at the two time points. Appendix F provides a description of the four standards, the alignment of standards to pre- and posttest questions, information on whether the pretest and posttest questions are the same or different across the two administrations, and student response distributions at the two administrations.

Students selected the correct answers in the posttest more often than in the pretest on 16 (80.0 percent) of the 20 questions. For the 10 shared questions, more students selected the correct answers in posttest administration than in pretest administration in seven cases. It is notable that for questions 2 (standard 4.1c energy), 3 (standard 4.1c energy), and 15 (standard 5.1b motion), most of students did not get the correct answers at either pre- or posttest administrations.

The overall correct across the 20 items was 32.6 percent at pretest and 47.4 percent in posttest. Students achieved higher score in posttest administration, and the difference is statistically significant. Figure 10 shows student overall pre- and posttest scores on the knowledge assessment.

Figure 10. Overall Pre- and Posttest Knowledge Assessment Scores



Knowledge assessment data were descriptively analyzed by New York standards. Students' average scores at posttest administration were higher than at pretest administration for all standards. The smallest change in learning was seen for standard 4.1c: Most activities in everyday life involve one form of energy being transformed into another. The greatest change in learning was noted in standard 5.1e: For every action there is an equal and opposite reaction.

Table 12 shows students average pretest and posttest scores on the knowledge assessment by standard.

Table 12. Average Pre- and Posttest Knowledge Assessment Scores by New York Standard

New York Standard	Average Percent Correct		Pre-Post Difference
	Pretest	Posttest	
4.1c (energy): Most activities in everyday life involve one form of energy being transformed into another.	25.4%	34.4%	9.0%
4.1e (energy): Energy can be considered to be either kinetic energy, which is the energy of motion, or potential energy, which depends on relative position.	41.4%	56.4%	15.0%
5.1b (motion): The motion of an object can be described by its position, direction of motion, and speed. The position or direction of motion of an object can be changed by pushing or pulling.	30.9%	46.2%	15.3%
5.1e (force): For every action there is an equal and opposite reaction.	26.2%	46.3%	20.1%

In addition, student knowledge assessment data were descriptively analyzed by overall teacher enactment of Playground Physics (teacher usage of Playground Physics and teacher delivery of Playground Physics Instruction). We compared teachers who met both teacher usage of Playground Physics and teacher delivery of Playground Physics indicator ratings to those teachers who did not meet both criteria for high fidelity. Six (33.3 percent) of 18 teachers did not meet high fidelity on both indicators, and 12 (66.7 percent) teachers did. Table 13 provides the average number of days energy, force and motion instruction was provided overall and using Playground Physics program and Table 14 details the average student pre- and posttest knowledge assessments scores on the four New York standards by whether or not their teacher met high fidelity rating on both teacher usage of Playground Physics and teacher delivery of Playground Physics Instruction. Teachers who had high fidelity rating on enactment of Playground Physics showed that they were providing more days of energy, motion and force instruction overall and using Playground Physics. Students of high enactment teachers performed slightly better at both pretest and posttest. However, overall, the change in learning was similar for students of teachers regardless of their Playground Physics enactment level. Thus, we found no evidence to suggest level of enactment of Playground Physics was related to performance on the knowledge assessment.

Table 13. Average Teacher Overall and Playground Physics Instruction Provided in Each Content Area by Teacher Enactment of Program Fidelity Rating

Teacher Enactment	Average Number of Days Providing Energy Instruction		Average Number of Days Providing Motion Instruction		Average Number of Days Providing Force Instruction	
	Overall	Playground Physics	Overall	Playground Physics	Overall	Playground Physics
High	7.6	6.1	6.2	4.2	5.9	3.9

Teacher Enactment (*n* = 12)						
Low Teacher Enactment (*n* = 6)	4.2	2.2	3.8	1.8	4.2	2.7
Total	**6.4**	**4.8**	**5.4**	**3.4**	**5.3**	**3.5**

Table 14. Average Student Pre- and Posttest Knowledge Assessments Scores on the Four New York Standards by Whether or Not Teacher Met High Fidelity Rating on Both Teacher Usage and Delivery of Playground Physics Instruction

New York Standard Questions	Pretest Average Percent Correct		Posttest Average Percent Correct	
	Low Teacher Enactment (*n* = 110)	**High Teacher Enactment (*n* = 433)**	**Low Teacher Enactment (*n* = 110)**	**High Teacher Enactment (*n* = 433)**
4.1c energy (4 questions)	25.9%	25.3%	32.5 %	34.9%
4.1e energy (7 questions)	36.5%	42.7%	59.1%	55.7%
5.1b motion (4 questions)	28.5%	31.5%	51.4%	44.8%
5.1e force (5 questions)	22.5%	27.1%	36.1%	48.9%
Total (all questions)	**29.6%**	**33.3%**	**47.3%**	**47.4%**

Summary of Student Outcomes and Limitations

Based on the student affect analysis, students exhibited less positive engagement in their science class at posttest than at pretest. Similarly, students exhibited less positive attitudes (Science self-concept, Interest in science) at posttest than at pretest. No significant changes in student intrinsic motivation or educational aspirations were noted. Because the survey was administered at the beginning and end of the school year, the student survey might not be a proximal enough to measure student affect following participation in Playground Physics. It is unclear whether this drop in engagement and attitude was a result of participating in Playground Physics or alternative factors that may affect students over the duration of a school year. For example, the posttest survey was administered at about the same time classes would likely have been preparing for New York Regents assessments. It is possible that student response to the posttest administration survey included their feelings toward preparing for the Regents exam. Alternatively, teachers could have completed use of Playground Physics several weeks before posttest administration. If this is the case, it is possible that some students did not remember their experience with Playground Physics as vividly as others who used Playground Physics right up to posttest administration.

Despite the less positive engagement in science class and attitudes toward science, students appeared to be learning about physics concepts as a result of their participation in Playground Physics. Students achieved higher score in posttest knowledge assessment administration than in pretest, and the difference was statistically significant. This result is promising but should be interpreted with caution. Because there was not a control group, it is unclear whether teacher use of Playground Physics in whole or as a supplement to their regular curriculum would lead to greater learning gains than those teachers who would have used only their own traditional instruction on energy, force, and motion with students. More so, because only 543 students of 1,108 students (49.0 percent) identified in teacher roster qualified for inclusion in the study, the final student analytic sample may not be representative of the original student sample.

Chapter 6: Discussion

Playground Physics show promise in its ability to increase student learning of the following physics concepts—energy, force, and motion. Students achieved higher scores on the posttest knowledge assessment compared to the pretest knowledge assessment. As stated previously, this result should be interpreted with caution. Because there is not a control group, it is unclear whether student participation in Playground Physics would lead to greater learning gains than those students who would have participated in teacher’s traditional instruction on energy, force, and motion. Interestingly, changes in student learning occurred even though component fidelity criteria for Playground Physics implementation were not met. It may be the case that the fidelity criteria set for this study year were too stringent.

What is not clear is how Playground Physics influences student affect and whether changes in affect are connected to student learning. The student outcomes would suggest that Playground Physics negatively impacts student engagement and attitudes toward science. However, formative feedback advocates the opposite. Teach survey data suggest that students were engaged in classroom activities while using the Playground Physics program. It is important to consider these results in combination with what was reported in the student outcomes analyses. It may be the case that the student affect surveys, administered at the beginning and end of the school year, were not proximal enough to the intervention to really capture changes in student affect that result from participating in the program.

The remainder of this summary will focus on triangulating the findings between the teacher survey and data collected for the Preliminary Findings From SciPlay Classroom Observations and Interviews report, which included data from classroom observations and teacher interviews. According to both observations and interviews, teachers most often used the Playground Physics multiple-device (student-centered) instructional approach. Observations suggest that most students were highly engaged with using the video features of the app and focused on academic tasks. These beliefs were also corroborated by teacher interviews.

It is clear from the observations, interviews, and the survey that technology was the primary challenge. Challenges with the iPad device quality and app functionality were reported often. Other challenges reported through the classroom observation and interview includes space limitations and behavior management. It should also be noted that one teacher failed to correct student misconceptions between direction of motion and acceleration. Despite these challenges, Playground Physics was well received. In particular, the interviewed and surveyed teachers felt Playground Physics was an easy to use instructional tool and believed that NYSCI adequately prepared them to implement the program. Teachers reported that Playground Physics was moderately or very educationally effective for teaching each of the three content areas and would use the program in the future. More so, teachers stated that using Playground Physics encouraged student engagement and facilitated student learning of physics concepts. In sum, findings from the classroom observations, teacher interviews, and teacher surveys would suggest that participating teachers find the program useful for themselves and the students they serve.

Based on the results of this study, AIR recommends NYSCI consider the following:

- **Examine fidelity of implementation criteria.** Component fidelity criteria set for the 2014–15 study focused on ideal implementation of the program. NYSCI may want to consider what adequate fidelity of implementation might look like during for the 2015–16 impact study. Allowing for greater differentiation in fidelity ratings might provide insightful information on how the program is provided by NYSCI and how participating teacher are using the program in their classrooms.
- **Increase energy transformation content.** Student outcomes data suggest that students are not learning about energy transformation (NY standard 4.1c) as much as other concepts. It is unclear why learning would not occur at a similar rate across all NY standards identified for this study. We speculate that this different may be due to limited energy transformation content in the curriculum materials. NYSCI may consider adding more background text or activities to support student learning of this concept.
- **Add technical support.** Through the teacher survey, it is clear that teachers ran into technology and app challenges. This may be due, in part, because the app was under active development and testing during this time. Although teacher interview data suggested that NYSCI was very responsive throughout the program implementation timeframe, NYSCI may consider creating an action plan for how they intend to address teacher concerns during the impact study. Being able to clearly articulate how a teacher should reach out for program support may help reduce some program implementation challenges.

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Appendix A. Playground Physics Curriculum Activities

The single- and multiple-device curriculum include the following activities:

- Bingo: This scavenger hunt-like activity helps new users get acquainted with and explore the many functions of the app.
- Fun With the App: This activity allows students to record videos at their discretion and uses the app to notice some interesting features of energy, force, and motion in their fun and playful performances. This activity encourages students to become involved more personally in the app and to engage them in learning the science.
- Recognizing Motion/Exceptions/Newton's Third Law: This worksheet presents students with a scenario and asks them to derive or complete relevant information about some feature of an object's energy, force, or motion.
- Predict Observe Explain: This activity encourages student's scientific reasoning and helps them make connections between relationships found within motion (e.g., difference between increasing speed versus constant speed) and energy (e.g., understanding the conditions under which kinetic and potential energy exist simultaneously).
- Data Match: This activity allows students to practice making claims, interpret data in both graphical and table form, and draw conclusions based on evidence from data.
- Agree-Disagree Circles: This activity encourages students to apply Newton's Third Law to various situations and to promote scientific reasoning. Agree-disagree statements give students an opportunity to practice thinking about their own thinking.
- Odd One Out: This activity allows students to draw upon what they know about motion and energy to analyze relationships found within these content areas. The activity encourages student use of their reasoning skills and can stimulate small-group or whole-class discussion.

The science investigation curriculum[12] includes the following activities:

- Bingo: See description under single- and multiple-device activities.
- Experimental Design: This activity encourages students to walk through and answer questions related to the first few steps of the scientific method: ask a question, develop a hypothesis, experimental/investigative design.
- Text Boxes: This literacy activity requires students to read background text on the topics of energy or motion and document big ideas from the text they read.
- Data Table: This worksheet allows students to document data results based on experimentation.
- Conclusion: This activity encourages students discuss whether their hypothesis was or was not supported, provide supporting evidence for this belief and reflect on limitations and ideas for future investigation.

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[12] Scientific investigation was created for motion and energy only.

Appendix B. Teacher Survey

Introduction

Welcome to the SciPlay survey!

You will be presented with several questions related to 5 topic areas:
(1) Background Information
(2) Training and Support
(3) SciPlay App and Curriculum Use
(4) Opinions of SciPlay
(5) Your Teaching Style

Please click the "next" button at the bottom of each screen to advance to the following page of the survey. The survey should take about 15-20 minutes to complete.

This survey is for teachers who are participating in the SciPlay program during the 2014-15 school year. This survey should not be taken by school administrators, science consultants, or other non-teaching staff.

1. Would you like to continue with this survey?

- Yes
- No

SciPlay Teacher Survey

Section 1: Teacher Background

The following items will ask you to describe your current teaching assignments and characteristics of your teacher preparation.

*2. Which school do you teach at?

*3. Including this year, how many years have you been teaching?

Year(s)

*4. Including this year, how many years have you been teaching science?

Year(s)

5. What grade level(s) are you currently teaching? (Select all that apply)

- 6
- 7
- 8
- Other (please specify)

6. Select the degree(s) you have earned? (Select all that apply)

- Bachelors
- Masters
- Doctorate

You have completed Section 1 of 5. Please press the Next button to continue to the next section.

SciPlay Teacher Survey

7. Please indicate the subject(s) your degree(s) were in. (Select all that apply)

- Biology/Life Sciences
- Chemistry
- Earth/Space Sciences
- Physics
- Other Science
- Science education (any science discipline)
- Mathematics/Mathematics Education
- Elementary Education
- Other Education (e.g., History Education, Special Education)
- Other (please specify)

SciPlay Teacher Survey

8. Please indicate the subject your teaching certificate is in. (Select all that apply)

- Biology
- Chemistry
- Childhood Education
- Earth Science
- Educational Technology
- English
- Gifted Education
- General Science
- Literacy
- Math
- Middle Childhood Education
- Physics
- Secondary Education
- Special Education
- Speech and Language Disabilities
- Students with Disabilities
- Technology Education
- Other (please specify)

SciPlay Teacher Survey

Section 2: Training and Support

In this section, you will be asked to describe your experiences with SciPlay professional development and support.

*9. Did NYSCI provide you with the following resources?

	Yes	No
SciPlay app.		
SciPlay curriculum materials		
2 or more Ipads		

10. How well did NYSCI's professional development prepare you to teach the SciPlay curriculum (instructional strategies and activities)?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

11. How well did NYSCI's professional development prepare you to use the SciPlay app.?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

12. What advice would you give to NYSCI about how to improve the professional development?

You have completed Section 2 of 5. Please press the Next button to continue to the next section.

SciPlay Teacher Survey

Section 3: SciPlay App. and Curriculum Use

In this section, you will be asked about the different lenses and activities your class used with SciPlay.

Please answer the following questions with a single science classroom in mind. Therefore, if SciPlay was used with more than one classroom, answer these questions with respect to the one that was scheduled second during the school day.

***13. Please write the start and end times for the class period during which SciPlay was used. If it was used with more than one class period, select the class that is scheduled second during the day:**

	HH		MM	AM/PM
Start time:		:		
End time:		:		

SciPlay Teacher Survey

Energy Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

***14. In total, how many class periods have you spent teaching energy (e.g., energy transformation, potential energy, kinetic energy) this year? Include all class periods spent on this topic, whether they involved SciPlay or any other curriculum.**

***15. Did you use SciPlay to teach energy concepts to this classroom?**

Yes

No

SciPlay Teacher Survey

Energy Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

*16. Of the [Q14] class periods you taught energy to this class, how many periods involved the SciPlay app or curriculum?

17. What percent of students in this class used the SciPlay app during the energy unit?

- None
- 1 – 20%
- 21 – 40%
- 41 –60%
- 61–80
- 81-100%

18. Which SciPlay instructional approaches did you use to teach energy to this class? (Select all that apply)

- Single-device
- Multi-device
- Long Term Science Investigation
- None of the SciPlay instructional approaches were used

19. Along with SciPlay, how much of your regular (non-SciPlay) energy curriculum did you use?

- None. I used only the SciPlay curriculum to teach energy.
- Some. I supplemented the SciPlay curriculum with some materials and activities from my regular curriculum.
- All. I used all of my regular curriculum and supplemented it with SciPlay.

20. To what extent did you find SciPlay to be educationally effective for teaching energy?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

SciPlay Teacher Survey

21. The next time you teach energy, would you use SciPlay again?

- Yes
- Yes, with changes
- Maybe
- No
- Not applicable

Please explain:

SciPlay Teacher Survey

Motion Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

***22. In total, how many class periods have you spent teaching motion (e.g. speed, position) this year? Include all class periods spent on this topic, whether they involved SciPlay or any other curriculum.**

***23. Did you use SciPlay to teach motion concepts to this classroom?**

- Yes
- No

SciPlay Teacher Survey

Motion Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

***24. Of the [Q22] class periods you taught motion to this class, how many periods involved the SciPlay app or curriculum?**

25. What percent of students in this class used the SciPlay app during the motion unit?

- None
- 1 – 20%
- 21 – 40%
- 41 –60%
- 61–80
- 81-100%

26. Which SciPlay instructional approaches did you use to teach motion to this class? (Select all that apply)

- Single-device
- Multi-device
- Long Term Science Investigation
- None of the SciPlay instructional approaches were used

27. Along with SciPlay, how much of your regular (non-SciPlay) motion curriculum did you use?

- None. I used only the SciPlay curriculum to teach energy.
- Some. I supplemented the SciPlay curriculum with some materials and activities from my regular curriculum.
- All. I used all of my regular curriculum and supplemented it with SciPlay.

28. To what extent did you find SciPlay to be educationally effective for teaching motion?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

SciPlay Teacher Survey

29. The next time you teach motion, would you use the SciPlay again?

- Yes
- Yes, with changes
- Maybe
- No
- Not applicable

Please explain:

SciPlay Teacher Survey

Force Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

***30. In total, how many class periods have you spent teaching force (e.g. Newton's third law of equal and opposite forces) this year? Include all class periods spent on this topic, whether they involved SciPlay or any other curriculum.**

***31. Did you use SciPlay to teach force concepts to this classroom?**

- Yes
- No

SciPlay Teacher Survey

Force Lessons

Reminder: Answer the following questions with one science classroom in mind. If SciPlay was used with more than one classroom, answer these questions with respect to the classroom that was scheduled second during the school day.

***32. Of the [Q30] class periods you taught force to this class, how many periods involved the SciPlay app or curriculum?**

33. What percent of students in this class used the SciPlay app during the force unit?

- None
- 1 – 20%
- 21 – 40%
- 41 –60%
- 61–80
- 81-100%

34. Which SciPlay instructional approaches did you use to teach force to this class? (Select all that apply)

- Single-device
- Multi-device
- Neither of the SciPlay instructional approaches were used

35. Along with SciPlay, how much of your regular (non-SciPlay) force curriculum did you use?

- None. I used only the SciPlay curriculum to teach energy.
- Some. I supplemented the SciPlay curriculum with some materials and activities from my regular curriculum.
- All. I used all of my regular curriculum and supplemented it with SciPlay.

36. To what extent did you find SciPlay to be educationally effective for teaching force?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

SciPlay Teacher Survey

37. The next time you teach force, would you use the SciPlay again?

- Yes
- Yes, with changes
- Maybe
- No
- Not applicable

Please explain:

SciPlay Teacher Survey

SciPlay Activities

The following items will ask you to identify which activities were used in any lens (e.g. energy, force, and motion) and class where SciPlay was used.

38. If you used the single- or multi- device approach, which of the following SciPlay activities did you use? (Select all that apply)

- Introductory activity
- Bingo
- Fun with the app
- Recognizing activity [Exceptions, Motion, Newton's Third Law]
- Predict Observe Explain
- Odd One Out
- Agree–Disagree Circles
- Data Match
- Not applicable—I did not use the single- or multi- device approach.

39. If you used a Long Term Science Investigation lesson, which of the following activities did you use? (Select all that apply)

- Introductory activity
- Bingo
- Asking a question
- Developing a hypothesis
- Investigation Design
- Procedure
- Results
- Conclusion
- Not applicable—I did not use a Long Term Science Investigation.

You have completed section 3 of 5. Please press the next button to continue to the next section.

SciPlay Teacher Survey

Section 4: SciPlay Opinions

In this section, please provide your opinions based on your experience implementing SciPlay.

40. How easy was it for students to use the SciPlay app?

- Not easy at all
- Somewhat easy
- Moderately easy
- Very easy
- Did not use this feature

41. Describe the level of student engagement during the SciPlay lessons, where engagement is defined as focus on the academic tasks in the lessons:

- Students were less engaged than in conventional lessons on these topics.
- Students were equally engaged as in conventional lessons on these topics.
- Students were more engaged than in conventional lessons on these topics.

42. Were the SciPlay curriculum materials organized in a useful manner?

- Not at all/slightly
- Somewhat
- Moderately
- Very much so

43. How well did the SciPlay curriculum match with...

	Not at all/slightly	Somewhat	Moderately	Very much so
Your students' ability level in this class				
NY state science standards for this grade level				
Your instructional style				

44. In your opinion, what aspects of SciPlay worked well?

45. In your opinion, what aspects of SciPlay did not work well?

You have completed Section 4 of 5. Please press the Next button to continue to the next section.

46. What additional advice would you give to NYSCI about how to improve SciPlay (app or curriculum materials)?

SciPlay Teacher Survey

Section 5: Your Teaching Style

The following items will ask you to describe your teaching style.

47. In general, about how often do you do each of the following in your science instruction throughout the school year?

	Never	Rarely (e.g., a few times a year)	Sometimes (e.g., once or twice a month)	Often (e.g., once or twice a week)	All or almost all science lessons
Introduce content through formal presentations.					
Demonstrate a science-related principle or phenomenon.					
Teach science using real-world contexts.					
Arrange seating to facilitate student discussion.					
Use open-ended					
Require students to supply evidence to support their claims.					
Encourage students to explain concepts to one another.					
Encourage students to consider alternative explanations.					
Allow students to work at their own pace.					
Read and comment on the reflections students have written in their notebooks or journals.					

48. How comfortable are you with supplementing curriculum with technologies like computers and tablets?

- Not at all comfortable
- Somewhat comfortable
- Mostly comfortable
- Very comfortable

You have completed Section 5 of 5. Please press the Next button to submit your survey.

SciPlay Teacher Survey

Survey End Page

Thank you for participating in the survey!

If you have questions about or difficulties with the survey, please contact Sonica Dhillon at (312) 283 – 2315 or at gdhillon@air.org

The director of this evaluation study, Jonathan Margolin, may be contacted at (312) 288 – 7632 or at

Appendix C. Student Outcome Measures

C.1. Playground Physics Student Survey Aligned to Student Affect Constructs

Section 1[13]: Below are several sentences about science. For each sentence, check the box that describes how much you agree with that sentence.

When you think about doing science, how much do you agree or disagree with the following sentences?	Really Disagree	Disagree	Agree	Really Agree
1. Compared to others my age, I am good at science.	☐	☐	☐	☐
2. I get good grades in science.	☐	☐	☐	☐
3. Work in science is easy for me.	☐	☐	☐	☐
4. I'm hopeless when it comes to science.*	☐	☐	☐	☐
5. I learn things quickly in science.	☐	☐	☐	☐
6. I have always done well in science.	☐	☐	☐	☐

Section 2[14]: Below are several sentences about science. For each sentence, check the box that describes how much you agree with that sentence.

When you think about your interest in science, how much do you agree or disagree with the following sentences?	Really Disagree	Disagree	Agree	Really Agree
7. I would like to learn more about science.	☐	☐	☐	☐
8. Science is a topic that I enjoy studying.	☐	☐	☐	☐
9. Science is boring.	☐	☐	☐	☐
10. Learning to solve new science problems is interesting.	☐	☐	☐	☐
11. I like learning about science.	☐	☐	☐	☐
12. I enjoy hearing about science.	☐	☐	☐	☐
13. I would enjoy belonging to a science club.	☐	☐	☐	☐
14. I like talking to friends about science.	☐	☐	☐	☐
15. Science is one of the most interesting school subjects.	☐	☐	☐	☐
16. What I learn in science class can be used to solve everyday problems.	☐	☐	☐	☐
17. I like reading books about science.	☐	☐	☐	☐

[13] Measures student attitudes toward science: Science self-concept
[14] Measures student attitudes toward science: Interest in science

Section 3[15]: When you think about your experiences in this class, how much do you agree or disagree with the following sentences?

In this science class…	Really Disagree	Disagree	Agree	Really Agree
18. I paid careful attention.	☐	☐	☐	☐
19. I actively participated.	☐	☐	☐	☐
20. I took part in class assignments.	☐	☐	☐	☐
21. I listened very carefully.	☐	☐	☐	☐
22. I was restless. *	☐	☐	☐	☐
23. I worked hard on what I was supposed to do.	☐	☐	☐	☐
24. I stayed focused on the class activity.	☐	☐	☐	☐
25. I ignored what the teacher was saying. *	☐	☐	☐	☐
26. I enjoyed the activities we did.	☐	☐	☐	☐
27. I often lost track of time in class.	☐	☐	☐	☐
28. Class was fun.	☐	☐	☐	☐
29. I enjoyed working with my classmates.	☐	☐	☐	☐
30. I often felt frustrated. *	☐	☐	☐	☐
31. Sometimes I got so interested in my work I didn't want to stop.	☐	☐	☐	☐
32. I liked the ways we learned things.	☐	☐	☐	☐
33. I often felt bored.*	☐	☐	☐	☐

Section 4[16]: Please rate your level of agreement for each of these sentences about your science class.

	Really Disagree	Disagree	Agree	Really Agree
34. I want to learn as much as possible from this class.	☐	☐	☐	☐
35. It is important for me to understand each science lesson completely.	☐	☐	☐	☐
36. I want to be able to remember what I learned in this class even after the year is over.	☐	☐	☐	☐
37. I like getting assignments in this class that really challenge me to learn new things.	☐	☐	☐	☐
38. I hope to know a lot more about science when this school year is over.	☐	☐	☐	☐

[15] Measures student engagement; questions 18–25 measure concentration, questions 26–29 measure enjoyment, and questions 30–33 measure interest.
[16] Measures student intrinsic motivation

Section 5[17]: We now want to know about your plans for the future. For each question below, let us know if you think you will do what we are asking about.

When you think about the future, how likely are you to do the following?	No	Maybe	Probably	Yes, Definitely
39. Take more than the required number of science classes in high school?	☐	☐	☐	☐
40. Take Advanced Placement science classes, courses that give college credit, in high school?	☐	☐	☐	☐
41. Attend college?	☐	☐	☐	☐
42. Take science classes in college?	☐	☐	☐	☐
43. Major in a science-related field in college?	☐	☐	☐	☐
44. Look for a job which uses science?	☐	☐	☐	☐

Section 6[18]: You will read several sentences about your experience using SciPlay, an app that can help students learn about science concepts through video recordings. For each statement, indicate whether you used the SciPlay app.

In this science class…	Yes	No	Not Sure
45. I recorded videos using the SciPlay app.	☐	☐	☐
46. I traced the path of objects using the SciPlay app.	☐	☐	☐
47. I used stickers in the SciPlay app.	☐	☐	☐

* Survey items were reverse coded for the scaling.

[17] Measures student educational aspirations
[18] Questions treated as manipulation check to see if students recall participation in Playground Physics.

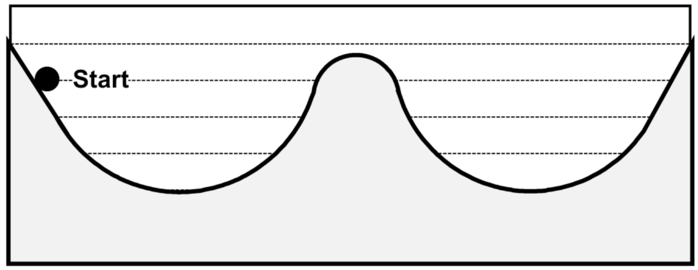
C.2. Playground Physics Pretest Knowledge Assessment

1. A girl and a boy are each holding a ball. The girl throws her ball, and the boy drops his ball. Which statement describes the kinetic energy of the balls while they are moving through the air?
    a. The ball that was thrown has kinetic energy, but the ball that was dropped does not.
    b. The ball that was dropped has kinetic energy, but the ball that was thrown does not.
    c. Both the ball that was thrown and the ball that was dropped have kinetic energy.
    d. Neither the ball that was thrown nor the ball that was dropped has kinetic energy.

2. A student uses a rubber band to shoot a toy car across a level floor. Assume no energy is transferred from the car to the floor or to the air. What happens to the total amount of energy in the system (car and rubber band) soon after the car has been released from the rubber band?
    a. The total amount of energy increases because the kinetic energy of the car increases and the energy of the rubber band stays the same.
    b. The total amount of energy increases because the increase in the kinetic energy of the car is more than the decrease in the energy of the rubber band.
    c. The total amount of energy decreases because the increase in the kinetic energy of the car is less than the decrease in the energy of the rubber band.
    d. The total amount of energy remains the same because the increase in the kinetic energy of the car is the same as the decrease in the energy of the rubber band.

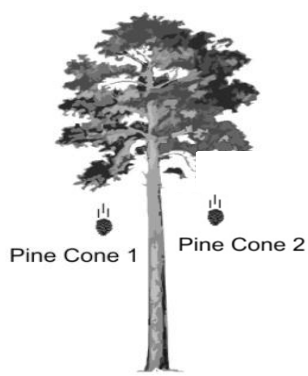
3. A boy holds a ball of clay above the floor. He lets go of the clay ball, and it speeds up as it falls to the floor. When the clay ball hits the floor, the ball and the floor each get a little warmer. (Assume that no energy is transferred between the clay ball and the air or between the floor and the air.) What happens to the total energy of the system (clay ball and floor) as the clay ball falls and hits the floor?
    a. The total amount of energy increases because the clay ball and the floor are warmer, and therefore have more energy.
    b. The total amount of energy decreases because the decrease in energy of the falling clay ball is greater than the increase in energy of the warmer ball and floor.
    c. The total amount of energy stays the same because the decrease in energy of the falling clay ball is equal to the increase in energy of the warmer ball and floor.
    d. The total amount of energy stays the same because the clay ball and floor have increased temperature, but not increased energy.

4. Imagine a ball on a track where no energy is transferred from the ball to the track or to the air. The ball starts from rest at the position labeled Start. Will the ball have enough energy to go over the hill on the track?



   a. Yes, because the energy that the ball gains as it goes down the first slope will be greater than the amount of energy it will lose as it goes up the hill.
   b. Yes, because the ball gains energy the entire time it is moving, so it will have enough energy to go over the hill.
   c. No, because the total amount of energy in the system remains the same, so the ball cannot go any higher than the point it started from.
   d. No, because the total amount of energy of the ball will decrease as it moves along the track, and it will not have enough energy to go over the hill.

5. Two pine cones are falling from a pine tree. Both pine cones are falling at the same speed. Pine Cone 1 weighs less than Pine Cone 2. Which statement describes the kinetic energy of the pine cones?



   a. Pine Cone 1 has more kinetic energy.
   b. Pine Cone 2 has more kinetic energy.
   c. Both pine cones have the same amount of kinetic energy.
   d. Neither pine cone has any kinetic energy.

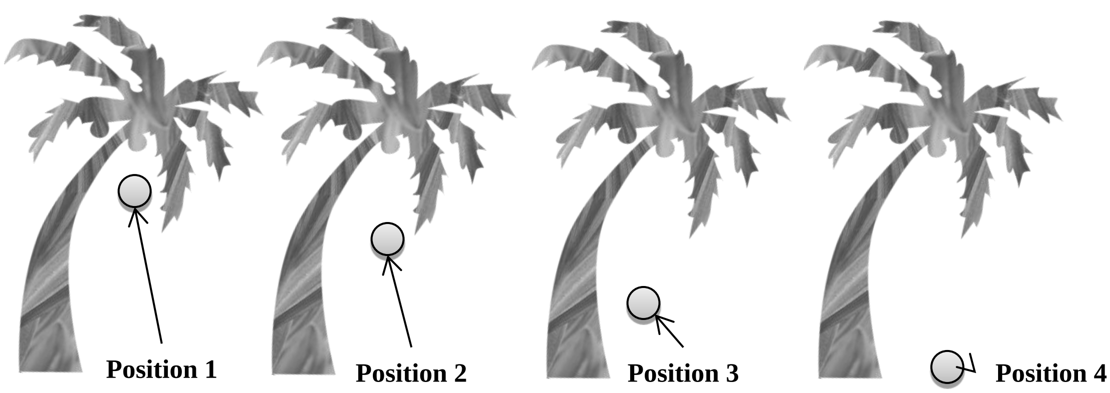
6. Two identical balls are rolling down a hill. Ball 2 is rolling faster than Ball 1. Which ball has more kinetic energy?

    a. Ball 1 has more kinetic energy.
    b. Ball 2 has more kinetic energy.
    c. Both balls have the same amount of kinetic energy.
    d. More information is needed to determine which ball has more kinetic energy.

7. A student places two books on a table. One book weighs less than the other book. Which book has less gravitational potential energy? (Consider the reference point for the ground to be the floor.)

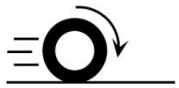
    a. The book that weighs less has less gravitational potential energy.
    b. The book that weighs more has less gravitational potential energy.
    c. Both books have the same amount of gravitational potential energy.
    d. Neither book has any gravitational potential energy.

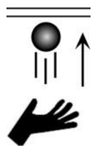
8. A coconut is falling from a palm tree. In which position does the coconut have the most gravitational potential energy?



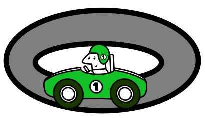
    a. Position 1
    b. Position 2
    c. Position 3
    d. Position 4

9. Which of the following is an example of the transformation of gravitational potential energy into kinetic energy?

a.  A tire rolling along a level floor

b.  A ball going up after being tossed into the air

c.  A drop of water falling from a faucet into a sink

d.  A car on a flat oval race track

10. A girl and a boy are playing on a teeter-totter. They both weigh the same. While the boy is down and the girl is up, which child has more gravitational potential energy?

a. The boy has more gravitational potential energy.
b. The girl has more gravitational potential energy.
c. They have the same amount of gravitational potential energy.
d. They do not have any gravitational potential energy.

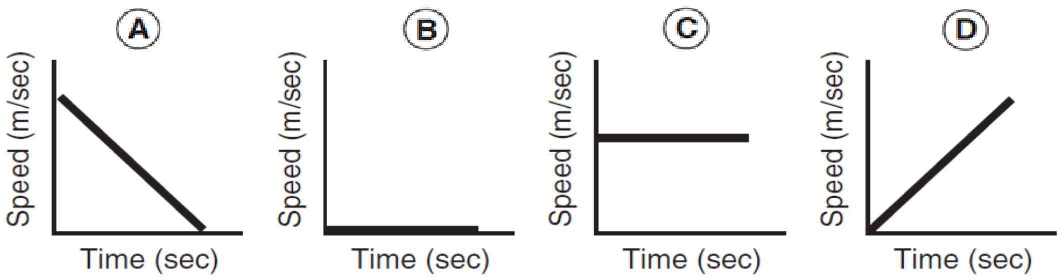
11. A boy holds a book above the floor. He lets go of the book and the book speeds up as it falls to the floor. Which statement describes the energy of the book as it falls?

a. Its kinetic energy increases and its gravitational potential energy increases.
b. Its gravitational potential energy decreases but its kinetic energy does not change.
c. Its gravitational potential energy decreases and its kinetic energy increases.
d. Its kinetic energy increases but its gravitational potential energy does not change.

12. An escalator at a shopping mall is 10 m long and moves at a constant speed of 0.5 m/s. If José steps onto the escalator at the bottom while it is moving, how long will it take him to travel the 10 m?

    a. 5 s
    b. 10 s
    c. 15 s
    d. 20 s

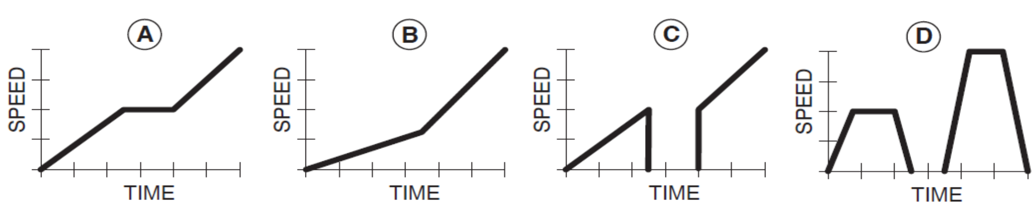
13. Which graph below shows an object slowing down?



14. A ball is thrown straight up into the air. What happens to the ball's speed as it goes up and as it comes down?

    a. The ball goes up at a constant speed, stops, and then comes down at a constant speed.
    b. The ball goes up at a constant speed, stops, and then moves faster and faster as it comes down.
    c. The ball goes up at a slower and slower speed, stops, and then comes down at a constant speed.
    d. The ball goes up at a slower and slower speed, stops, and then comes down faster and faster.

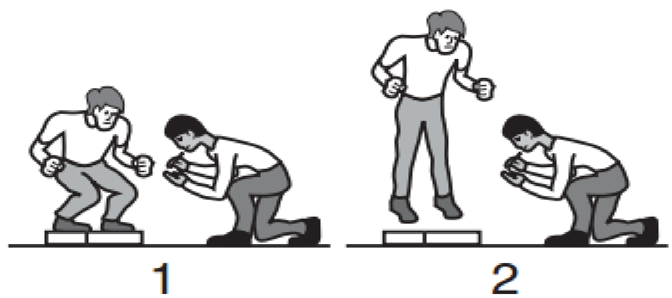
15. Carolyn walks to school. One morning, halfway to school, she stopped to watch a bird building a nest. When she realized she was late, she ran the rest of the way to school. Which graph below shows Carolyn's speed during her walk to school?



16. A student pushes against a tree with a force of 10 newtons (N). The tree does not move. What is the amount of force exerted by the tree on the student?

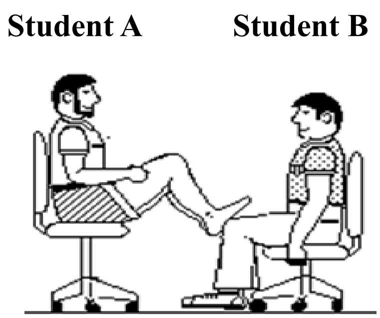
    a. 0 N
    b. 5 N
    c. 10 N
    d. 20 N

17. A student in a lab experiment jumps upward off a scale as the lab partner records the scale reading. What does the lab partner observe during the experiment?



    a. The scale reading remains unchanged during the entire time the student is in contact with the scale.
    b. The scale reading increases momentarily then decreases as the student moves upward from the scale.
    c. The scale reading increases the entire time the student is in contact with the scale.
    d. The scale reading decreases momentarily then increases as the student moves upward from the scale.

18. **Teacher A** weighs 160 pounds and **Teacher B** weighs 120 pounds. They sit in identical office chairs facing each other. The chairs have wheels. **Teacher A** puts his feet on the knees of **Teacher B** and suddenly pushes outward with his feet, causing both chairs to move.



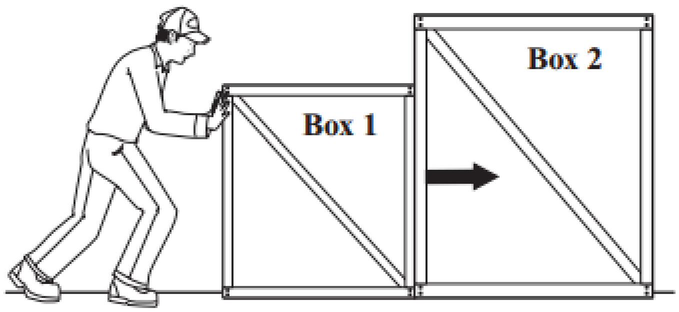
During the push, while the teachers are still in contact, which teacher applies a larger force on the other?

a. The forces from each teacher gets cancelled out by the other teacher.
b. **Teacher A** applies a force on **Teacher B**, but **Teacher B** doesn't apply any force on **Teacher A**.
c. **Teacher A** applies a larger force. **Teacher B** applies a smaller force.
d. Each teacher applies the same force on the other, but they react differently.

19. A soccer player kicks a 0.5-kilogram stationary ball with a force of 50 newtons. What is the force on the player's foot?

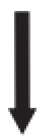
a. 0 N
b. 25 N
c. 50 N
d. 100 N

20. A worker in a warehouse pushes two wooden boxes across a floor at a constant speed, as shown in the diagram below.



The arrow in the diagram represents the force **Box 1** exerts on **Box 2**. Which arrow represents the reaction force?

a. 

b. 

c. 

d. 

C.3. Playground Physics Posttest Knowledge Assessment

1. A girl and a boy are each holding a ball. The girl throws her ball, and the boy drops his ball. Which statement describes the kinetic energy of the balls while they are moving through the air?

    a. The ball that was thrown has kinetic energy, but the ball that was dropped does not.
    b. The ball that was dropped has kinetic energy, but the ball that was thrown does not.
    c. Both the ball that was thrown and the ball that was dropped have kinetic energy.
    d. Neither the ball that was thrown nor the ball that was dropped has kinetic energy.

2. An engineer is building a roller coaster and wants the roller coaster car to go over two hills. In order for the roller coaster car to make it over both hills, should the first hill be higher or lower than the second hill?

    a. The first hill has to be higher than the second hill because the roller coaster car will lose energy as it rolls along the track, so it will not be able to get over a second hill that is as high as the first hill.
    b. The first hill can be lower than the second hill because the roller coaster car will gain enough energy as it rolls along the track to get over a second hill that is higher than the first hill.
    c. It doesn’t matter which hill is higher as long as they are both lower than the starting point because no energy is lost as the roller coaster car rolls along the track, so it can get over any hill that is lower than the starting point.
    d. It doesn’t matter which hill is higher because even though the total amount of energy that the roller coaster car has will decrease going uphill, it will increase enough going downhill to get over any size hill.

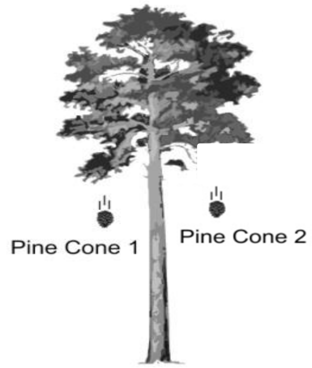
3. A boy holds a ball of clay above the floor. He lets go of the clay ball, and it speeds up as it falls to the floor. When the clay ball hits the floor, the ball and the floor each get a little warmer. (Assume that no energy is transferred between the clay ball and the air or between the floor and the air.) What happens to the total energy of the system (clay ball and floor) as the clay ball falls and hits the floor?

    a. The total amount of energy increases because the clay ball and the floor are warmer, and therefore have more energy.
    b. The total amount of energy decreases because the decrease in energy of the falling clay ball is greater than the increase in energy of the warmer ball and floor. Although
    c. The total amount of energy stays the same because the decrease in energy of the falling clay ball is equal to the increase in energy of the warmer ball and floor.
    d. The total amount of energy stays the same because the clay ball and floor have increased temperature, but not increased energy.

4. Is energy transformed while a rock is falling from a cliff?

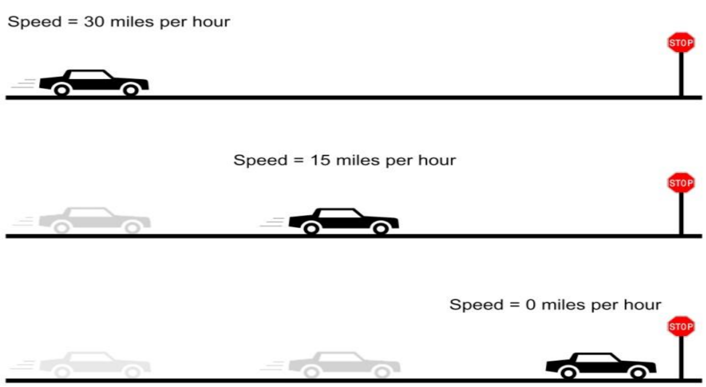
    a. Yes, kinetic energy is transformed into gravitational potential energy as the rock falls.
    b. Yes, gravitational potential energy is transformed into kinetic energy as the rock falls.
    c. No, because the rock lost all of its gravitational potential energy once it started to move.
    d. No, because one form of energy cannot be transformed into another form of energy.

5. Two pine cones are falling from a pine tree. Both pine cones are falling at the same speed. Pine Cone 1 weighs less than Pine Cone 2. Which statement describes the kinetic energy of the pine cones?



    a. Pine Cone 1 has more kinetic energy.
    b. Pine Cone 2 has more kinetic energy.
    c. Both pine cones have the same amount of kinetic energy.
    d. Neither pine cone has any kinetic energy.

6. A man is driving a car. He slows down to stop at a stop sign. When does the car have the most kinetic energy?

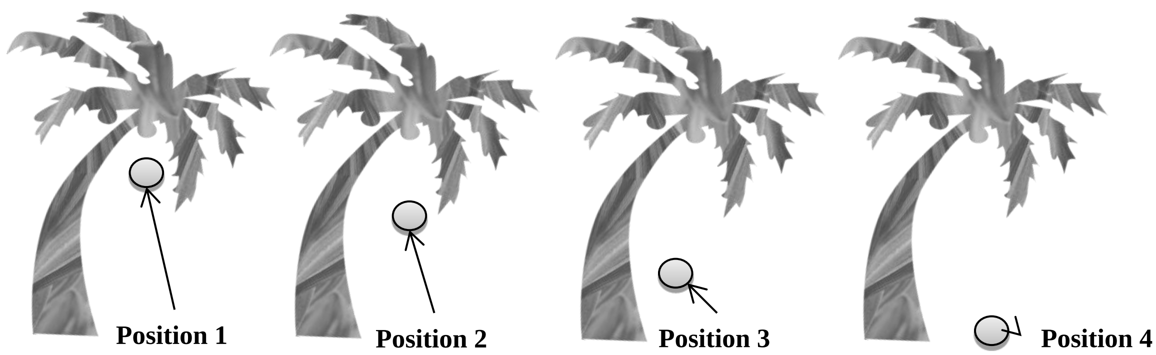


    a. When the car's speed is 30 miles per hour
    b. When the car's speed is 15 miles per hour
    c. When the car's speed is 0 miles per hour
    d. The car's kinetic energy is the same at all speeds

7. Object 1 and Object 2 are the same distance from the center of Earth, but Object 1 has more gravitational potential energy than Object 2. How does the weight of Object 1 compare to the weight of Object 2?

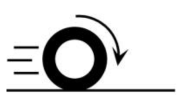
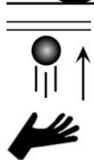
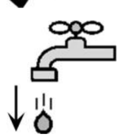
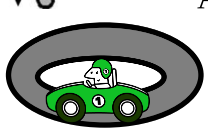
    a. Object 1 weighs more than Object 2
    b. Object 1 weighs less than Object 2.
    c. Object 1 weighs the same as Object 2.
    d. More information is needed to compare the weights of the objects.

8. A coconut is falling from a palm tree. In which position does the coconut have the most gravitational potential energy?



    a. Position 1
    b. Position 2
    c. Position 3
    d. Position 4

9. Which of the following is an example of the transformation of gravitational potential energy into kinetic energy?

    a.  A tire rolling along a level floor
    b.  A ball going up after being tossed into the air
    c.  A drop of water falling from a faucet into a sink
    d.  A car on a flat oval race track

10. A person hangs three pictures on the wall. The pictures all weigh the same. Picture 1 and Picture 2 are at the same height above the floor. Picture 3 is directly below Picture 1. Which pictures have the same amount of gravitational potential energy?

    a. Pictures 1 and 2
    b. Pictures 1 and 3
    c. Pictures 2 and 3
    d. Pictures 1, 2, and 3

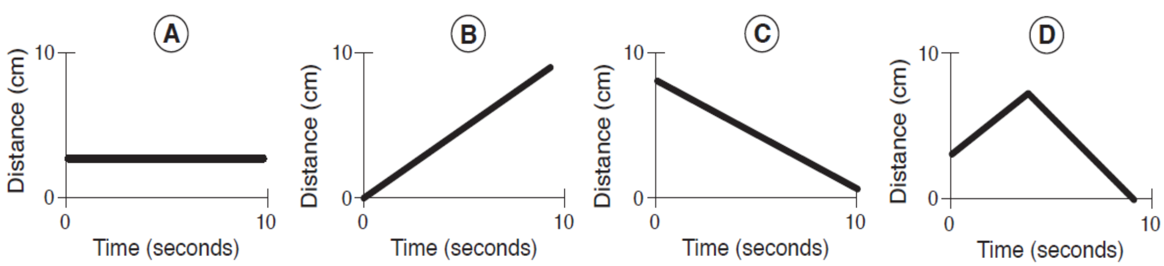
11. How does changing the speed of an object affect the kinetic energy of the object?

    a. A decrease in speed causes an increase in kinetic energy.
    b. An increase in speed causes an increase in kinetic energy.
    c. An increase in speed causes no change in kinetic energy.
    d. A decrease in speed causes no change in kinetic energy.

12. In 2 seconds, a ball travels 100 cm. What is the average speed of the ball?

    a. 25 cm/sec
    b. 50 cm/sec
    c. 100 cm/sec
    d. 200 cm/sec

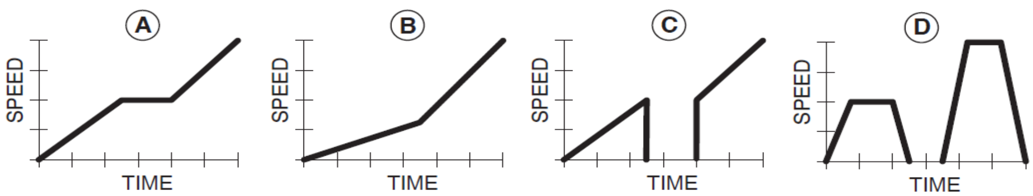
13. Kaitly is watching a wind-up toy walking across a table. She observes that the toy covers 1 cm every second for 10 seconds. What graph below most closely represents the toy's journey across the table?



14. A ball is thrown straight up into the air. What happens to the ball's speed as it goes up and as it comes down?

    e. The ball goes up at a constant speed, stops, and then comes down at a constant speed.
    f. The ball goes up at a constant speed, stops, and then moves faster and faster as it comes down.
    g. The ball goes up at a slower and slower speed, stops, and then comes down at a constant speed.
    h. The ball goes up at a slower and slower speed, stops, and then comes down faster and faster

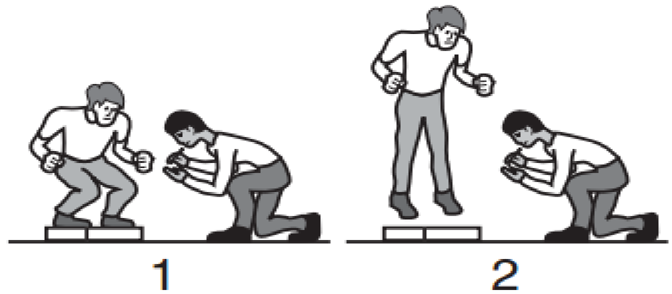
15. Carolyn walks to school. One morning, halfway to school, she stopped to watch a bird building a nest. When she realized she was late, she ran the rest of the way to school. Which graph below shows Carolyn's speed during her walk to school?



16. A student pushes against a wall with 20 N of force and the wall does not move. How much force does the wall exert?

    a. 0 N
    b. Less than 20 N
    c. 20 N
    d. More than 20 N

17. A student in a lab experiment jumps upward off a scale as the lab partner records the scale reading. What does the lab partner observe during experiment?



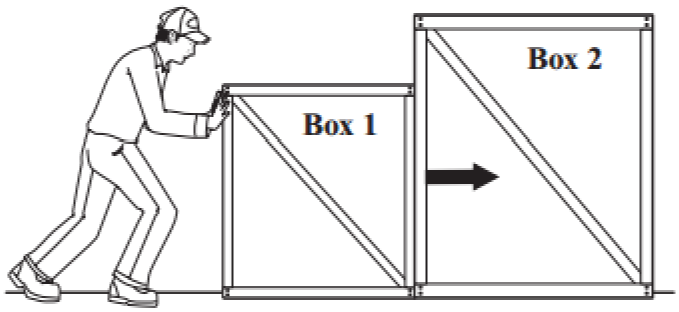
f. The scale reading remains unchanged during the entire time the student is in contact with the scale.
g. The scale reading increases momentarily then decreases as the student moves upward from the scale.
h. The scale reading increases the entire time the student is in contact with the scale.
i. The scale reading decreases momentarily then increases as the student moves upward from the scale.

18. A toy school bus and a toy car crash head-on. Which applies a larger force on the other?
a. The toy bus, because it's heavier
b. Neither applies any force on the other; the toy car gets smashed up because it's in the way of the toy bus
c. The toy bus applies a force on the toy car, but the toy car doesn't apply any force on the toy bus
d. They both apply the same force on each other; the toy car gets smashed up because it has less substance

19. A soccer player kicks a 0.5-kilogram stationary ball with a force of 50 newtons. What is the force on the player's foot?

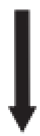
e. 0 N
f. 25 N
g. 50 N
h. 100 N

20. A worker in a warehouse pushes two wooden boxes across a floor at a constant speed, as shown in the diagram below.



The arrow in the diagram represents the force **Box 1** exerts on **Box 2**. Which arrow represents the reaction force?

e. 

f. 

g. 

h. 

Appendix D. Calculating Playground Physics Fidelity

Indicator	Criteria	Indicator Measures	Indicator Metric	Component Metric
Playground Physics Professional Development				
NYSCI delivery Playground Physics professional development	Delivery of three professional development sessions	NYSCI professional development Attendance Records ▪ professional development session 1 dates include 12/9/2014 and 12/10/2014 ▪ professional development session 2 dates include 12/13/2014 and 12/14/2014 ▪ professional development session 3 dates include 12/15/2014 and 12/16/2014 PD_Dlvry = number of sessions offered/6 sessions.	PD_Dlvry_Rtng = "High" if PD_Dlvry = 1 PD_Dlvry_Rtng = "Low" if PD_Dlvry < 1	PD_Overall_Total = PD_Dlvry + PD_Attnd_Average
Teacher attendance of Playground Physics professional development	Attendance at all three professional development sessions	NYSCI professional development Attendance Records professional development_Day1 = attend session1 professional development_Day2 = attend session 2 professional development_Day3 = attend session 3 For responses, code "yes" = 1; "no" = 0;	PD_Attnd_Total = PD_Day1 + PD_Day2 + PD_Day3 PD_Attnd_Average = PD_Attnd_Total/3 PD_Attnd_Rtng = "High" if PD_Attnd_Average = 1 PD_Attnd_Rtng = "Moderate" if PD_Attnd_Average = .66 PD_Attnd_Rtng = "Low" if PD_Attnd_Average < .66	PD_Overall_Rtng = "High" if 81% of teachers have a PD_Overall_Total >= 1.81 PD_Overall_Rtng = "Low" if 81% of teachers have a PD_Overall_Total < 1.81

Indicator	Criteria	Indicator Measures	Indicator Metric	Component Metric
Playground Physics Materials				
Teacher receipt Playground Physics materials	Teacher receipt of the following materials: ▪ App ▪ Curriculum ▪ Two iPads	Teacher Survey Q7_app = receipt of app Q7_crlm = receipt of curriculum Q7_ipads= receipt of 2 iPads For responses, code "yes" = 1; "no" = 0;	PD_Mtrl_Total = Q7_app + Q7_crlm + Q7_ipads PD_Mtrl_Average = PD_Mtrl_Total/3 PD_Mtrl_Rtng = "High" if PD_Mtrl_Average = 1 PD_Mtrl_Rtng = "Low" if PD_Mtrl_Average < 1	PD_Overall_Mtrl_Rtng = "High" if 95% of teachers have a PD_Mtrl_Average >= .95 PD_Overall_Mtrl_Rtng = "Low" if 95% of teachers have a PD_Mtrl_Average < .95

<table>
<tr><th>Indicator</th><th>Criteria</th><th>Indicator Measures</th><th>Indicator Metric</th><th>Component Metric</th></tr>
<tr><td colspan="5">Enactment of Playground Physics</td></tr>
<tr><td>Teacher usage of Playground Physics</td><td>Number of days using Playground Physics</td><td>Teacher Survey
Q14_enr_inst_sciplay_num = number of days Playground Physics was used to teach energy
Q22_mtn_inst_sciplay_num = number of days Playground Physics was used to teach motion
Q31_frc_inst_sciplay_num = number of days Playground Physics was used to teach force
For responses, teachers can select integer from 1 to 9 or “10 or more”</td><td>PP_inst_sciplay_num = Q14_enr_inst_sciplay_num + Q22_mtn_inst_sciplay_num + Q31_frc_inst_sciplay_num

PP_Inst_Rtng = "High" if PP_inst_sciplay_num >= 7
PP_Inst_Rtng = "Moderate" if PP_inst_sciplay_num = 4, 5 or 6
PP_Inst_Rtng = "Low" if PP_inst_sciplay_num < 4</td><td>PP_Inst_H_Rtng = 1 if PP_Inst_Rtng == "High"
PP_Inst_H_Rtng = 0 if PP_Inst_Rtng == "Moderate"
replace PP_Inst_H_Rtng = 0 if PP_Inst_Rtng == "Low"

PP_Cnpt_H_Rtng = 1 if PP_Cnpt_Rtng == "High"
replace PP_Cnpt_H_Rtng = 0 if PP_Cnpt_Rtng == "Low"

PP_Enact_Total = PP_Inst_H_Rtng + PP_Cnpt_H_Rtng

PP_ Enact_Rtng = "High" if 81% of teachers have a PP_Enact_Total = 2
PP_ Enact_Rtng = "Low" if 81% of teachers have a PP_Enact_Total < 2</td></tr>
</table>

Indicator	Criteria	Indicator Measures	Indicator Metric	Component Metric
Teacher delivery of Playground Physics instruction	Number of content areas introduced to students	Teacher Survey Q13_enr_sciplay = Playground Physics used to teach energy Q21_mtn_sciplay = Playground Physics used to teach motion Q30_frc_sciplay = Playground Physics used to teach force For responses, code “yes” = 1; “no” = 0	PP_Cnpt_Total = Q13_enr_sciplay + Q21_mtn_sciplay + Q30_frc_sciplay PP_Cnpt_Average = PP_Cnpt_Total/3 PP_Cnpt_Rtng = "High" if PP_Cnpt_Average == 1 PP_Cnpt_Rtng = "Low" if PP_Cnpt_Average < 1	

Appendix E. HLM Technical Approach

AIR used the following equation for the HLM to examine changes on survey measures of the five constructs between pre- and posttest administration for the student survey.

$$Y_{tij} = \beta_0 + \beta_1 Post_{tij} + \beta_2 Z_j + \beta_3 X_{ij} + u_j + v_{ij} + \varepsilon_{tij}$$

In this model, Y_{tij} is the scale score of a student *i* of teacher *j* at time *t*; β_0 is the mean of pretest scores; $\beta_1$is the parameter of interest measuring the pre-post difference; $Post_{tij}$ is an indicator of whether the score Y_{tij} is pretest or posttest score (1 for posttest score and 0 for pretest score); Z_j and X_{ij} are vectors of teacher and student level covariates, respectively; β_2 and β_3 are vectors of coefficients showing the relationships between those covariates and the scale score; u_j is a teacher random effect; v_{ij} is a student random effect; and ε_{tij} is a score-level error term.

Appendix F. Knowledge Assessment Responses and Standards Alignment

Table F.1. Response Distributions of Knowledge Assessment, Pretest and Posttest Administrations

Question	New York Standard (Pretest and Posttest)	Pre-Post Standard Deviation	Pretest		Posttest		Number of Respondents
			Wrong	Correct	Wrong	Correct	
1	4.1c	Same	52.9%	47.1%	34.1%	65.9%	543
2	4.1c	Different	84.2%	15.8%	92.8%	7.2%	543
3	4.1c	Same	84.2%	15.8%	86.2%	13.8%	543
4	4.1c	Different	77.2%	22.8%	49.4%	50.6%	543
5	4.1e	Same	69.8%	30.2%	65.7%	34.3%	543
6	4.1e	Different	34.3%	65.7%	31.3%	68.7%	543
7	4.1e	Different	51.4%	48.6%	41.1%	58.9%	543
8	4.1e	Same	53.4%	46.6%	54.1%	45.9%	543
9	4.1e	Same	65.4%	34.6%	48.3%	51.7%	543
10	4.1e	Different	60.8%	39.2%	34.6%	65.4%	543
11	4.1e	Different	75.0%	25.0%	30.2%	69.8%	543
12	5.1b	Different	63.5%	36.5%	17.1%	82.9%	543
13	5.1b	Different	50.3%	49.7%	40.9%	59.1%	543
14	5.1b	Same	76.8%	23.2%	70.2%	29.8%	543
15	5.1b	Same	93.0%	7.0%	94.8%	5.2%	543
16	5.1e	Different	61.9%	38.1%	46.0%	54.0%	543
17	5.1e	Same	49.0%	51.0%	31.9%	68.1%	543
18	5.1e	Different	89.1%	10.9%	62.6%	37.4%	543
19	5.1e	Same	70.0%	30.0%	58.4%	41.6%	543
20	5.1e	Same	87.1%	12.9%	61.9%	38.1%	543

Notes:

4.1c (energy): Most activities in everyday life involve one form of energy being transformed into another. For example, the chemical energy in gasoline is transformed into mechanical energy in an automobile engine. Energy, in the form of heat, is almost always one of the products of energy transformations.

4.1e (energy): Energy can be considered to be either kinetic energy, which is the energy of motion, or potential energy, which depends on relative position.

5.1b (motion): The motion of an object can be described by its position, direction of motion, and speed. The position or direction of motion of an object can be changed by pushing or pulling.

5.1e (force): For every action there is an equal and opposite reaction.

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