SMALL GROUP VS. WHOLE CLASS USE OF INTERACTIVE COMPUTER SIMULATIONS: COMPARATIVE CASE STUDIES OF MATCHED HIGH SCHOOL PHYSICS CLASSES

Although it is generally felt that online simulations are better used in small groups working hands-on at computers, many teachers do not have ready access to the number of computer stations required. We ask whether teachers can engage students in effective, active learning when the students are not able to explore a simulation/animation on their own. Several teachers taught a number of high school physics topics in their classes using simulations in either of two conditions: a) small groups working hands-on at computers, and b) whole classes observing simulations projected from a single computer onto a screen before the class. We examine sets of matched classes to compare pre-post gains and teaching strategies used. The three teachers of the classes analyzed here anticipated that the small class format would work better, and students did appear at first glance to be more engaged in small groups. However, results showed that the whole class format produced similar—and in one comparison, significantly stronger—gains, as measured by pre-post tests. We use the pre-post results and videotape evidence to look at issues that may have affected student learning in the two kinds of situations.

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Small Group vs. Whole Class Use of Interactive Computer Simulations: Comparative Case Studies of Matched High School Physics Classes

Although it has been recommended that computer simulations be used with students working hands-on at computers (Jones, Jordan, & Stillings, 2001) and many online educational simulations appear to be designed with that use in mind, in our experience, many teachers do not have ready access to the number of computer stations required for small group hands-on work. However, when simulations and animations are used in a whole class format—for example, projected in front of the class onto a whiteboard—teaching can all too easily devolve into a show-and-tell format, and students may not engage in the kind of active learning that most hands-on activities appear designed to encourage. From a constructivist standpoint, we ask what comparisons can be made between the learning taking place from interactive simulations in Whole Class and Small Group situations.

Although a number of studies have investigated the effects of instructional guidance for animations or simulations when the guidance was provided within the learning materials themselves (review by Cook, 2006), investigated the effectiveness of animations when teachers provided the verbal information (Russell & Kozma, 2005), and studied the use of simulations in small groups or by individual students (Adams et al., 2008; Buckley, 2000; Linn, 2003; Reid, Zhang, & Chen, 2003; Williams, Linn, Ammon, & Gearhart, 2004), there do not appear to be many studies that address the question of how to provide instructional guidance for simulations and animations when these are used in a full class setting. Jones, et al. (2001) believe we know very little about how to use animation effectively in instruction. Principles suggested by theory and by laboratory work with simulations (Lowe, 2003; Mayer & Moreno, 2002) would appear to need further validation in science classroom contexts (Cook, 2006), and may well have to be modified to be usable by teachers employing available simulations in full class situations.

Considering the fact that the hands-on activity afforded by small group work would appear to offer students a more active learning experience, and considering that the teachers in our study have stated they prefer to allow students to work with simulations in small groups and feel experienced teaching in that format, it might be expected that the small group format would work better for them. On the other hand, studies have reported a variety of issues concerning the effective use of small group discussions in science classes, such as the fact that students can exhibit a low level of engagement with tasks (Bennett, Hogarth, Lubben, Campbell, & Robinson, 2010). We asked:

- *What differences in learning do we see between students using simulations in small group vs. whole class situations?*
    - o How do pre-post gains compare between students a) working hands-on with and discussing computer simulations in small groups and b) students who observe the simulations in whole class settings and engage in whole class discussion?
- *What teaching moves do we observe in small group and whole class work with simulations?*

- Specifically, what strategies do we observe teachers using to guide discussions to promote conceptual understanding and the development of mental models?
- What differences do we observe between teacher moves in small group and whole class work with simulations?

Our longer-term goals are 1) to develop a set of specific recommended strategies for teachers to employ when using online educational simulations as a support for mental modeling in middle and high school science education and 2) to discover and articulate principles of instruction that can help guide teachers, curriculum designers, and educational software developers.

We first present the results of several comparisons between pre-post gains resulting from short lesson sequences (1-3 class periods) taught to matched sets of classes. Each matched set had one or more classes that used simulations in a whole class format and one or more that used the same simulations in small group format. The bulk of this paper is a qualitative, case study section, in which we focus on questions raised by the pre-post results. We examine in detail what happened in response to (and in one case, in anticipation of) a single prompting question on an activity sheet used in four classrooms comprising two sets of matched classes. We then list some major teacher moves used in the two conditions, drawing from information gathered across the entire study, including teacher interviews and observation notes from all classes observed in the study. This analysis suggests some unexpected avenues for further research.

Method

Participants

218 high school junior and senior physics students participated in the study. The study was conducted in twelve high school physics classes taught by three teachers in two high schools, one in a small, upper-middle class suburban town and the other in an industrial community. The classroom observations were conducted as part of a larger, 3-year study; the observations reported here were conducted during the first two years of the study and involve all matched sets of classes in which external school factors (fire drills, snow days, or other unexpected disruptions to lesson plans) did not destroy the equivalence of classroom conditions. Participation for each student was voluntary with provisions made for any student who wished to remain off camera. However, almost all of the students in these classrooms elected to participate.

Materials and Procedure

Selected topics from the physics curriculum were taught to matched sets of classes using lesson plans that incorporated online simulations/animations. For each matched set, the teacher used the same simulation(s), activity sheet, and other materials in the two conditions but varied the way in which the simulations or animations were used. In the whole class condition, the teacher used a single computer projected onto a screen in front of the class and guided a whole class discussion as students worked through the activity sheet. In the small group condition, multiple computer stations were available with 2-4 students to a computer and the students were allowed to engage in hands-on exploration guided by the activity sheet. In both conditions, the teacher began by introducing the computer activity in a whole class format, though teachers varied in the extensiveness of this introduction. In both conditions, the teacher was available for questions the entire time the simulation was in use. Other than the constraints provided by the technological set-up and the data-collection needs of the study, teachers were free to conduct their classes as they saw fit and were encouraged to use the best teaching strategies they could devise for each situation. Control for time on task was implemented by using the same activity sheets and other materials (manipulatives; prediction sheets asking students to predict what would happen in a system) in the two conditions, and the same number of class periods to cover the material. The lesson plans, activity sheets, and prediction sheets were developed by the teachers and reviewed by the research team. The pre-post surveys were developed jointly by the teachers and research team and consisted of transfer questions not directly addressed during instruction; this was to minimize the possibility of a test effect and also because we wished to measure conceptual rather than rote learning. The simulations were selected ahead of time by the teachers from on-line sources. In one of the lessons, appropriate simulations were lacking so a member of the research team used Pacific Tech's Graphing Calculator to design simple animations to supplement the simulation. These were saved as Quicktime Movies and uploaded to the school server. The classes were observed and videotaped. Videotapes were then transcribed with the use of Transana transcription software (University of Wisconsin).

Matched sets of classes were observed for the following lesson sequences. "1 SG" and "1 WC" indicate one class section taught in small group format and one in whole class format, respectively.

Gravitational potential energy: School 1

1.	Advanced Placement Physics	1 SG, 1 WC	Teacher 1
2.	Honors Physics	1 SG, 1 WC	Teacher 2
3.	College Preparatory Physics	1 SG, 1 WC	Teacher 1

Materials: *Energy Skate Park simulation* http://PhET.colorado.edu; activity sheet; pre/post survey.

Linear velocity and acceleration: School 2

4.	Honors Physics	3 SG, 3 WC	Teacher 3

Materials: *RampnRoll simulation* http://www.wsst.org/node/94; activity sheet; pre/post survey.

We also present results for two additional comparisons involving some of the same students as in the above studies. The classes below were held during different semesters than the classes above, and though some of the same students were involved, the classes had been reshuffled somewhat. These lessons both involved projectile motion. Although the lesson plans and the level of students at the two schools were similar, they were not identical. Our intention is not to draw comparisons between groups at different schools but to compare each teacher's small group lesson to the same teacher's whole class lesson by using pre/post surveys conducted immediately before and after the lesson sequence in question.

Projectile motion: Schools 1 & 2

1.	Honors Physics School 1	1 SG, 1 WC	Teacher 2
2.	Honors Physics School 2	1 SG, 2 WC	Teacher 3

Materials: *Projectile Motion simulation* http://galileoandeinstein.physics.virginia.edu/more_stuff/Applets/home.html; three simple

Quicktime movies; several balls; prediction sheet; Day 1 Activity sheet; Day 2 Activity sheet; pre/post survey.

Organization of the Paper

We first present pre/post results from the comparisons described above. Then we examine questions raised by these results through the qualitative analysis of several transcript segments. (Gender differences in Comparison #4 above are discussed in a companion paper, Vasu, in these proceedings.) Finally, we discuss some of the teacher moves observed in the two conditions.

Quantitative Results

Scores were tabulated from multiple-choice questions on the pre-post surveys.[1] To evaluate the results for each matched set of classes, we used a 2x2 (Condition [whole class, small group] x Time [pre, post]), or in one instance, a 3x2 (Condition [class 1, class 2, class 3] x Time [pre, post]) repeated measures ANOVA. Gains are expressed as fractions of a perfect score. All groups had significant pre-post gains at better than the $p < .001$ level.

Table 1: *Gravitational Potential Energy (Energy Skate Park)*

Pre/post gains					
School 1	*Teacher 1*	*Advanced Placement*		$F(1, 41) = 3.4095$	$p = .0721$
Small Grp	(N=21)	Avg. Gains = .0278;	sd = .0223		
Whole Cls	(N=22)	Avg. Gains = .0852;	sd = .0217		
School 1	*Teacher 2*	*Honors*		$F(1, 39) = 4.7182$	$p = .0360$*
Small Grp	(N=19)	Avg. Gains = .1075;	sd = .0462		
Whole Cls	(N=22)	Avg. Gains = .2443;	sd = .0429		
School 1	*Teacher 1*	*College Preparatory*		$F(1, 25) = .3844$	$p = .5408$
Small Grp	(N=15)	Avg. Gains = .2722;	sd = .0575		
Whole Cls	(N=12)	Avg. Gains = .2188;	sd = .0643		

To the surprise of the teachers (see teacher comments next section), in no comparison did we find an advantage for the small group condition. In the comparisons of Teacher 1's Gravitational Potential Energy lessons, there was no significant difference between the two conditions in pre-post gains at the $\alpha = .05$ level; in fact, Teacher 1's Advanced Placement classes approached a significant difference in favor of the whole class format, $F(1, 41) = 3.4095$, $p = .0721$. In Teacher 2's mid-level Honors class using the same simulation, there was actually a significant difference in favor of the whole class format, $F(1, 39) = 4.7182$, $p = .0360$.

[1] See example in the appendix.

The percentage gains in the AP class were very small; however, there appeared to be a ceiling effect on the pretest. In such a situation, it can be helpful to compare the actual gains to the gains that are possible, given the high pre-survey results. Therefore, we computed normalized gains, which consider the amount of room for improvement between the pre-survey results and a perfect score. For the normalized gains of a class <g>, where *%<G>* is the average gain of the class as a percentage of a perfect score, *%<Sf>* is the average final score as a percentage, and *%<Si>* is the average initial score (see Hake, 1998):

$$\langle g \rangle = \%\langle G \rangle \,/\, \%\langle G \rangle_{\max} = (\,\%\langle Sf \rangle - \%\langle Si \rangle\,)\,/\,(\,100 - \%\langle Si \rangle\,)$$

$$= \frac{(\text{Gain1} + \text{Gain2} + \ldots + \text{GainN})}{(\textit{perfect score} \times \text{N}) - (\text{Pre1} + \text{Pre2} + \ldots + \text{PreN})}.$$

The normalized gains for Teacher 1 Advanced Placement classes Skatepark lesson were

<g> = 50% for WC; <g> = 16% for SG.

In other words, given the room remaining between their pre-scores and a perfect score, the class that used the simulation in the whole class format achieved 50% of the gains possible for that class while the class that used the simulation in the small group format achieved 16% of the gains possible for them.

The classes in linear velocity and acceleration were taught by a single teacher to six classes: three classes in a whole class format in Year 1 and three classes in a small group format in Year 2. For consistency with the other tables, the small group results are listed first. (This comparison is analyzed from another perspective in Vasu and Sweeney, 2010.)

Table 2: *Linear velocity and acceleration (RampnRoll)*

Pre/post gains					
School 2	*Teacher 3*	*Honors*		$F(1, 103) = .1769$	$p = .6749$
Small Grp	(N=53)	Avg. Gains = .3151;	sd = .0277		
Whole Cls	(N=54)	Avg. Gains = .3315;	sd = .0274		

Teacher 3 was accustomed to teaching linear velocity and acceleration using RampnRoll in small groups. Therefore, in Year 2, she not only had an additional year's experience with the simulation, but she was teaching in the small group format with which she was more familiar and which she had stated that she preferred. However, there was no significant advantage in pre/post gains for her three hands-on classes.

For the additional comparisons below, the important thing to note is that, for each teacher, the gains in the class(es) taught in the whole class condition were almost identical to the gains in the class taught in the small group condition by that teacher.[2]

[2] Though the Honors physics designation was similar in the two schools, it was not identical. The two teachers used the same simulations and animations and similar lesson plans. However, the students at the different schools encountered the topic at different points during the physics instructional sequence and had different amounts of prior exposure to whole class and small group instruction. Also, Teacher 2 taught the topic as a two-day sequence while

Table 3: *Projectile motion (Projectile Motion simulation; 3 Quicktime movies)*

Pre/post gains		
School 1 Teacher 2 Honors	$F(1, 41) = .0014$	$p = .9705$
SG (N=24) Avg. Gains = .3646; sd = .0687		
WC (N=19) Avg. Gains = .3684; sd = .0772		
School 2 Teacher 3 Honors	$F(2, 50) = .0892$	$p = .9148$
SG (N=19) Avg. Gains = .3421; sd = .0674		
WC1 (N=16) Avg. Gains = .3125; sd = .0735		
WC2 (N=18) Avg. Gains = .3542; sd = .0692		

Qualitative Analysis and Discussion

In view of the lack of advantage in pre-post gains for students who had used the simulations in hands-on small group situations, across several topics and several teachers, we ask:

- *Why did the whole class format produce gains as strong as those of the hands-on small group format?*

The advantages of hands-on work with computer simulations appear, at least in our experience, to have become widely accepted. However, our pre-post results would suggest that there may be some counter-balancing advantages in the whole class format. It was certainly our impression that at times the discussion in the whole class conditions was richer, but we were not sure analysis of the transcripts would reflect this. As might be expected, we also occasionally saw students with their heads on their desks in what appeared to be a "couch potato" reaction to whole class discussion. Even though there is a wealth of data from these studies—pre/post data, student artifacts, teacher interviews, researcher observation notes, videotapes—how to make efficient use of these data to detect and focus on important factors has proved a challenging question. The next section constitutes the first step of this analysis, in which we look at what happened in four of the gravitational potential energy classes in response to one of the questions on the activity sheet. We hope to use these matched discussion segments to begin to investigate what aspects of the discussion appear similar and what appear different in the small group and whole class discussions.

Four Classes on Gravitational Potential Energy

The gravitational potential energy lessons were centered on "Skatepark," a simulation from the PhET project at the University of Colorado (http://phet.colorado.edu/index.php). The simulation has track sections that can be rearranged and shaped, and several skaters with different masses that can skate on the track. It has a variety of visual tools to help students parse

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Teacher 3 taught it as a 3-day sequence. Although it is interesting that the gains in the two schools were similar, no conclusions can be drawn here from between-teacher comparisons.

the animated imagery and to focus on the abstract quantities under discussion: pie charts, bar graphs, a zero point potential energy line that can be moved, a ruler, animated line graphs. In addition, there is an option to have the skater leave behind a trail of dots, which can then be clicked on to obtain a readout of quantities associated with the skater at that point in the path. The user can change the value of gravity by moving the skater and track to different planets or into space. Friction can be turned off or on and there are thrusters that can apply forces when in space. When selecting the simulation, the teachers had stated they liked the fact that it is manipulable; that its various visual charts change in real time; that the zero-point line can be moved; that the gravitating planet can be changed; and finally, that in their experience, students find it engaging and humorous.

Much of the lesson focused on the parabolic-shaped track shown in Figure 1. The teacher and students referred to this set-up as a "half-pipe," though an actual half-pipe does not have this shape. Objectives of the lesson were for students to begin to understand how potential and kinetic energy can change into each other, the relationship between gravitational potential and height, the arbitrary nature of the choice of potential energy zero line and how this choice affects the measured values of energy, and the relationship between gravitational potential energy and gravitating mass. The physicist's idea is that the gravitational potential energy possessed by the skater at the top of the half-pipe is converted to kinetic energy as the skater accelerates to the bottom of the half-pipe. The total of these energies remains constant unless some new energy is introduced into the system from outside the system; however, the value assigned to the potential energy—and, thus, the value calculated for the total energy—depends on the elevation one has chosen to be at zero potential. From past experience, the teachers had identified the idea of a movable (e.g., arbitrary) zero potential energy line as a particular stumbling block for their students, especially at the Honors and College Prep levels. A related conceptual difficulty was the idea of a negative energy, especially a negative total energy. One of the questions on the activity sheet (Appendix 2) was designed to address this directly; Question 7 asked, "Could the total energy be zero at some position? Explain." The answer is yes, this happens when the zero potential energy line is located where the skater comes to instantaneous rest at the top of his arc.

Observations in prior years had indicated that this was a topic that had provoked student questions in both small group and whole class discussion. We thought analyzing the current transcripts of the four Skatepark classes in which there was no ceiling effect on the pre/post, that is, the Honors and College Prep classes, should allow us a window onto how this topic was dealt with this year. Teacher 2 taught the lesson to his classes over a two-day period, while Teacher 1 elected to teach it to her classes in a single day.

Honors Physics Skatepark Discussions (Teacher 2)

Small group discussion. The following is a transcript segment from the small group that was on camera during Day 1 of the 2-day lesson. There were four students in the group, two on each side of a lab table, with the computer on the table between them. The computer controls were accessible, at least initially, to all four students. The teacher circulated the room, checking

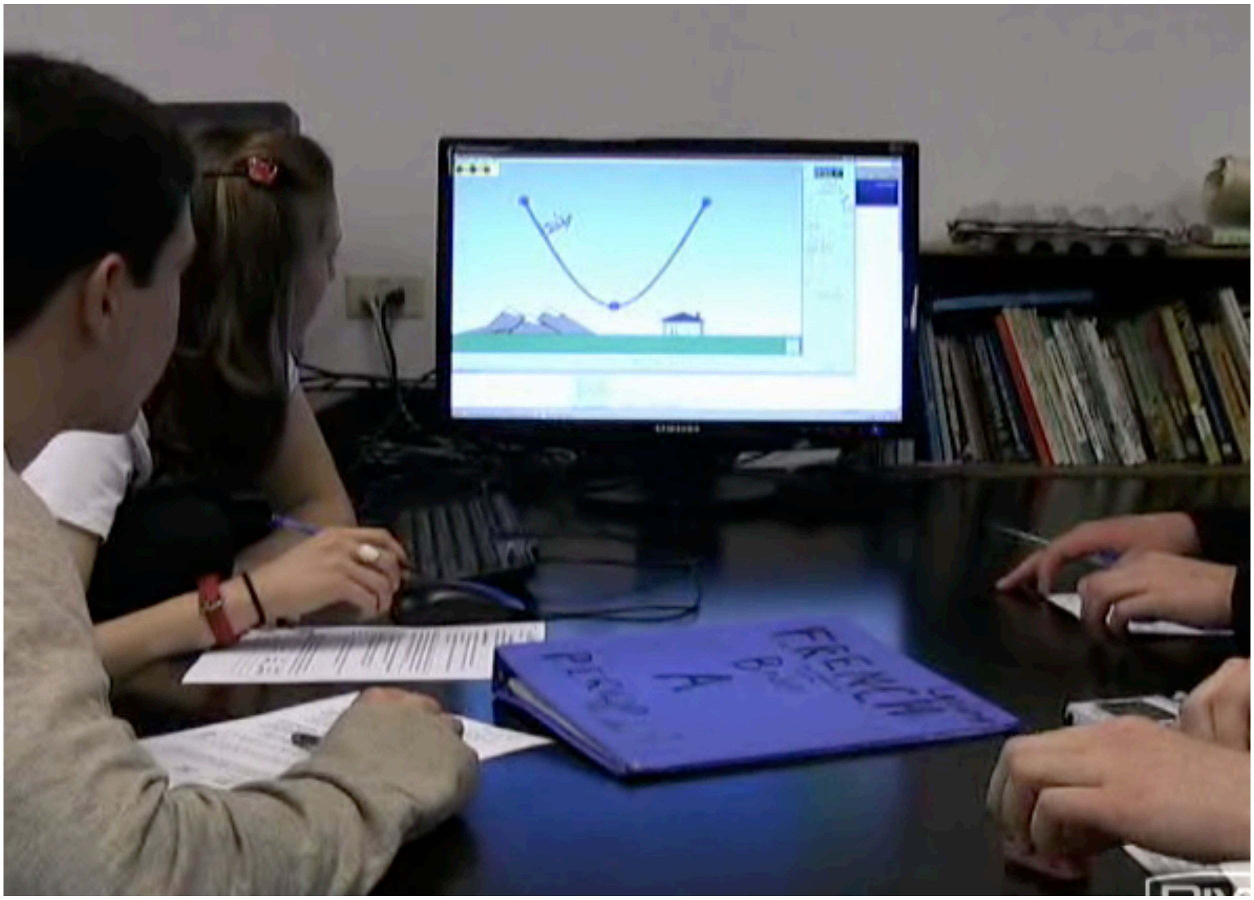

Figure 1. Small group working with *Skatepark*, a PhET simulation.

in with groups and answering questions.

The transcript segment begins 23 minutes into the lesson (15 minutes into the small group work), at the point the students read Question 7. It ends when they move to Question 8. During this segment, the simulation appears much the way it does in Figure 1, but the skater is not moving and the students have become focused on their activity sheets rather than on the computer screen.

S3: "Could the total energy be zero at some position? Explain." That would have to be that there is no kinetic and no potential and no thermal.

S1: Yeah-

S3: Which I don't think- Is that ever possible?

S1: No.

(*Students write for 9 sec*.)

S4: [How about] space?

S1: No.

S4: [*inaudible*]? (*Shrugs*)

S1: Absolute zero is only theoretical. So.

S4: Well, so is everything else in the world that was [*inaudible*].

S1: Yeah, so it's only theoretical.

S3: Alright.

S1: Yeah, but it's still theoretical.

During this segment, although S3 appears to be wondering about the idea of zero total energy, when S1 says "No," S3 does not question further. Instead, all four of the students write down their answers for Question 7. None of the students are heard to question S3's statement that, for the total energy to be zero, each kind of energy contributing to the total would also have to be zero. If S1 is saying that the thermal energy can never be zero, he is correct; though a negative potential energy, for instance, could still result in a total energy of zero. The idea of a negative value for energy is never mentioned in this group, although the simulation is designed to show negative values for potential energy (with multiple visual tools) whenever the zero point energy line is raised above the bottom of the track. The activity sheet does not directly instruct the students to try the zero point line at higher positions, and they do not conduct this or any other exploration with the simulation to investigate Question 7.

Of potential concern is the fact that the back and forth between the students does not develop into a substantial discussion of the concepts and they quickly move on to the remaining problems on the worksheet, having spent approximately one minute talking and writing about Question 7. The topic of a zero value for energy does not arise again for this group and a few minutes later they announce that they are done, even though they have an additional day to work with the simulation if they wish. (Some, but not all, of the other small groups in the class continued the activity well into the second day. In fact, some of them had almost as much time on task the second day as the first day. It was up to each group how long they took, however. Once groups completed the activity, many of them explored the simulation in other ways.)

Whole class discussion. This class was taught on the same two days by the same teacher as the class above and used the same materials. However, in the Whole Class condition, the teacher did not reach Question 7 until the second day of the lesson sequence. Counting the time on task from the first day, Question 7 was reached 51 minutes into the Whole Class lesson sequence as compared with 23 minutes into the sequence for the Small Group described above. (The two classes had similar times on task: Whole Class used 67 min. for the two days while Small Group used 61 minutes. However, they did not necessarily use this time in the same ways.)

Figure 2. Whole class working with *Skatepark*, a PhET simulation.

The transcript segment begins when the teacher reads Question 7 and ends when he moves to Question 8. Much of the time it is not possible to determine from the videotape which student is speaking.

T: Now it's asking us, "Could the total energy be zero at some position?" How could we get a total energy of zero? (*Pause for several seconds*.) Go ahead.

S: Not in that situation. You only could if the person was on the ground, not moving.

T: Do they have to be on the ground not moving?

S: Well, I said 'point zero.'

T: OK.

S: Whatever you are saying is zero height.

T: Alright, for example, if I grabbed him, just, just chill right there. Right there, don't move. (*T stops skater at the bottom of the half-pipe. Teacher pauses while students look at the simulation. A few students chuckle*.) Now, if we look at the graph, we see that the energy is pretty much zero. Right? Maybe not exactly- within a small amount. Please. (*Gesturing toward a student*.)

S: Um, I think if you take the bottom point, then you move it down, so it's more like a "V", I think the potential energy decreases. I'm not exactly sure why, but-

T: Alright, so I think what "Aaron" is saying is that if we lower this point on the graph [on the pipe]- do this- like that? (*Although this cannot be fully seen on the videotape, it can be inferred that the teacher drags the bottom point of the half-pipe down to the ground, with the consequence that the track stretches to look more like a "V" than a "U."*)

S: Yeah.

T: The potential energy decreases?

S: Yeah, but then you bring in the sides [of the half-pipe] closer, I think.

(*Teacher does not appear to comply with this last request. Students confer with neighbors. Teacher waits 11 seconds before speaking again.*)

T: OK, so what "Edward" is saying is that it depends on where the zero line is. So one of the ideas here is that there is the ground, and then there is- the zero reference line. They're two different things. We can move the zero reference line around and we can put it on the ground. That's kind of a natural place for it. For example, in this room, where is the most natural place to call zero reference?

S: The floor.

T: Yeah, the floor, 'cause it's kind of difficult in this room for us to put things lower than that. (*Holds up his pen and drops it on the floor.*) But we could also make it higher up and say, ooo now it's negative! Just as we could move this reference line up and say yeah, now it's got negative energy and if I look at the graph, energies are negative. (*Moves zero reference line about 2/3 the way up the half-pipe and then points to the position of the bars on the bar graph, which have moved so that they extend below the x-axis rather than above it, as before.*) Just means above- (*pause*) Positive and negative now is not a direction, this is not a vector; it's a scalar quantity. But we can arbitrarily make zero different places and say, more than zero, less than zero. But it doesn't tell us left and right, or up and down, or north and south, it's not a direction.

The discussion took 2¾ minutes as compared to the minute spent on the topic by the small group. It began in a way that was similar to that of the small group: the question was read aloud and a student gave a quick answer in response, to the effect that there would have to be no potential energy and no kinetic energy ("On the ground, not moving"). However, there was a subtle difference in the reading of the question in the whole class—the teacher rephrased the question as soon as he read it, making it more active ("How could we get…?"). The student who answered may have understood the concept of zero point energy better than the speakers in the small group that happened to be on camera in the other class, and that could have helped to facilitate the discussion. However, it was our impression that, no matter the nature of the student response, in the whole class discussion there was often follow-up from the teacher.

It may be instructive to look more closely at how these extra few seconds of follow-up are used here. The teacher initially does not offer any new information, but uses a tactic advocated by Minstrell (Van Zee & Minstrell, 1997); he rephrases the student's answer as a question, "Do they have to be on the ground not moving?" The student clarifies her answer in response to the teacher's probing. The teacher, still without adding any new information, illustrates the student's suggestion with the simulation. Since the student answer is only partially correct (holding the skater still at the zero point is not the only way she could have zero total energy), it might seem puzzling that the teacher does not make a stronger move. We suggest that the teacher's interaction with the student and affirmation of her comment helped keep the class engaged in active discussion; the discussion then continues rather than lapsing, as another student suggests that the half-pipe be changed so that its bottom point rests on the ground.

The new speaker actually takes the discussion farther away from the point that the teacher is trying to make by equating the ground with the zero energy line, whereas the previous student had appeared to understand that the zero point was relative. However, the teacher uses this

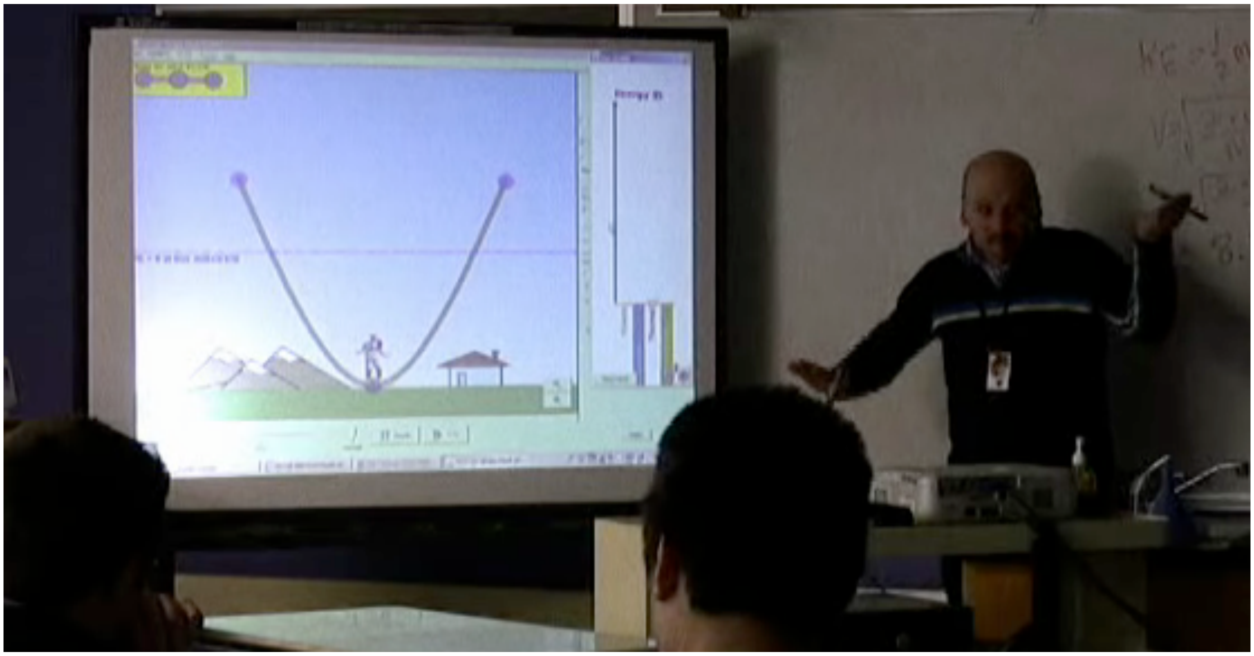

Figure 3. T: "(N)ow it's got negative energy and if I look at the graph, energies are negative."

statement as an opportunity to illustrate the difference between the ground and the zero reference line. He finishes up with a mini-lecture on negative energy; this lasts less than a minute. He illustrates the concept with the simulation and points to the animated bars on the graph, which now are below the zero line, indicating that both potential and total energy are negative.

One possibility to consider is that stronger students may be more willing than weaker ones to speak up in whole class discussion; if so, some important doubts held by more reluctant, weaker students may not be voiced in the whole class situation. On the other hand, when doubts are voiced in small group, our observations indicate these doubts may not be followed up or explored. In the next transcript segment, a doubt is voiced, but not until the class discussion has already moved away from Question 7. We include this segment because it is a return to the concept of Question 7, the possibility of non-positive energy values.

A couple of minutes after the transcript segment above, the simulation automatically resets the zero reference line to the default position at ground level. This appears to prompt a student to ask the following.

> S: That's something that really confuses me. Like, with the zero reference line, when you move, like, it just doesn't make sense, like the energy amount due to that reference line. Like how does that work?

The teacher responds with a 2-minute mini-lecture, takes a student comment, and then continues for 2½ minutes more, using a rather abstract analogy (the temperature scale) and elaborating on a student-supplied example (sea-level for the zero of the altitude scale). Although five minutes of lecture is probably not what the teacher intended to do, it does address the topic in several different ways.

These two classes had a significant difference in their pre/post gains in favor of the whole class condition from which the above transcript segment is taken. We do not argue that lecture is the ideal way to teach, but suggest that mini-lectures probably have a place. Not only did more of this class time get spent on the existence of non-positive energy values than in any of the small groups that were observed, but the student input on this topic in this whole class discussion, though the teacher spoke frequently, was still more than the student input on the topic in the small group. We believe this may be one factor that helped compensate for the lack of hands on opportunity afforded these students. If the same pattern is observed in other matched sets of classes, this suggests one possible direction for further qualitative analysis.

Other teacher contributions to the whole class discussion were: making sure that helpful features of the simulation were used; pointing to critical features of the simulation that may have otherwise been overlooked; and appropriating student-initiated ideas into the discussion to keep it going, even when the student ideas were incorrect.

College Preparatory Physics Skatepark Discussions (Teacher 1)

Whole class discussion. For our discussion of the matched set of classes taught by Teacher 1, we discuss the Whole Class condition first for narrative reasons. Teacher 1 elected to compress the lesson for both her classes into a single day, even though the College Preparatory classes were taught at a more conceptual level than the Honors Physics classes taught by Teacher 2 and were considered to be less advanced. She used the same activity sheet and other materials that Teacher 1 used. She gained a little time by giving the pre-survey on the previous day and by instructing the students to skip Questions 5 and 6 on the Activity sheet. The lesson sequence was taught to the College Preparatory classes several weeks later in the term than it was to the Honors classes.

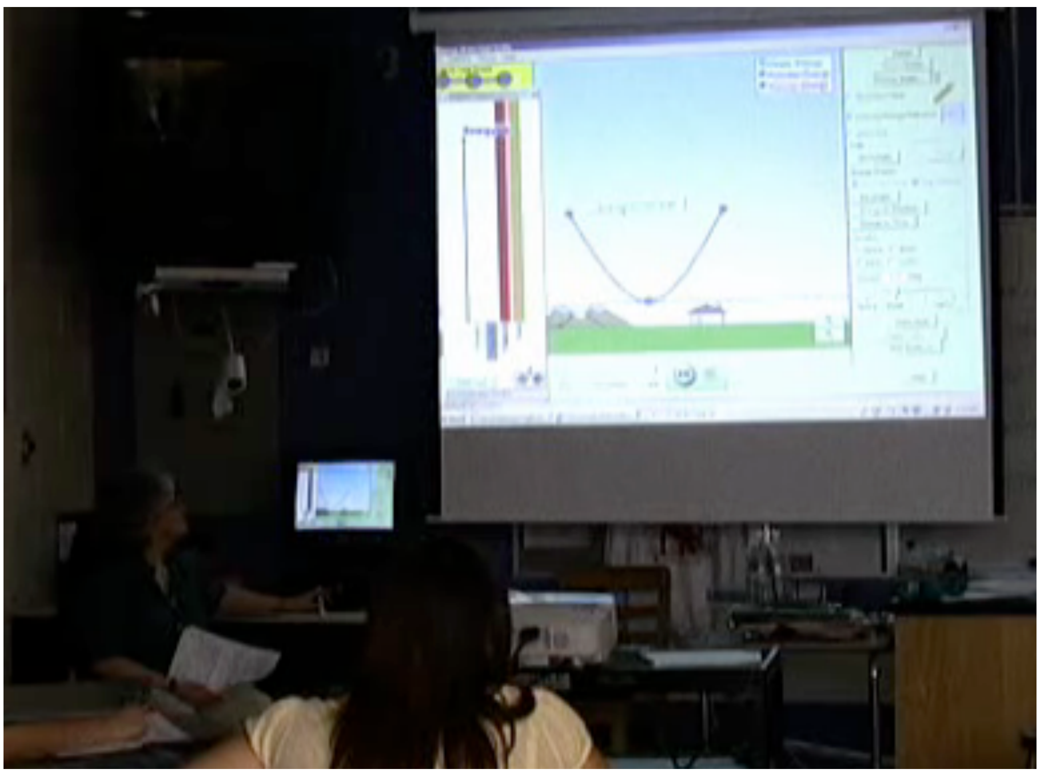

Figure 4. S2: “Wait, he had negative potential energy, what?”

In this class, the question about negative total energy arises before the discussion has reached Question 7. The physicist's idea is that the gravitational potential energy possessed by the skater at the top of the half-pipe is converted to kinetic energy as the skater accelerates to the bottom of the half-pipe. As he or she moves, friction causes some of the kinetic energy to be converted to thermal energy. The total of these energies remains constant unless some new energy is introduced into the system from outside the system.

At the point the transcript begins, the teacher has picked up the skater and dropped him onto the track and onto the ground from various points so that the students can see how the animated bar charts react. At one point the skater falls below the zero potential energy line and the following discussion takes place, starting almost 26 minutes into the lesson.

S2: Wait, he had negative potential energy, what?

S3: Because he went below the line.

S: Oh, OK.

T: Yeah, yeah, this potential energy went negative. What's up with that, "Max"? What do you think?

S: He went below the line.

T: He fell below the line. So let me bring him back and catch him. If I move him down here, like I put him on the ground, he's got negative-

S: -Negative total- (*overlapping*)

T: -potential energy.- And negative *total* energy! That's interesting.

(*The bar graphs in the computer display look similar to the way they do in Figure 3, with the potential and total energy bars hanging down below zero.*)

S: And no thermal. Oh, you should throw him straight down to the ground and see what his thermal is.

(*Teacher does so.*)

S: Whoa.

S: Wait, is thermal, is more than total?

T (*repeats*): Whoa, thermal is more than total?

S: Because he has negative potential energy.

S: Oh snap.

S: But you can't really have negative potential energy in real life.

T: Well, it kind of depends. If you said the top- the roof of this building is my zero that I'm gonna define, then when I'm on the ground it is negative. And not until I get myself up on the roof does it become zero. So, so it's sort of semantics- I mean, it's sort of like a definition, but yes, it can be negative. Usually, we choose the lowest point that we're gonna get to, which if he stays in the half-pipe, is in the half-pipe. We usually choose that as our zero for potential energy.

This video segment lasts 1¼ minutes. A move that the teacher uses here four times is to repeat certain student comments while adding emphasis, "-and negative *total* energy! That's interesting." She also manipulates the simulation in ways that appear to arouse student interest such as dropping the skater from various heights. This is an activity not suggested by the activity sheet, but one it could be imagined students engaging in if left to their own devices in a hands-on small group setting.

When, in the midst of making the point that the skater has negative potential energy, she hears a student say, "And negative total energy," the teacher picks up on this statement and gently encourages the discussion in this direction, anticipating the topic of Question 7. After about a minute of discussion, the teacher provides an explanation for the existence of an arbitrary zero point potential energy line and the existence of negative gravitational potential energy. There is no guarantee, however, that all the students understand or believe this explanation.

A short time later, the teacher skips Questions 5 and 6 to get to Question 7. The following transcript segment begins when the teacher reads Question 7 and ends when she turns to Question 8. This segment, about 30 minutes into the lesson, provides an additional 3 ¼ minutes for students to focus on the topic of non-positive total energy, although the conversation portion takes up only the first 2½ minutes. The last minute or so is mostly taken up with the students writing down their answer for Question 7. Note that even though the students have observed the skater having negative total energy earlier, this does not mean that they believe the skater can have *zero* total energy.

T: We're gonna zoom right over to seven. And this is an interesting question, we kind of talked about this. "Could the total energy be zero at some point?"

S: No.

S: On the moon.

S: 'Cause there is no such thing as [*inaudible*].

S: And there is nothing there.

S: On the moon!

S: Even a rock has potential energy.

S: Not on the moon, on the earth.

S: No, it can't.

S: Everything has energy.

S: Cause it has the chance of moving.

S: Earth is always moving.

S: Well what if, what if you just cement the [*inaudible*]?

(*Several overlapping comments from students, inaudible*.)

T: So, remember that potential energy reference line? Right now, the skater is sitting there- whoops. Why, why- oh, it's the Bug. (*The skater has been changed to a small-mass option, a bug*). We'll move him [*inaudible*]. (*T changes skater back to human*.) The skater is sitting there and he's got lots of energy and it's always positive, right? His total energy is always positive. What could I do to maybe make his total energy be not so positive?

S: Start him at the line.

T: Start him what?

S1: Just move the line up. (*Referring to the zero potential energy line*.)

S2: At the line.

S3: Move the line up to the top. (*Referring to the top of the half-pipe*.)

T: Move the line- the reference line? Let me get rid of the "Choose Skater" thing.

S1: What would happen if you just put him at the very bottom?

(*Teacher apparently moves zero potential energy line to the bottom, though this is not clear from the videotape.)*

S2: Told you. Wooo.

S3: Now move it down so the total gets to zero. No, up- Yeah, right there.

(*The skater is moving back and forth on the half-pipe. The bars on the energy bar graph swing between zero and very large values, some positive and some negative. As the teacher moves the zero potential energy line to the top of the skater's arc, the Total Energy bar disappears*.)

S3: (*pause*) Oh, it has to be where he lands! (*Referring to where the skater has zero velocity at the top of his arc. On a real half-pipe, the skater would land on the lip of the pipe at that point*.)

(*The remaining two bars on the bar graph, for Kinetic and Potential Energy, are swinging in opposition, one going from zero to positive and back, the other from zero to negative and back, the two bars reaching zero together as the skater reaches the top of his arc*.)

S2: Where he is moving?

S3: Where he stops for a second.

T: Where he's stopped? If you call the top of his rise, where he stops for a second, cause when he stops his kinetic energy is- zero (*pause*), and you call *that* the zero potential energy, then in a sense, total energy could be zero at some point. And what about if, uh, you just totally stopped him?

(*Teacher stops the skater at the bottom of the half-pipe*.)

S3: No.

S: No.

T: Yeah, let's put, tot-

S: Yeah it's-

S: So it's all-

T: Yeah, I mean, he is not moving, right? He's not moving and he is down here at zero potential energy. He's got zero total energy. (*The energy bars have all disappeared.*) So yeah, what do you think? It's a complicated question. There are many ways of answering it. If you just said yes or no, would that be a good way to answer a question like that?

Several students: No. No.

T: So you need to do a little explaining. So just take a minute or two, and see if you can write some kind of answer and explanation. You could say yes or you could say no, but you need to explain.

(*Students write for 33 sec.*)

S: What's the name of that line again?

T: The reference line? Potential energy reference.

(*Students continue to write for 17 sec.*)

The first thing to note is the large number of student-student exchanges here. Even though the teacher takes a fairly strong hand in guiding the discussion, she is willing to take cues from students and to try their suggestions for operating the simulation. Occasionally she challenges the students with a question, "What could I do to maybe make his total energy be not so positive?" One student thinks she knows how to get the total energy to zero and calls out instructions that the teacher follows, resulting in the zero potential energy line being positioned at the top of the skater's arc. This does produce a total energy of zero, though the salient visual on the computer display is the sight of the kinetic and potential energy bars on the animated bar chart swinging wildly back and forth in opposition. Eventually, the teacher stills the skater at the bottom of the half-pipe, where she has placed the zero potential energy line for the moment, and all the energy bars register zero. But she suggests that this is not the complete answer. Finally, she prompts her students to write an answer that is more than a simple yes or no.

This rich discussion can be compared with the discourse on the same topic observed in the matched Small Group discussion.

Small group discussion. The same teacher taught a matched Small Group discussion class on the same day. She began with a lengthy introduction to the simulation in the whole class setting before sending the students back to their individual computer stations. As the students worked in their groups, the teacher circulated the room, answering questions and asking them. The small group being videotaped had two students. They reached Question 7 about thirty-four minutes into the lesson (comparable to the timing in the Whole Class discussion), 20 minutes after they had arrived at their station and begun the activity sheet.

The transcript segment begins when one of the students reads Question 7 and ends when the two students turn to Question 8.

S2: "Could the total energy be zero at the same position?" No, because you don't lose energy. You don't lose or gain energy.

S1: No, because energy is conserved.

(*Students write.*)

This exchange lasted 27 seconds, including writing. This was the total time spent by this group on the topic of non-positive energy; negative energies were never addressed. Unlike in the whole class discussion, this small group did not use the simulation to explore Question 7; this appeared to us to be fairly typical of the small group discussions we observed. One hypothesis is that these students were in a "data collection mode," possibly their concept of what laboratory work is supposed to be. It is possible that these students view a "conceptual discussion mode" as something that occurs during whole class discussion rather than during lab. If so, successful work on conceptual issues in small groups will depend on changing the norms and attitudes of students toward small group interactions. Another hypothesis is that, should these students implicitly hold a strong preconception that energy is a quantity akin to a substance and must be positive, the idea of exploring other options or of testing their ideas with the simulation might be unlikely to occur to them without prompting.

There was no statistical difference between the pre-post gains of this class and those of the matched, whole class discussion ($p = .5408$), suggesting that the strengths and weaknesses of this teacher's small group and whole class lessons balanced. The hands-on nature of the simulation was designed to afford a rich exploration of the concepts for the small groups, the activity sheet provided a thought-out and detailed guide, and the teacher circulated the room prodding groups and remaining available for questions; however, students did not always appear to notice interesting aspects of the simulations before them and, if they posed questions, frequently did not appear to know how to explore them.

Teaching Strategies

It was our impression as observers that some active learning was going on during both the whole class and the small group discussions and activities. Evidence that learning of some kind did occur and that it was not rote learning is the fact that all classes showed significant gains on the transfer problems on the pre-post surveys (see appendix for an example). Average gains ranged from 11% to 37% for all classes except for the Advanced Placement classes, where gains, though significant, were small due to a ceiling effect on the pre-survey.

In our observation notes for the 17 classes listed in Tables 1-3, the following teaching strategies were noted.

Small and large group conditions

- Teacher asks students to predict the answers for some of the questions they will investigate with the simulation to motivate them to think about important conceptual issues and to help them focus their visual attention on important aspects of the simulation.
- Teacher uses manipulatives in whole class introduction of the lesson, e.g., tosses balls around the room.

Small group condition

- Teacher introduces simulation in whole class environment before sending students off to their groups, demonstrates most of the controls and visual features.
- Teacher circulates from group to group, checks in on progress and answers questions.
- Teacher diagnoses what students are and are not getting from simulation, devises

one or more prompting questions in response, circulates and asks each group the same question(s).

- When students ask questions, teacher asks them what they can do to test for the answers, “What can you measure to see?” to encourage them to think of their own ways of interacting with the simulation.
- Teacher has quiet activities planned for those who finish with the simulation early (homework, review).
- Teacher wraps up the topic in whole class discussion, invites students to summarize, takes questions. (This was frequently planned but seldom done.)

Whole class condition

- Teacher quickly introduces simulation in whole class environment; shows some, but not all, of the controls.
- Teacher invites students to call out suggestions for manipulating the simulation.
- Teacher allows/encourages a student to come up and operate the mouse.
- Teacher pauses simulation and asks students, ““Who will venture a guess about what will happen next?”
- Teacher asks students what they are seeing, points to important but subtle visual features on the screen.
- Teacher repeats selected student comments, adding emphasis.
- Teacher appropriates student-initiated ideas into discussion even when they are partially or wholly incorrect.
- When students ask questions, teacher asks them what they can do to test for the answers, as though students were at the controls themselves. Then he runs their tests for them if practical.
- Teacher waits several seconds after asking a question before moving on, allows silent time while students think or compose their questions.
- After a question on the activity sheet has been discussed in whole class discussion, teacher allows students to talk among themselves as they write their answers.
- Teacher poses question and explicitly invites students to “turn to your neighbor” to discuss it, thereby providing a small-group or partner discussion experience in the midst of the whole class set-up.
- Teacher offers analogies.
- Teacher offers concrete examples.
- Teacher describes the activity in the simulation as though the students were in the world of the simulation. (“If you were there, you would pump your knees in order to go higher.”)
- Teacher asks students to summarize what they have learned, either at the end of

the class or at the beginning of the next one. (This strategy was seldom observed.)

Although some of the strategies listed in the Whole Class category may have been used by the teachers when visiting individual small groups, these strategies were seldom if ever noted in our small group observations.

As can be seen, even though the technology was arranged either for group work or for whole class discussion, the teachers occasionally found ways to introduce some aspects and possible strengths of whole class to the small group work (whole class discussion before and/or after the activity) and some aspects of small group to the whole class discussion (turn to your neighbor). Most of the teachers asked frequent questions, especially during whole class discussion, often answering student questions with further questions. One teacher reported afterward, 'Thinking like a constructivist is a full time job, redefining ones role as Question Asker rather than Info Giver. The learner wants the answer, so it is hard." At another point he commented, "It became clear to me that synthesizing, summarizing, and restating was an important move." This teacher seldom if ever had enough time at the end of his classes (either condition) to do a whole class summary; however, in the whole class condition, he appeared to synthesis, summarize, and restate student comments throughout the discussion.

Questions Raised

Some teachers expressed surprised when whole class lessons threatened to take longer than small group lessons, as they had expected the small group students to spend more time exploring the simulations in an open, "play" mode. Also, the teachers tended to underestimate the time they would spend in whole class discussion. They reported finding themselves deviating from the activity sheets more than expected during these discussions because their responses to student questions frequently triggered more student questions, and these, though fascinating, could lead away from the current problem. However, total time on task was consistent across the groups, though how that time was distributed did appear to be different. Further analysis may include such factors as the relative time spent in causal reasoning, model-based reasoning, and using the visual affordances of the simulations to assist with these types of reasoning (as opposed to using the simulation to obtain numerical results for assigned problems, for instance). We also would like to know whether students are developing their own animated mental models in response to the models presented on the screen; this suggests gesture analysis as a further step (McNeill, 1999; Monaghan & Clement, 1999; Clement, 2008).

During follow-up interviews and meetings, the teachers reported changes in their own attitudes, coming to see advantages and disadvantages for the students in both situations. Upon being asked what advice he might give to other teachers as a result of his experience teaching matched classes in the two conditions, one teacher said,

> Carefully select which simulations you use in whole class and small groups. Even if you have a computer for every student, it might be beneficial to do some simulations in whole class format so that the teacher can entertain each question in front of the whole group, can keep more control over how the simulation is explored, can take care of unexpected misconceptions as they arise, and can cue students into the meaning of the symbolic representations used by the simulation. Also, simple simulations might only need a few seconds in front of the whole class to impart what they have to offer.

In addition to dealing with misconceptions once they arise, this teacher also found the whole class format valuable for detecting and diagnosing misconceptions that might not come to light otherwise. Our observations and transcript data suggest that whole class discussion may be especially useful in situations where persistent misconceptions are likely to be a factor; we believe this bears further investigation.

We hypothesize that, for the classes who only saw the simulations projected from a single computer before the entire class, certain kinds of active learning activities helped compensate for the lack of opportunity for hands-on exploration. These include: pausing the simulation; having students predict what would happen next and write down their predictions; having the students turn to their neighbors and discuss their predictions before the simulation continued; inviting students to suggest what to do next with the simulation. One teacher reported that students' prediction-making ability appeared to improve through several cycles of such activity in the whole class situation; she hypothesized that immediate feedback from her and from the rest of the class had been an important factor.

Conclusion

We are in the beginning stages of the analysis of a large number of classes observed during a three-year project. Nonetheless, we believe these initial results offer encouragement to teachers who do not have the resources to allow their classes to engage regularly in small group work at the computer. In the present experimental comparisons, students in the full class conditions did not do significantly worse than those in the small group conditions. In the Small Group transcript segments initially examined, we were surprised to find little discussion, occasional misinterpretation of the intended conceptual focus of a question, and a "get and report the data" mindset. In addition, persistent misconceptions may have prevented some students from even considering or examining some issues. Our initial examination of Whole Class transcript segments revealed that there appear to exist teaching strategies for promoting at least some of the active thinking and exploration that has been considered to be the strength of small group work. Furthermore, these examples suggest the somewhat surprising possibility that, within a constructivist framework, there may be certain instructional situations where a whole class discussion mode can provide a more effective support activity for a computer simulation than can the use of small group hands-on work—even if the resources are there. Determining when this might be true is, we suggest, an important topic for future research.

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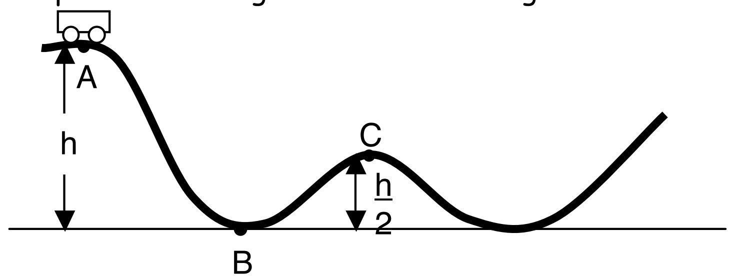
Skate Park Pre-Survey Name________________________ Date____________

1. Consider the roller coaster below. Assume no friction or air resistance. The cart starts from rest at point A and begins to roll to the right.



a. If Point C were not fixed at h/2, how high could Point C be in terms of the initial height h and still have the cart pass over it?

b. Assume that Point C is fixed at h/2. Fill in the table with the cart's gravitational potential energy and kinetic energy. Express these in terms m, g and h (the mass of the cart, the acceleration due to gravity near the surface of Earth, and the height of Point A).

	A	B	C
Gravitational Potential Energy			
Kinetic Energy			

c. How would these values change if there were friction present? Fill in the chart below indicating **INCREASE**, **DECREASE** or **SAME** as compared to part (b).

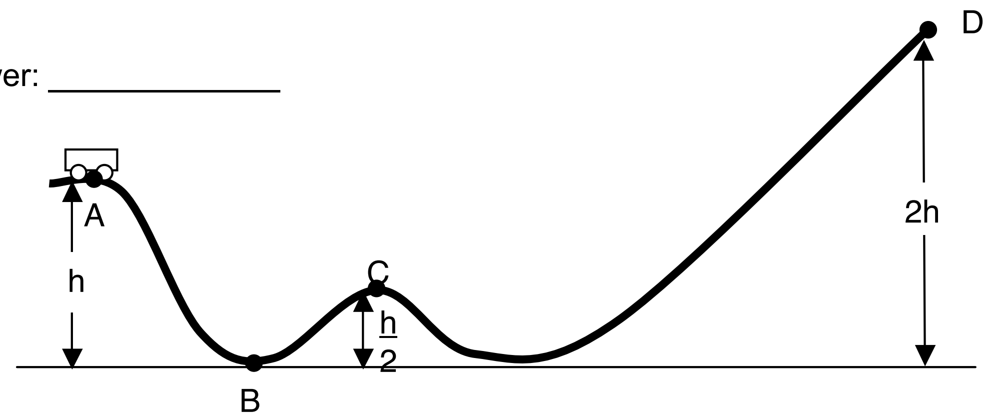
With Friction	A	B	C
Gravitational Potential Energy			
Kinetic Energy			

d. How would the values in part (b) change if the roller coaster were located on the Moon? Fill in the chart below indicating **INCREASE**, **DECREASE** or **SAME** as compared to part (b).

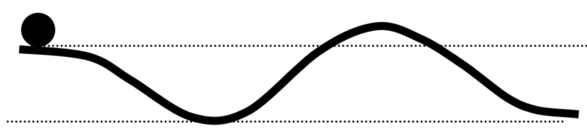
Moon, no Friction	A	B	C
Gravitational Potential Energy			
Kinetic Energy			

2. Back on Earth, consider the frictionless roller coaster shown below. In terms of m, g, and h, how fast would the roller coaster have to be going at its start (Point A) in order for it to make it up to Point D?

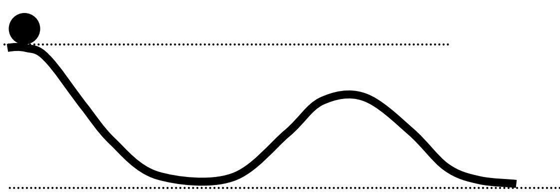
Answer: ______________



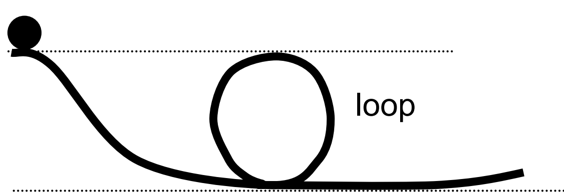
3. Which of the following marble tracks would allow a marble starting from rest and rolling to the right to make it to the end of the track without leaving the track. (Ignore friction and air resistance.)



Circle: Yes / No
Explain:

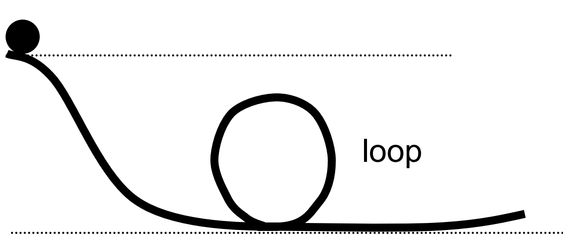


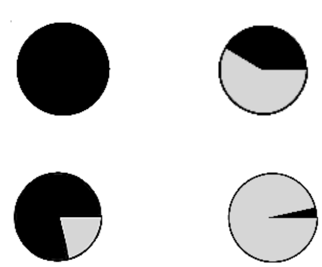
Circle: Yes / No
Explain:



Circle: Yes / No
Explain:

4. For the track below, circle the pie chart that best represents the marble's energy at the top of the loop. Kinetic energy is the lighter color, gravitational potential energy is the darker color.





KE: Lighter color

PE: Darker color

Name: ______________________ Date:_______________

Period: _____________________ Partners: _____________________________

Online Simulation Lab → PHET: Energy Skate Park

Purpose: *The purpose of this simulation lab is to strengthen your understanding of energy conservation in real-world applications.*

Exploration Activities

Open up the University of Colorado, PhET Energy Skate Park simulation:

- Go to http://phet.colorado.edu/simulations/sims.php?sim=Energy_Skate_Park
- Click **RUN NOW**!
- Spend FIVE MINUTES to explore the simulation and familiarize yourself with the controls.

RESET Instructions: When directed to **RESET** click the reset button in the top – right corner. Then place the potential energy reference line at bottom of the track by clicking **POTENTIAL ENERGY REFERENCE** and dragging the line. This way, the skater's gravitational potential energy will be zero at the bottom.

- **RESET** and begin the exploration below, **using just the simple track provided** (you'll have a chance to do more later!).

1. Does the skater hit the same height on the opposite sides of the track?
   a. What must be true about the system for this to be possible?
   b. Click the Track Friction button to adjust the coefficient of friction. What do you observe about the skater as you adjust the setting?

<u>Hint</u>: **SHOW GRID** may help!

2. **RESET**. Before continuing, discuss with your partners where the gravitational potential energy, PE, the kinetic energy, KE, and the total energy the skater will be the most: at the top or bottom of the path. Fill in the prediction column in the chart below.

	PREDICT WHERE?	Try it! **ACTUALLY WHERE?**	**AMOUNT** (Round to **nearest 10 J**)
PE MOST?			
KE the MOST?			
Total Energy MOST?			

Name: ______________________ Period: ____

3. Check your predictions by clicking on the **SHOW PATH** button and letting the rider lay down several rounds of purple dots before clicking **PAUSE**. Now click on a purple dot at the top and at the bottom to display data that will help you to determine where each type of energy is the most. (*You may need to hide the PE reference line in order to click on dots underneath it.*) Record the values in the table above, **rounding to the nearest 10 Joules**.
   a. What does total energy mean?

   b. Does KE = $\frac{1}{2}$ m v^2? (show your calculation)

   c. Does PE = mgh? (show your calculation)

Click **CHOOSE SKATER** to find its mass

<u>Hint</u>: You may need to move things around to see everything.

RESET. Turn on the energy Pie Chart and Bar Graph.

4. Without changing anything else, use the **CHANGE SKATER** button explore how skater's mass affects each type of energy. How does changing the skater's mass affect each type of energy?

   Potential Energy:

   Kinetic Energy:

   Total Energy:

5. Double check that the energy reference line is located a the bottom of the track, then hide it. Pick your favorite skater and use the purple dots to fill in the chart below for a position near the **TOP** of the track. Then use these values to predict the values at the **BOTTOM** of the track.
6. Check your predictions using the purple dot data and fill in the actual below:

(Round to the nearest 10 J)	**Top** (J)	**Bottom** (J)	
	Actual	Prediction	Actual
Height			
Potential Energy			
Kinetic Energy			
Speed			

Name: ______________________ Period: ____

7. Could the total energy be zero at some position? Explain.

RESET. Turn on the energy Pie Chart and Bar Graph.

8. Turn on a moderate amount of **TRACK FRICTION**.
   What happens to the maximum values of the 4 different types of energy over time?

Gravitational Potential Energy	
Kinetic Energy	
Thermal Energy	
Total Energy	

9. Turn off **TRACK FRICTION**. **PREDICT** what you think would happen to the maximum value of each type of energy if you moved the skater to Jupiter or the Moon.

PREDICTIONS	Jupiter	Moon
Gravitational PE		
Kinetic Energy		
Total Energy		

10. Try it! Record what happens and explain each case, paying particular attention to the changes in the maximum values.

Actual	Jupiter	Moon
Gravitational PE		
Kinetic Energy		
Total Energy		

Name: ______________________ Period: ____

11. **RESET**, pull down the **TRACKS Menu** and select **LOOP**, and **SHOW GRID**. Observe what is happening and then **PAUSE** the skater, set him to start at a height of 5.5 meters, just a SMALL AMOUNT MORE than the loop height. Before hitting **RESUME**, predict whether the skater will make it all the way around the loop.
    a. **PREDICTION** (and reasoning):

    b. ACTUAL (and new reasoning, if you were wrong!)

12. **RESET. Turn on the energy Pie Chart and Bar Graph.** Now select SPACE as your location. Play with the "thrusters." Describe what happens to each type of energy each time you apply the thruster rockets and explain as clearly as you can why this happens:

    Kinetic Energy:

    Potential Energy:

    Thermal Energy:

    Total Energy: