HANDS ON SMALL-GROUP VS. WHOLE-CLASS USE OF ANIMATIONS AND SIMULATIONS: COMPARATIVE CASE STUDIES IN PROJECTILE MOTION

Years one and two of a three-year study revealed that, contrary to their teachers' expectations, students working hands on with computer animations and simulations in *small groups* with a teacher circulating among the groups performed no better, as measured by pre-post gains, than students engaging in teacher-moderated *whole class discussions* while observing the animations and simulations projected onto a screen before the class. Similar results have been obtained in year three. Initial case study analyses suggested there might 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. The present study analyzes transcripts from a Projectile Motion lesson sequence taught during years two and three. Pre-post results are presented. Comparative case study analyses of matched sets of classes look closely at features of whole class and small group discussions that accompanied use of Quicktime animations, coding for presence of several factors that appeared to be associated with active reasoning in the initial case studies. One finding was the presence in whole class discussion of many more episodes of support for interpreting the meaning of visual elements in the animations than was present in the small groups. The Whole Class case studies examined here suggest the possibility that there may be certain instructional situations where there is an advantage to spending at least part of the time with the simulation or animation in a whole class discussion mode.

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This material is based upon work supported by the National Science Foundation under Grants REC-0231808 and DRL-0723709, John J. Clement, PI. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Hands on Small-Group vs. Whole-Class Use of Animations and Simulations: Comparative Case Studies in Projectile Motion

This study is part of a larger three-year study on teaching strategies for using interactive simulations in either small group or whole class settings in high school physics. It incorporates the most recent year of pre-post data from short Projectile Motion lesson sequences (1 to 3 days) conducted during years two and three of the study and discusses newly completed comparative case study analyses of selected transcripts. Results from the first two years of the study, involving the Projectile Motion and two other lesson sequences (Stephens, Vasu, & Clement, 2010; Vasu & Sweeney, 2010), were surprising in that they showed no evidence for an advantage of hands-on small group work with simulations over use of the same simulations in whole class discussion settings. It appeared that both lesson formats could involve active discussion and reasoning by the students, but initial observations and analysis of a lesson sequence on gravitational potential energy suggested differences in the kinds of discussion that took place in the two settings. The present study asks whether pre-post data from the Projectile Motion sequence of year three is consistent with the data of the first two years. It also seeks to shed more light on pre-post results by developing coding criteria for looking at qualitative patterns in large transcript samples from the Projectile Motion sequence.

Background

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; Zietsman & Hewson, 1986), 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. Some believe we know very little about how to use animation effectively in instruction (Jones, Jordan, & Stillings, 2001). 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 with simulations than a whole class format, 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 than a whole class format. 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).

Research such as Adams, et al. (2008) has found that simulations can be highly effective, but only if the student's interaction is directed by the student's own questioning. This suggests that hands-on exploration could be vital for the kind of engaged exploration that Adams, et al., found associated with conceptual gains. In our own study, we found teachers strongly in favor of small group work with simulations. After the second year, one teacher (who had not seen the results) said, "When at all possible, most of the time simulations are better done with students working in (small) groups." However, as reported previously (Stephens, Vasu, & Clement, 2010; Vasu & Sweeney, 2010), comparison of pre-post gains during the first two years of our larger study did not bear this out. In no comparison did we find a significant advantage for the small group condition; if anything, there was a slight trend in favor of the whole class setting. These results led to comparative case study analyses to look more closely at what was going on in the whole class and small group activities with the simulations. A previous study analyzing transcripts from a Gravitational Potential Energy lesson sequence suggested several possible factors that might have offset the advantage of hands-on exploration (Stephens, Vasu, & Clement, 2010). For instance, there appeared to be a difference in the amount of time spent addressing certain conceptual difficulties when they emerged. In the small group transcript segments examined for that study, the investigators were surprised to find little discussion, occasional misinterpretation of the intended conceptual focus of a question, and a "get and report the data" mindset. However, observation notes indicated that some differences between whole class and small group activity observed in the Gravitational Potential Energy sequence might not have held for the Projectile Motion sequence—not surprising, considering the differences in the designs of computer resources and lesson plans used in the two sequences. In this study, I look for possible differences between behaviors in small group and whole class conditions in the Projectile Motion sequence.

Research Questions

The results of preliminary analysis of data from the first two years of the study led to the following research questions:

1. Are the third year pre-post results for the Projectile Motion lesson sequence consistent with results from the first two years of the study? Is there any evidence for an advantage for including substantial hands-on small group work with the simulations and animations as opposed to working with them exclusively in a whole class context?
2. Do students engage in discussion about concrete causal factors while working with the Projectile Motion animations?
3. How do teachers and students support other students who exhibit conceptual difficulties during their work with the Projectile Motion animations?
4. How do teachers and students support other students in the recognition and use of visual affordances of the Projectile Motion animations?

Method

Participants

230 high school junior and senior physics students participated in the study of the Projectile Motion lesson sequence; 200 of these were present on all days of the sequence and completed both pre and post-tests. The short lesson sequence was taught multiple times over the course of two years (years two and three of the larger study) by three physics teachers in two high schools, one in a small, upper-middle class suburban town and the other in an industrial

community. Pre-post data is presented from eleven classes, comprising 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

The Projectile Motion simulation (Figure 1) was selected ahead of time by the teachers from freely available on-line sources and was used to target the understanding of the relationship between the angle and range of a projectile. However, teachers also wanted to address the independence of vertical and horizontal components of motion, and on-line simulations to address this concept in the way the teachers wished appeared to be lacking. Therefore, this researcher used Pacific Tech's Graphing Calculator to design simple animations to supplement the Projectile Motion simulation. Three of these animations were saved as QuickTime movies and uploaded to the school server.

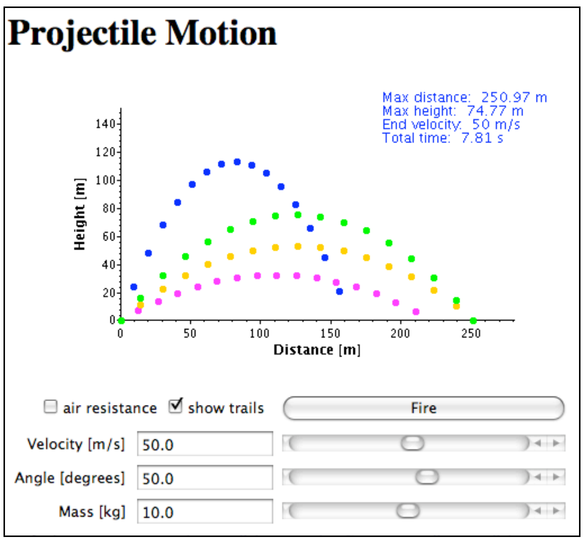

Fig. 1: *Projectile Motion applet, a simulation used in Part I of the lesson sequence. The simulation creates a motion map of different projectile trajectories.*

http://galileoandeinstein.physics.virginia.edu/more_stuff/Applets/ProjectileMotion/jarapplet.html

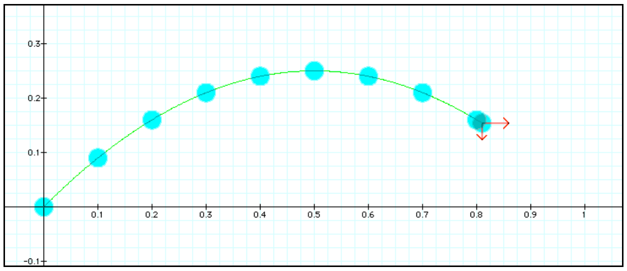

Fig. 2: *Vectors Animation used in Part II of the lesson sequence. When run, dots appear on the screen sequentially at equal intervals of about one second, creating a motion map. Animated vectors in red represent the two components of velocity. QuickTime controls allow playing at various speeds, stepping through the frames individually, manually moving the projectile by dragging a slider forward or backward, pausing and looping.*

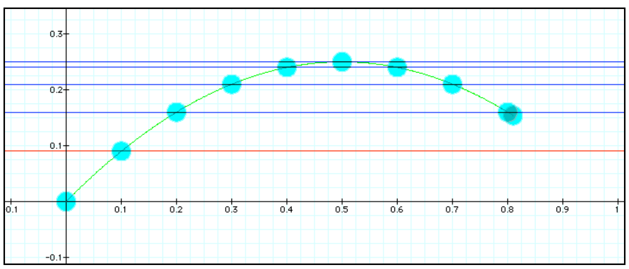

Fig. 3: *Lines Animation I, used along with the Vectors Animation above. As dots create a motion map, lines appear at equal time intervals to show the progress of the projectile in the vertical direction. The controls are identical to those in the Vectors Animation.*

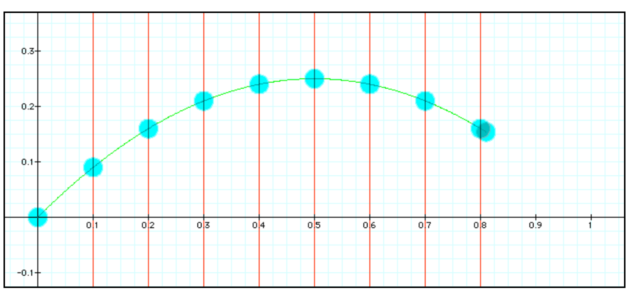

Fig. 4: *Lines Animation II. Lines appear at equal time intervals to show the progress of the projectile in the horizontal direction. The controls are identical to those in the Vectors Animation.*

The lesson sequence lasted between 1 and 3 days depending on the level of physics and the teacher. The lesson plans, activity sheets, and prediction sheets were developed by the teachers and reviewed by the research team. Classes were taught in matched sets so that quasi-experimental comparisons could be conducted. Although materials varied slightly for each level of physics, for each matched set, the teacher used identical simulation and animations (Figures 1-4), activity sheets and other materials in the two conditions but varied the way in which the simulations and animations were used. In the whole class condition, the teacher used a single computer to project the visuals onto a screen in front of the class and facilitated a whole class discussion as students worked through the activity sheets. In the small group condition, multiple computer stations were used with 2-4 students to a computer; they were allowed to engage in hands-on exploration and small group discussion guided by the activity sheets while the teacher circulated among the groups. In both conditions, the teacher began by introducing the computer activity in a whole class format. 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, the team-reviewed worksheets, the lesson mode (whole class or small group) 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 (balls for tossing around the room, prediction sheets asking students to predict various aspects of the motion of a projectile) and the same number of class periods to cover the material within each matched set. The pre-post surveys were developed jointly by the teachers and research team and consisted of transfer questions that were not directly addressed during instruction; this was to minimize the possibility of the teachers' teaching to the test and also because the desire for the study was to measure conceptual rather than rote learning. A sample activity sheet, prediction sheet, and pre-post survey are provided in the appendix.

The classes were observed and videotaped and the videotapes transcribed with the use of Transana transcription software (Woods & Fassnacht, 2010). The following matched sets were observed for the Projectile Motion lesson sequence. "1 SG" and "1 WC" indicate one class section taught in small group format and one in whole class format, respectively. One teacher had three matched classes and taught two of them in the whole class format.

2008-2009

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

2008-2009

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

Organization of the Paper

Quantitative pre/post results are presented first because they raise questions that will be addressed in the discussion of the qualitative analysis that constitutes the bulk of the paper.

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, the following were used: a 2x2 (Condition [whole class, small group] x Time [pre, post]), or in one instance, a 3x2 (Condition [class 1, class

[1] See example in the appendix.

2, class 3] x Time [pre, post]) repeated measures ANOVA. Gains are expressed as percentages of a perfect score. All groups had significant pre-post gains at better than the $p < .001$ level.

AP stands for Advanced Placement Physics, *HP* for Honors Physics, and *CP* for College Prep Physics, in order of decreasing difficulty level.

Table 1: *Comparisons of Pre/Post Gains Expressed as Percentages of a Perfect Score*

	Small Group		*Whole Class*		*Whole Class*				
	M	*SD*	*M*	*SD*	*M*	*SD*			*p*
2008-2009									
HP School I	.3750	.3248	.3393	.3517			$F(1,44)$ =	.1280	.7222
HP School II *	.3421	.2739	.3542	.2663	.3125	.3355	$F(2,50)$ =	.0892	.9148
2009-2010									
AP School I	.1746	.1919	.1596	.1578			$F(1,39)$ =	.0751	.7855
HP School I	.3466	.3534	.3750	.3472			$F(1,35)$ =	.0584	.8104
CP School I	.2361	.2894	.3125	.2488			$F(1,21)$ =	.4552	.5072

**This teacher had three class sections and taught two in the Whole Class format.*

The results of the most recent year of whole class/small group comparisons of the Projectile Motion sequence are consistent with the results of the previous year: in no comparison is there evidence for an advantage for the small group condition over the whole class condition. The *p* values are far from significance at the $\alpha = .05$ level indicating that the pre-post gains within each matched set were very similar across conditions.

The percentage gains in the AP class were small; however, the pretest scores were fairly high. In such a situation, it can be helpful to compare the actual gains to the gains that are possible, given high pre-survey results. Therefore, normalized gains $\langle g \rangle$ were computed. These consider the amount of room for improvement between the pre-survey results and a perfect score. For the normalized gains of a class $\langle g \rangle$, where $\%\langle G \rangle$ is the average gain of the class as a percentage of a perfect score, $\%\langle Sf \rangle$ the average final score as a percentage, and $\%\langle Si \rangle$ 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 result is the average gain of the class expressed as a percentage of the gain possible for that class.

Table 2: *Pre/Post Normalized Gains for Matched Classes in Projectile Motion*

		Small Group	*Whole Class*	*Whole Class*
2008-2009				
HP School I	<*g*> =	.6098	.7600	
HP School II	<*g*> =	.6753	.8361	.5714
2009-2010				
AP School I	<*g*> =	.7938	.7791	
HP School I	<*g*> =	.5398	.6250	
CP School I	<*g*> =	.4048	.4487	

Comparing the first rows in Tables 1 and 2, for example, we can see that for the Honors Class in year 2008-2009 in School One, the small group condition had average gains of 38% as compared to the whole class condition average of 34%. However, Table II reveals that, given the room remaining between their pre-scores and a perfect score, the small group condition achieved 61% of the gains possible for their class while the whole class condition achieved 76% of the gains possible for them. The normalized gains also show no evidence for an advantage for the small group condition over the whole class condition.

These results are also consistent with the results from other lesson sequences taught in years one and two, in which there was no evidence for a small group pre-post advantage; see Stephens, Vasu & Clement (2010) and Vasu & Sweeney (2010).

Qualitative Analysis and Discussion

In view of the apparent lack of advantage with respect to pre-post gains for students who had used the simulation and animations hands-on in small groups, this study attempts to develop methods that can shed more light on the following question: *Why did the whole class format produce gains as strong as those of the hands-on small group format?* Although the advantages of hands-on work with computer simulations appear to have become widely accepted, certainly accepted by most—if not all—of the teachers encountered during the course of this study, the quantitative results suggest there could be some counter-balancing advantages in the whole class discussion format. There are many lenses through which these issues could be addressed: relative rates of participation in discussion, nature of arguments proposed, socio-cultural perspectives on the functioning of the various small and whole class groupings, and so on. However, the present study has chosen to address these issues through the lenses of Research Questions 2-4 above, which focus on how the teacher and students support other students who are having difficulties.

A constant comparative method was used to code four transcripts from the 2008-2009 Projectile Motion lesson sequence for evidence to address each of the Research Questions 2-4. A major part of the effort behind this study occurred as coding categories were honed and coding criteria developed for them. In the present study, these criteria are used to code extended transcript selections from four new transcripts, these from the 2009-2010 lesson sequence. These case study analyses provide existence demonstrations of the phenomena identified, and the coding criteria developed therein should allow one to analyze a greater number of transcripts in future studies. The case studies also provide initial grounding for generating initial hypotheses about the mechanisms at work in the two classroom conditions.

It should be noted that the camera was focused on only one small group at a time in the small group condition. In this study, the camera was viewed as a proxy for the experience of an individual student. Coded transcripts can be thought of as reflecting what an individual student might have been exposed to during the course of the lesson.

Coding Criteria

Research Question 2: Do students or teachers engage in discussion about causal factors while working with the Projectile Motion animations?

Code: *Student mentions causality*: Student asks question about or mentions a concrete explanation as to why some aspect of the phenomena in the system under discussion is occurring.

Code: *Teacher mentions causality*: Teacher asks question about or mentions a concrete explanation as to why some aspect of the phenomena in the system under discussion is occurring.

For present purposes, "causality" is considered to be a concrete explanation for why the phenomena in the system under discussion are occurring, as distinguished from an explanation given solely in terms of kinematic relationships or equations. If a student discussed the lack of a cause (*e.g*., absence of forces) resulting in lack of an effect (*e.g*., lack of acceleration), this was counted. The transcripts were coded for any mention of a concrete cause for some characteristic of projectile motion. Concrete causes suggested in class discussions included gravity, inertia, “force of the throw” (which could reflect the presence of an alternative conception) and air resistance. A corresponding code was used to indicate when a teacher mentioned a concrete cause. Time spent on these discussions was noted.

Research Question 3: How do teachers and students support other students who exhibit conceptual difficulties during their work with the Projectile Motion animations?

Code: *Evidence for conceptual difficulty*: Student expresses frustration, confusion, or puzzlement in connection with ideas presented within the animation, the worksheet, or the class discussion.

Code: *Response to conceptual difficulty:* Classroom activity following episodes coded as “evidence for conceptual difficulty” was considered a response if it bore some relationship to the expressed difficulty.

The transcript was coded for presence of discussion time spent on addressing episodes of student conceptual difficulty. It was also noted where there was evidence for conceptual difficulty with no corresponding response. No attempt was made to separate these responses into teacher or student responses; many of them were in the nature of joint discussion with overlapping comments. Total amount of time spent in response to expressions of difficulty was noted.

Research Question 4: How do students or teachers support other students in the recognition and use of visual affordances of the Projectile Motion animations?

Code: *Student supports interpretation of visual affordance:* Student attempts to help another student interpret the meaning of a visual feature or relationship in the animation by pointing out the feature or relationship, giving a hint, gesturing in the air or over the display to indicate the feature or relationship, or asking a prompting question.

Code: Teacher supports interpretation of visual affordance: Teacher attempts to help a student interpret the meaning of a visual feature or relationship in the animation by pointing out the feature or relationship, giving a hint, gesturing in the air or over the display to indicate the feature or relationship, or asking a prompting question.

Individual support "moves" were counted. If a teacher pointed out a feature while asking a prompting question, this was counted as a single move. In long support episodes, a pause for response or a shift in tactics (asking a different prompting question, for example) was considered to demarcate between moves. However, if the same move was repeated several times in a row, it was only counted once.

The transcript selections analyzed below are the portion of each class during which students were working with the animations and the animation worksheets. After preliminary analysis of the entire lesson sequence for several classes, this animations portion of the sequence was selected for more in-depth analysis because it appeared to highlight in a particularly clear way issues observed throughout the sequence. In the Honors Classes, work with the animations occurred on the second day of the 2-day sequence. For the AP classes, which completed the entire sequence in a single day, work with the animations began about 15 minutes into the class period. The two teachers differed in the amount and nature of introductions and wrap-ups they gave for the lessons; however, all classes began with an introduction by the teacher in which balls were tossed around the room and the students and teacher discussed what is meant by "projectile motion." This occurred before the worksheets were handed out, and usually before the animations were brought up. Although the only sections for which complete coding results are given are those when students were working with the animations and animations worksheet, occasionally other parts of the transcript will be mentioned. If, for example, the introduction included extensive discussion of concrete causes for projectile motion, then this will be mentioned, although not counted in the tables of results.

The four transcripts form two matched sets, each with one class taught in whole class format and a second taught in small group format. Teacher 1 taught Honors Physics and Teacher 2 Advanced Placement Physics. For each matched set, an overview is provided of the small group and whole class discussions. The coding results for the two discussions are then compared.

Case Study Comparison I: Honors Physics, Teacher 1

Honors Physics small group discussion

The small group on camera appeared to be a relatively well-functioning group. The three students, S1, S2, and S3, appeared to have a good background in the topic and may have been a little too advanced for the activity sheet; at times they laughed over what they saw as the obviousness of the questions (though they were not always correct). They did encounter some conceptual difficulties but appeared able to work through these together as a group.

At the beginning of this Part II activity, almost immediately upon viewing the Vectors Animation (Figure 2), S3 speculated that the animation was showing the velocity components. She stated that the vertical velocity changes but that the horizontal velocity stays the same. This is a concept that many students appear to have trouble grasping. However, this group seemed not to have trouble with the idea of independence of motion or of a constant horizontal velocity. They did have some trouble describing *how* the velocity was changing and in what direction the acceleration was.

S2 expressed confusion concerning what the axes in the animated graphic represented. She quickly figured out the source of her confusion, saying that for some reason she always associates the vertical axis with *x*, but this realization did not enable her to correctly interpret the axes in the animations. A few minutes later, she said she thought they represented *time* and *velocity*, a common but incorrect assumption in the classes observed for this study. S3 understood that they represented *position*, arguing that this had to be true because the display showed a parabola. At one point in response to S2's confusion, S1 drew what he thought a *time-velocity* graph would look like as opposed to the *position-position* graph in the animation.

Another source of confusion was about the direction of acceleration. Even though S3 knew that the vertical velocity was changing and that the horizontal velocity was not changing, she still wondered whether the projectile wasn't accelerating along the direction of travel. S1 was sure that the acceleration was constant and due to gravity, saying that acceleration is "down in the Y direction," though a moment later he said "up and then down." S3 continued to express confusion about the direction of acceleration, saying, "I don't get it. What do they mean by 'direction'?" Eventually, the group agreed that the acceleration was in the vertical direction and that they knew this was true because Arrow A (vertical arrow) changed length.

Thus, by the time they had finished with the first animation (velocity arrows, Figure 2), they had figured out most of the target concepts for the lesson, though it is not clear they all were sure the vertical acceleration was downward the whole time.

These students rapidly moved through the questions about the second animation (Figure 3), which used horizontal lines to indicate varying vertical velocity. With the third animation (Figure 4), which used vertical lines to indicate constant horizontal velocity, S2 had momentary confusion between vertical and horizontal. However, the students were clear that the *y* component was changing and that the *x* component was not, and S2 quickly realized that the vertical lines gave information about the horizontal motion. On this animation, which indicated constant horizontal velocity, the three students had trouble deciding how to answer whether the animation showed acceleration. They understood that all three animations showed the same thing and that acceleration was present, but they paused for several seconds as they tried to figure out what were the indicators for this in the third animation. Finally, S3 pointed out that since the line of the trajectory wasn't straight but the horizontal component was constant (as shown by the equal spacing between the vertical lines), that, by process of elimination, the acceleration must be in the vertical direction. (Although this is accurate, it had been hoped that students would also realize that the variable spacing in the second animation indicates acceleration in the vertical direction.)

This group finished their activity sheet well before some of the other groups and then turned to unrelated activities. Discussion in terms of Research Questions 2-4 follows.

Q2 Mentions causal factors: Gravity was mentioned only once as a concrete causal factor, near the beginning, but this did not seem to be much of an issue for these students; they seemed to be aware that gravity produces the acceleration and to be comfortable with this. They did not mention inertia, the absence of a horizontal gravitational force, or any other possible reasons for the constant velocity in the horizontal direction, instead relying on observation patterns in the animations when reasoning about this component.

Q3 Response to conceptual difficulty: There were many expressions of difficulty. Each time a student exhibited conceptual difficulty in this group, the discussion turned to that difficulty (if not already focused on it) and stayed with the issue until the students had agreed on an answer. This was not the case for many of the small groups observed, but it was true for this one. 3 minutes 49 seconds of this transcript was coded as "response to conceptual difficulty" out of 15 minutes of discussion. The following excerpt gives an idea of the joint reasoning about the animations that occurred in this group. The first line was coded as "evidence for conceptual difficulty" and the remainder as "response to conceptual difficulty." (The third line was also an expression of difficulty but not of a new difficulty; it could also be viewed as the student responding to her own difficulty by continuing the discussion rather than letting the question drop, as was frequently observed.) Square brackets denote gestures.

S3: *[moves right hand as though throwing something vertically toward her partners]* Projectile- is different than- wait, no.
S1: There is still a constant acceleration.
S3 *(looking at S2, slowly, questioningly):* Is it?
S1: Because- *(pause)*
S3 (*quickly*): Yeah, because, think about it, the acceleration, it starts, even though it starts a little *[holds hand up, thumb and forefinger together, moves it in a short arc up and away from her face]* negative, right, and it goes, it's still-
S1: So it's still *(inaudible)* down in *y*.
S3 *(overlapping)*: If so, in what direction? *(pause)* In what direction, though? *(pause)*
S1: Well, it goes *[points upward]* both up and then *[points downward]* down.
S3: Yeah. What does it mean by direction, though?
S2: Like, is it going horizontal, is it-
S3: Oh, is it, acceleration in the-
S2: In the *y* or the *x*.
S3: Ohhh.
S1: *Y*, right?
S3: The *y*, the (*inaudible*) of the *y* is changing.
S1: Yeah.
S2: Yeah.

Q4 Support for interpretation of visual affordances: There was one instance counted as "supporting interpretation of a visual affordance" of the animations, where S3 gestured to show S2 what the line on the display would look like if there were no acceleration present. There was also an instance where S1 drew on a piece of paper to show another student how a *time-velocity* graph would look. This did not fit the coding criteria as it did not directly address a visual feature of the animation, although it would seem likely to have provided indirect support.

A possible explanation for the lack of episodes coded as "support for interpretation of visual affordances" may be the fact that these three students seemed fairly evenly matched in their understanding of the visual elements in the animation. When there was difficulty with the visuals, they appeared more apt to reason jointly rather than have one student act in a clearly supporting role.

Although the class as a whole spent 34 minutes on the activity sheet, time on task for this group was about 15 minutes.

Honors Physics whole class discussion

As with many of the lessons observed, spontaneous events occurred in this class that were not anticipated in the lesson plan. After more than twenty minutes on task with the activity sheet and animations, insistent questioning from a student prompted the teacher to do something he hadn't planned; he performed a lecture demonstration that lasted almost 5 minutes. After a few more questions, the teacher began to wrap up the discussion. But then another series of student questions led to nine more minutes of discussion and mini-lecture. Finally, the teacher ended the discussion by saying, "My sense is, this is not helping for you. It's not clicking."

The research questions are discussed here in the order Q3, Q4, Q2 because this will result in a chronological overview of the student activity.

Q3 Response to conceptual difficulty: About 18 minutes into the activity, students began exhibiting confusion. They were trying to interpret the indicators for constant velocity present in the third animation (with sequential vertical lines), in light of the fact that they were positive there was acceleration occurring in the system.

T: Does anyone have a sense as to what equal distance in equal times indicates about velocity?
S *(sounding puzzled)*: I was gonna say that it was equal, but like, the velocity changes.

A moment later:

T: Can you say more about what it is that you see that's equal here?
S: No.

And a short time later:

S: We're just confused because if it had a constant- if it didn't have acceleration, it would be linear.

A total of 14 ½ minutes, most of the remainder of the discussion, was coded as "response to conceptual difficulty" as the teacher guided the discussion to stay focused on the issue of both constant and accelerated components of velocity being present within a system.

Q4 Support for interpretation of visual affordances: There were 25 episodes with this code, all of them teacher moves. A particularly interesting episode occurred during the last part of the lecture demonstration, almost a half-hour into the activity.

Despite the fact that on the preceding day the students had appeared able to reason with the motion maps in the Galileo Projectile Motion simulation (Part I of the lesson sequence; see Figure 1), the teacher began to suspect, from student questions such as those mentioned above, that on this second day of the sequence, the students were misinterpreting the motion maps in the animations as *position-time* or *velocity-time* graphs. The motion maps were plotted on horizontal and vertical position axes but students had not worked with position-position graphs. The teacher decided to try a lecture-demonstration although he did not have the equipment needed, and so had to ask students to imagine much of it.

After tossing a ball from the front to the back of the room several times, he asked students to imagine a spotlight shining from the back of the room toward the whiteboard on the front wall, casting a moving shadow of the projectile, viewed head-on, onto the whiteboard. He pointed out that this shadow would travel straight up and down. He drew marks on the whiteboard to represent the heights of the projectile's shadow at different points in time. He then asked the students to imagine another spotlight shining from the ceiling down to the floor and pointed out that the shadow of the projectile would travel across the floor. He then turned back to the animation display (projected onto a rolling SmartBoard positioned near the wall-mounted whiteboard) and used a marker to annotate the projected display of the animated motion map. He drew marks on the y-axis, and pointed out their equivalence to the marks he had drawn earlier on the whiteboard. He then drew marks on the *x*-axis and pointed out their equivalence to the shadows he had asked them to imagine on the floor. Turning back and forth between his drawings on the whiteboard and the animated display on the Smartboard, he described the equivalence in different ways. He drew a straight horizontal arrow below the *x*-axis and an upside down U-shaped arrow next to the *y*-axis. He also labeled his marks on the *x*-axis as "CONST" and his marks on the *y*-axis as "ACCEL." This whole episode was accompanied by many depictive gestures as the teacher demonstrated the components of motion, and sound effects as the teacher emphasized the equal time lapses between the dots in the motion map.

The last minute and a half of this demonstration, when the teacher was drawing an equivalence between the positions of (imaginary) shadows and positions of marks on the axes in the display, was coded in its entirety as a single long episode of "teacher supports interpretation of visual affordance," the affordance being the ability of the marks on the axis to indicate the position of the projectile at regular intervals.

Q2 Mentions causal factors: Gravity is mentioned only once, and then not in the context of a clear causal relationship. The following excerpt occurs near the end of the discussion, after the lecture demonstration.

T: And so this is really the essence of projectile motion. Motion with a constant horizontal velocity and a constant vertical acceleration.
S2: So wait, it's like acceleration and the velocity by the time, right? *(inaudible)*
T: I didn't quite follow the question.
S3: Wait, you just said there was constant acceleration, but I thought it was changing acceleration.
T: Acceleration is just gravity. *(Turning back to S3)* I actually didn't *(inaudible)*, didn't understand the question you asked.
S3: Well, like, if you try to find what the *(inaudible)*-

T: Define the time intervals between the dots?
S3: Yeah, the acceleration and the velocity?
T: Well, this movie, there's no units on these axes. The fact is, that most, I'd say 99.999 percent of the time, we deal with projectiles on Earth. And on Earth, we know the acceleration. It's 9.8, which we often round off to ten meters per second every second, in the direction down toward the local surface.

It may be that gravity had been discussed as a cause for the motion on an earlier day and that the teacher did not feel a need to discuss it further. However, on this day, rather than saying, for example, that the acceleration of a projectile is *caused* by gravity or that gravity produces the difference between the characteristics of the vertical and horizontal velocity components, instead, the teacher states that acceleration *is* gravity. For these students, many of whom appear to have trouble distinguishing between velocity and acceleration, it would seem that this statement could have potential to increase confusion. Nonetheless, it was counted as the mention of a concrete cause for acceleration.

Length of whole class discussion accompanying work with the activity sheet was about 37 minutes, as compared to the 34 minutes allowed the small group discussions (though not all of the small groups utilized the entire time).

Honors Physics comparison summary of results

Pre-post results

As Table 1 showed, the pre-post gains for these two classes were as follows.

Table 3: *Pre-post results*

Pre/Post Gain Comparisons for Matched Classes	Small Group *M*	Small Group *SD*	Whole Class *M*	Whole Class *SD*			*p*
Honors Projectile Motion	.3466	.3534	.3750	.3472	$F(1,35) =$	.0584	.8104

From Table 2, normalized gains <*g*> were 54% of possible gains for this small group discussion and 63% for the whole class discussion.

Coding results

To interpret the results in the keyword maps (Figure 5), it should be remembered that the video camera was viewed as a proxy for an individual student. In the whole class situation the camera usually stayed in one place. In the small group situations, it moved along with the students as they broke up into small groups and adopted the vantage point of an individual within a particular small group. Therefore, the codes are not intended (and practically, were not able) to represent everything going on in any of the classrooms, but rather to represent what could be experienced from the vantage point of a single student as represented by a single camera lens.

In the keyword maps, the transcript segments run chronologically from left to right, spanning the time when the students were working with the animations and animation worksheets. Color blocks below each transcript segment denote the codes assigned to that segment; the codes are listed on the left.

TEACHER 1 hp 2009

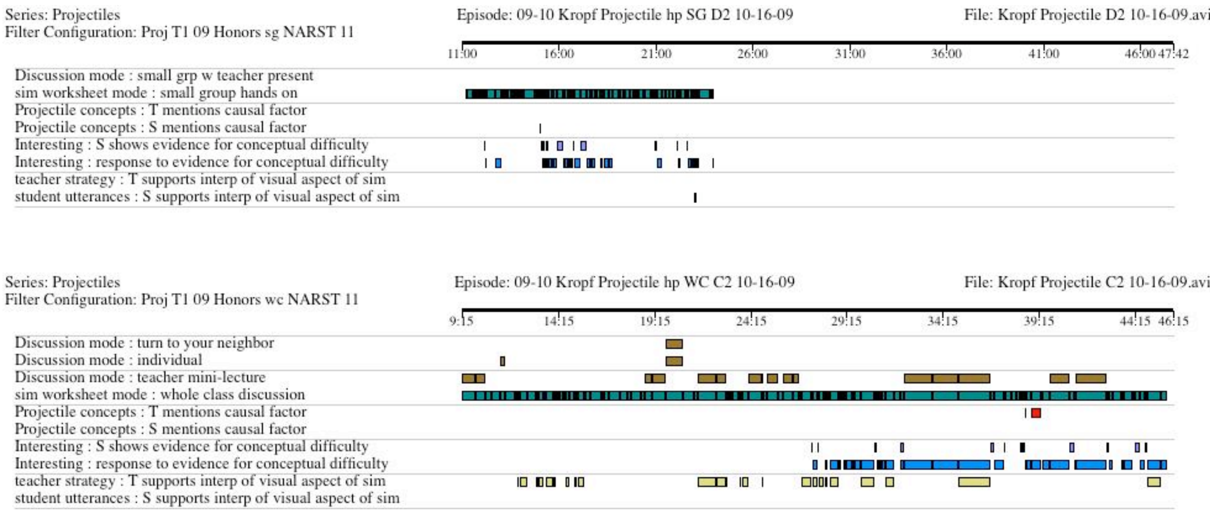

Fig. 5. Keyword map from Transana

Table 4: *Summary of qualitative results*

	Small Group Format	Whole Class Format
Time on task w/activity sheets	39 min	39 min
Time with animations	34 min	37 min
Length of tape analyzed	13 min*	37 min
Mention of concrete causal factors	Total length: **6 s** Teacher: 0 Student: 6 s	Total length: **36 s** Teacher: 36 seconds Student: 0
Support for interpretation of visual affordances	Total support episodes: **1** Teacher: 0 Student: 1	Total support episodes: **25** Teacher: 25 Student: 0
Response to evidence for conceptual difficulty	Many episodes of difficulty Response length: **3 min 49 s**	Many episodes of difficulty Response length: **14 min 39 s**

*The small group on camera took only 13 minutes to finish their activity sheet, then moved on to unrelated work.

It can be seen from the above that, compared to the small group, on camera the whole class had:

- slightly more discussion about concrete causes, though this was short
- many more episodes of support for the interpretation of visual affordances in the animations
- 15 minutes in response to student difficulties compared to 4 minutes for small group (41% of on-camera time compared to 31%)

Discussion about Honors comparison

The small group was unusual among those observed during the course of the study, in that these students actually did attempt to support each other with their conceptual difficulties. However, even accounting for the much greater time on task in the whole class discussion, there was still a higher percentage of response to student conceptual difficulties in the whole class discussion than there was in the small group discussion. This comparison points out another hazard of small group work—failing to take advantage of the entire time allotted. Although the small group students were fairly knowledgeable, they did not appear to know how to take their investigation with the animations any further than they did. There was a feature in the first animation that could have answered their questions about the direction of acceleration (the tip of the vertical velocity component starts above the ball and moves steadily downward). However, it appeared common for small groups to turn to other tasks once they had finished the worksheet rather than delving more deeply into unresolved issues.

Case Study Comparison II: Advanced Placement Physics, Teacher 3

In the 2009-2010 AP classes, both the Galileo simulation and the Projectile Motion animations were shown on the same day, with the animations shown first. The part of the discussion that concerned the animations was coded and analyzed. Although these students had not had the prior benefit of experience with the Galileo simulation at the time they discussed the animations, this was equally true of both the whole class and small group conditions. Moreover, these students tended to be more advanced than the Honors class students and, in general, appeared more ready to interpret and reason with the animations. The remainder of each class, which concerned the interactive Galileo simulation, was transcribed and read to see whether any student frustration expressed and ignored during the animations discussion was addressed at any point before the end of the discussion. In both lesson formats, work with the computer was preceded by a teacher-led question and answer session about concrete causes of projectile motion.

Advanced Placement small group discussion

In this small group, S3 attempted to act as an "authority," though the other students did not always defer to him. Rather than attempting to support his group mates in gaining understanding, S3 tended to make factual pronouncements, not all of which were correct. Describing the responses of this group to some of the conceptual difficulties of its members will serve to illustrate a sense of the discussion.

Q3 Response to conceptual difficulty: S1 and S2 expressed conceptual difficulties on several occasions. Although S3 was incorrect at times, he never expressed this as a difficulty.

In the following extended episode, S2 was the first who exhibited difficulty. The issue was a question on the worksheet asking how one could tell whether or not there was acceleration in the Vectors Animation.

S1: *[pointing to the beginning of the trajectory on the display]* There is acceleration at the beginning *[points to the end of the trajectory]* and then at the end. Because of the force.
S3: I uh, I don't think we're supposed to read into it that hard.
S2: Well, isn't that like-
S3: *(inaudible)* the animation get the *(inaudible)*. Changing like y component. That's enough for me. I mean, like, nothing else is making it-

S2: Is this a position graph? Doesn't a slope like that mean it's accelerating? It's accelerating.
S3: If th- yeah.
S2: There is acceleration going up and then when it goes down gravity- well, gravity- I don't know.
S3: I don't know, I don't think we're supposed to read that hard about it. Like, there're two other graphs, that we're just supposed to get the idea done, so I'm just gonna say, "it is gravity."

S2 appeared to be trying to reason about a visual aspect of the animation that indicated acceleration, namely, the slope of the graph, but S3 advocated just writing down that "there is gravity" and getting it done with. In trying to reason about what they were "supposed" to do, S3 appeared to have missed the point of the question. S2, however, clearly *did* picked up on the point of the question and re-read it emphatically,

S2: "How do you *know*?"

S3 gave a short, inaudible response. The students wrote quietly on their activity sheets. A moment later, it became clear that S2 was sticking with the issue:

S2: I said the parabolic shape shows that it is accelerating.
S3 *(in an authoritative tone)*: A parabolic shape indicates change in slope, which is characteristic of some kind of acceleration.

The students turned back to their activity sheets and wrote**.** A little later, S1 expressed confusion about a similar issue with respect to Lines Animation I, which had horizontal lines indicating the motion along the *y*-axis. The question was, "What does the spacing between the lines indicate about the acceleration?"

S1: Should we just say, like, it decreases as it goes up, increases as it goes down? Like that?
S2: Huh?
S1: Should we do it like that? Like, it incr- it decreases as it goes up, and increases as it goes down? Just like that?

(There was a pause as the students looked at the display screen, the animations still running on loop.)

S1: It changes uniformly?

To this, his classmates gave no response. Instead, S3 made a comment about how the two animations they had up and running were starting to "desync," to run out of synchrony with each other (synchrony was not required for their interpretation). Then the students wrote on their activity sheets without talking. A few moments later, S1 tried again to ask what the spacing between the lines in the animation indicated. S2 and S3 had apparently gone on to the questions for Animation III while S1 was still working on the questions for Animation II. This resulted in confusion and miscommunication that was never cleared up. S1 asked his question several more times, finally appearing frustrated at responses such as the following.

S1 *(re-reading the question)*: "What does the spacing- "
S3: Magical dilemma of life, whether we know too much or not.
S1 *(sounding frustrated)*: No, you can't just say something that (*inaudible*), make it sound like- (*inaudible*).

However, he quickly appeared to rein in his frustration and, with quiet persistence, continued to bring up the topic until, after about 5 minutes, he finally dropped it. The students left the animations and moved on to the Galileo simulation and the simulation activity sheet.

During the Galileo simulation part of the discussion, which was transcribed but not coded, the conversation never returned to S1's questions about acceleration and velocity. This is not surprising because the simulation explored a different aspect of projectile motion than did the animations. However, there was an interesting resolution to the slightly uncomfortable dynamic reflected in the transcript excerpts above. At one point S3 left the group. While he was away, S1 and S2 used the simulation to discover a surprising fact about projectiles (unequal masses shot at equal velocities will travel the same path in the absence of air resistance) and S1 figured out a concrete cause of this phenomenon (one has to use more force with the more massive projectile to get it up to speed). When S3 returned, S1 and S2 asked him what his prediction had been for the case of unequal masses. When he answered incorrectly, S1 and S2 looked at each other, shrugged and laughed. S1 responded (with a note of glee?), "You will be pleasantly surprised." After this point, the dynamic of the group changed, S1 sounding more confident and pointing out when his predictions were correct.

Q2 Mentions causal factors: During the animations portion of the lesson, concrete causes (e.g., gravity) were mentioned on two occasions for a total time of less than a minute. This may have been due to the fact that they had already been discussed rather extensively during the introduction to the lesson.

Q4 Support for interpretation of visual affordances: There was no support for the interpretation of visual affordances observed during the animations portion of the small group discussion. The teacher gave a small amount of support to the whole class during the introduction to the animations before the students broke up into groups (this was not counted). She also gave some support to the small group on camera at the end of their discussion about the Galileo simulation (which was not a part of the animations discussion and was not counted).

This small group discussion provides a contrast to the well-functioning Honors small group that was observed. Socio-cultural factors may have played an important role in the performance of this small group. However, because the lesson sequence was implemented so differently in the AP and Honors classes, no direct comparison between the two small group discussions was attempted.

Length of the small group discussion accompanying work with the animations and animations activity sheet was about 16 minutes.

Advanced Placement whole class discussion

The first two minutes of this whole class discussion about the animations was essentially a mini-lecture; the teacher used analogies and gestures to describe what the students were seeing on the display screen. Shortly after the mid-point of the discussion, the teacher suggested to the class that they turn to their neighbors as they fill out their activity sheets. This initiated a 4-minute period where most students worked alone on their sheets, although a few occasionally spoke quietly with their neighbors. The remaining time in the animations discussion was an active 6-minute block that constituted the heart of the discussion and a 2 ½ minute wrap-up discussion when the students discussed the answers they had written.

At the very beginning of the discussion, when the Arrows Animation had just begun playing, a student gave a very clear description of the relationship between the arrows, the direction of acceleration, and the changes in velocity.

T: (The worksheet) is asking you what do you think the arrows indicate about velocity. … (W)hat do you think each of those arrows is representing?
(Several students raise hands.)
S: I think that the vertical one is the velocity for going up and down. So that *[with left hand, points toward screen and traces an upward arc with her forefinger]* as you're going up, the *[suddenly flips her hand so that her forefinger is pointing downward]* acceleration is *[moves forefinger downward]* negative, so the arrow is getting smaller. And then, like the acceleration of gravity, once you hit the peak, *[moves forefinger slightly up and then back downward]* the velocity is negative, and the *[points downward with forefinger]* acceleration of gravity is negative, too.

This was coded as a supporting move by the student, as she used gestures and words to try to convey her understanding to the rest of the class. It is impressive in that this is a rare instance where a student identified the aspect of the representation that indicates both the presence and the direction of acceleration. About the only bit of information in the vertical arrow she did not point out was that one can tell that the acceleration is constant because the movement of the tip of the arrow relative to its tail is constant. (No one has picked up on that in any of the class discussions analyzed so far.)

An interesting question might be, where could the teacher go from here? The student has essentially given the answers. In such a situation, how can the teacher provoke reasoning on the part of students in the class who have not yet mentally engaged with the animation? Rather than keeping the focus of the discussion on the direction of acceleration, a difficult concept for many students, the teacher returned the focus to the visual appearance of the arrow and asked students what it might represent in terms of components.

T: So that's the one that they're calling Arrow A? So if we were to talk about that arrow, it gets smallerrrr *[looks at display screen, animation apparently still running on loop]* and then it gets biggerrrrr and it's got something to do with the acceleration- What would you call that? As a component?
S: "j hat."
(T laughs.)
T: It's the j hat, in the j hat direction, right? But what is it, is it position?
S: Velocity.
T: It's sort of like the velocity component? Maybe? Yeah? What about the horizontal one, the other one, Arrow B? What's that one doing?

S: Staying the same.
T: What does it represent?
S: The horizontal velocity.

The teacher then paused (froze) the animation and asked students, if these are the components, what is the actual direction of the velocity?

The teacher provided visual support in this segment by gesturing over the animation and asking students about relationships between features in the animation, and the students answered by relating the presence or absence of forces to the presence or absence of acceleration.

Q2 Mentions causal factors: During the animations portion of the lesson, concrete causes were mentioned on three occasions, twice by students and once by the teacher, for a total time of less than a minute. This may have been due to the fact that causes had already been discussed rather extensively during the introduction to the lesson.

Q3 Response to conceptual difficulty: There was no evidence for conceptual difficulty observed during this discussion. This could have been because those with difficulties did not want to bring them up. However, this discussion appeared to go smoothly, with most students appearing to understand the concepts.

Q4 Support for interpretation of visual affordances: There was extensive support for the interpretation of visual elements in the animation; the student episode described above and 18 teacher episodes were observed.

Length of whole class discussion accompanying work with the animations and animations activity sheet was about 15 minutes.

Advanced Placement comparison summary of results

Pre-post results

As Table 1 showed, the pre-post gains for these two classes were as follows.

Table 5: *Pre-post results*

Pre/Post Gain Comparisons for Matched Classes	Small Group *M*	Small Group *SD*	Whole Class *M*	Whole Class *SD*			*p*
AP Projectile Motion	.1746	.1919	.1596	.1578	$F(1,39) =$	.0751	.7855

From Table 2, normalized gains <g> were 79% of possible gains for the small group discussion and 78% for the whole class discussion.

Coding results

In the keyword maps (Figure 6), the transcript segments run chronologically from left to right, spanning the time when the students were working with the animations and animation worksheets.

TEACHER 3 2009 (Blauner)

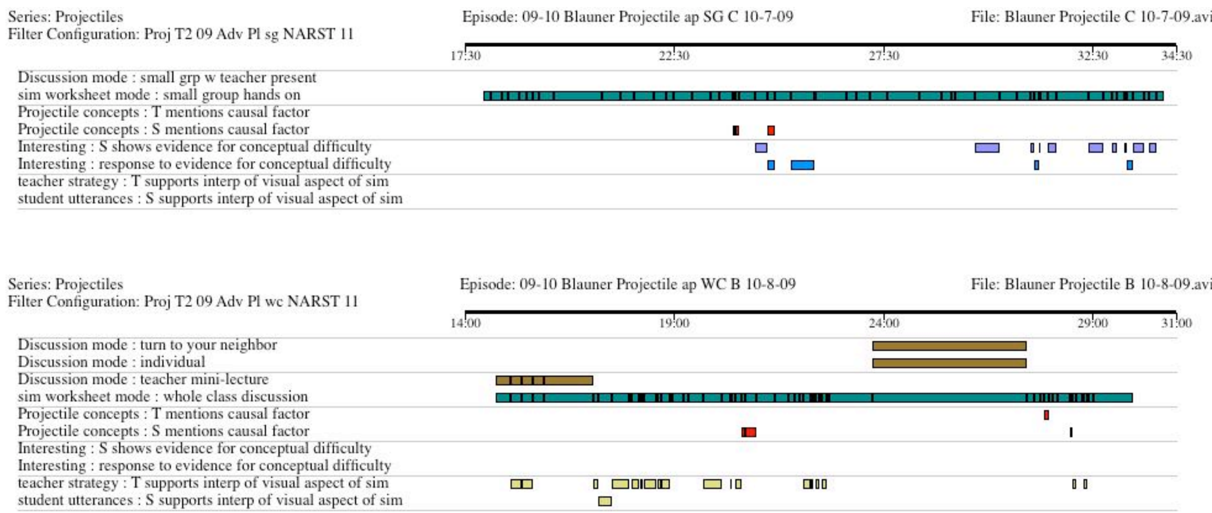

Fig. 6 *Transana map of coding results*

Table 6: *Summary of qualitative results*

	Small Group Format	Whole Class Format
Time on task w/activity sheets	19 min	15 min
Time with animations	16 min	15 min
Length of tape analyzed	16 min	15 min
Mention of concrete causal factors	Total length: **43 s** Teacher: 0 Student: 43 s	Total length: **33 s** Teacher: 7 s Student: 26 s
Support for interpretation of visual affordances	Total support episodes: **0** Teacher: 0 Student: 0	Total support episodes: **19** Teacher: 18 Student: 1
Response to evidence for conceptual difficulty	Episodes of difficulty: 9 Response length: 1 min (tot)	Episodes of difficulty: 0 Response length: 0

It can be seen from the above that, compared to the small group on camera, the whole class had:

- about the same amount of discussion of concrete causes, short in both cases
- many more episodes of support for the interpretation of visual affordances in the animations
- no episodes of student difficulty (and so no response), while the small group had 9 episodes of student difficulty with a total response time of only a minute.

Discussion about Advanced Placement comparison

In the AP classes, the teacher had the students complete the entire sequence in a single day. In both whole class and small group formats, she led the class in a question and answer session about concrete causes during the introduction to the lesson in which students suggested gravity, air resistance, and force from the hand as concrete factors that influence the motion. Both classes seemed comfortable with those concepts and this may have been why the issue of causes did not arise much during the work with the animations. Though there were no visual support episodes noted during the small group discussion, there had been one episode of teacher support earlier before students had gone to their groups. The time on task for the whole class discussion was about the same as the time on task for the small group on camera. The small group appeared to have some problems functioning, as one student repeatedly brought up questions that were not addressed. The whole class discussion appeared to function well; however, it may be that these Advanced Placement students were hesitant to bring up their conceptual difficulties in front of the class. Whatever the strengths and weaknesses for each format with regard to the post-test, they appeared to balance out across the two classes as a whole, with each class attaining approximately 80% of the gains possible, given their fairly high pre-test scores.

Summary of Findings for All Groups

Quantitative

- Third year *pre-post results* from three new comparisons of Whole Class and Small Group formats were consistent with results from the first two years of the study, as reported in Stephens, Vasu, & Clement (2010) and Vasu & Sweeney (2010): comparisons of pre-post gains showed no evidence for an advantage of working with the simulation and animations hands-on in small groups over working with them exclusively in a whole class context.

Qualitative

- Case study analyses of four classes revealed little discussion of *causal factors* in any of them. Although one of the teachers had led each of her classes in a discussion about causal factors during an introduction that preceded the activity, the other teacher had not.
- A comparative case study analysis of the matched Honors Physics Projectile Motion classes revealed differences in how *conceptual difficulties* were responded to in the whole class and small group formats. For instance, the whole class investigation into conceptual difficulties continued far longer than in the corresponding small group discussion even though students on camera in the two classes had expressed similar levels of confusion and frustration. This is consistent with findings from an earlier study (Stephens, Vasu, & Clement, 2010) in which response time to a specific conceptual difficulty that had elicited similar levels of confusion and frustration across classes was investigated. Although, in the present study, there was no expression of conceptual difficulty observed in the AP whole class discussion, there were several such episodes in the matched small group discussion and they were responded to very briefly or not at all.
- Two comparative case study analyses of matched Physics Projectile Motion classes at the AP and Honors levels both showed many more support episodes for the *interpretation of visual affordances* in the whole class conditions. In the Honors Physics small group, there was only one episode, in the AP Physics small group, there were none. In the Honors and AP whole class discussions there were many support episodes, an average of 2 every three minutes and more than 1 a minute respectively. Most of these were teacher episodes.

Table 7: *Summary of qualitative findings*

	Small Group Discussion	Whole Class Discussion
Mention of concrete causal factors		
Honors classes	< 1% of discussion time	< 2% of discussion time
Advanced Placement classes	~ 4% of discussion time	< 4% of discussion time
Response to evidence for conceptual difficulty		
Honors classes	Many episodes of difficulty Response length: 31% of discussion time	Many episodes of difficulty Response length: 41% of discussion time
Advanced Placement classes	Episodes of difficulty: 9 Response length: 6% of discussion time or < 7 seconds per episode	Episodes of difficulty: 0 Response length: 0
Support for interpretation of visual affordances		
Honors classes	< 5 episodes per hour	~ 41 episodes per hour
Advanced Placement classes	0 episodes per hour	76 episodes per hour

The qualitative findings reveal no evidence for an advantage for the small group hands-on condition over the whole class discussion condition when using interactive animations (pause, speed up, slow down, reverse, step through, loop) in these high school physics classes. The qualitative findings, which were from the animations portion of the lesson sequence, support the quantitative findings, which reflect learning from the entire lesson sequence (including work with interactive simulations, whole class introductions, and in some cases, whole class wrap-ups) and include findings from an additional two classes.

These qualitative findings compliment qualitative results from a different lesson sequence reported in Stephens, Vasu, & Clement (2010) that utilized a sophisticated, highly interactive simulation. In that study, discussion about a particularly difficult concept continued far longer in the whole class discussions than in the small group discussions.

General Discussion

The above results indicate that small group hands-on work may not be the only productive choice when using interactive simulations, especially when conceptual difficulties are likely to arise. We believe these results offer encouragement to teachers who do not have the resources to allow their classes regularly to engage in small group work at the computer. There appear to exist whole class teaching strategies for promoting at least some of the active thinking and exploration possible in hands-on work. These results promise to be of interest to anyone who incorporates interactive simulations in instruction: teachers, curriculum developers, designers of educational software. We believe these findings, though early, point to a need to further develop and refine our theories of instruction.

As in earlier years, some teachers expressed surprise when whole class lessons ran until the end of the allotted time. They reported tending to underestimate the time they would spend in whole class discussion, finding themselves deviating from the activity sheets more than expected because their responses to student questions frequently triggered more student questions, and these, though fascinating, could lead away from the current problem. Also, the teachers had expected the small group work to take longer than the whole class work, anticipating that groups would spend time exploring the simulations and animations in an open, "play" mode in addition to filling out the worksheet and this did not always happen. In spite of these challenges, total time allotted the task was approximately the same across conditions within each matched set, though how that time was utilized was somewhat different.

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.

I hypothesize that, for the classes who only saw the simulations projected from a single computer before the entire class, certain kinds of teaching strategies helped compensate for the lack of opportunity for hands-on exploration. These strategies, which have been documented in a much larger sample of transcripts that includes the transcripts analyzed here (Leibovitch, Stephens, Price, & Clement, 2011), include: pausing the simulation; having students predict what will happen next and write down their predictions; having the students turn to their neighbors and discuss their predictions before the simulation continues; inviting students to suggest what to do next with the simulation, and using various methods to support students in interpreting visual affordances of the simulations and animations.

Conclusion

Analysis of a large number of classes observed during the course of our project is ongoing. The results obtained so far appear to 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 experimental comparisons conducted so far, students in the whole class condition did not do significantly worse than those in the small group condition. Although the two Small Group discussion case studies examined in detail here varied in the amount of discussion of conceptual issues, they both seemed to have a narrow "get and report the data" mindset that may have inhibited discussion. In one of the groups, this was manifested by the students keeping close tabs on the time and finishing less than half way through the allotted time. In the other, conceptual questions were occasionally discouraged as distracting from the main task of finishing the activity sheet. The Whole Class case studies examined here indicate 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 there may be certain instructional situations where there is an advantage to spending at least part of the time with the simulation or animation in a whole class discussion mode, for instance, to provide consistent support activities for students' interpretation of the visual elements on the screen.

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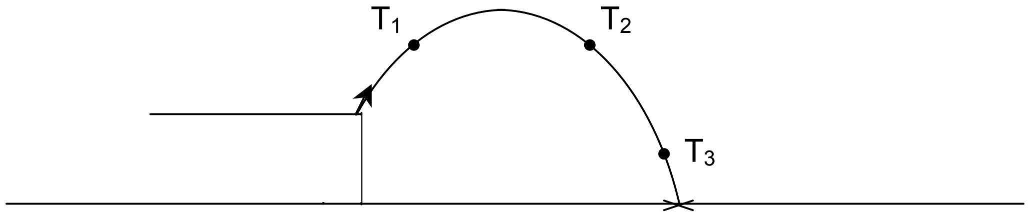
Projectiles Pre-Survey Name________________________ Date____________

The drawing shows the path of a baseball thrown upward at an angle from a cliff. T_1, T_2, T_3, refer to *time 1*, *time 2*, *time 3*, respectively, during the flight of the baseball. At T_1 the baseball is at the same height as it is at T_2. **IGNORE AIR RESISTANCE**.



For each question, circle the answer that agrees most closely with your thinking.

1. What do you think is happening to the vertical component of the velocity as the ball passes through each point T_1, T_2, T_3?

T_1: A) getting larger in upward dir. B) staying the same C) getting smaller in upward dir. D) other

T_2: A) getting larger in downward dir. B) staying the same C) getting smaller in downward dir. D) other

T_3: A) getting larger in downward dir. B) staying the same C) getting smaller in downward dir. D) other

2. What do you think is happening to the horizontal component of the velocity as it passes through each point T_1, T_2, T_3?

T_1: A) getting larger B) staying the same C) getting smaller D) other

T_2: A) getting larger B) staying the same C) getting smaller D) other

T_3: A) getting larger B) staying the same C) getting smaller D) other

3. For a given launch speed, what launch angle will give you the most total time in the air? (This is also called "hang time.")

A) 30^0 B) 45^0 C) 60^0 D) 90^0 E) Other

Briefly explain your reasoning.

4. For a given launch speed, what launch angle will give you the least total time in the air? (This is also called "hang time.")

    A) 30^0 B) 45^0 C) 60^0 D) 90^0 E) Other

    Briefly explain your reasoning.

5. a. For equal masses and speeds, can more than one launch angle give the same range?

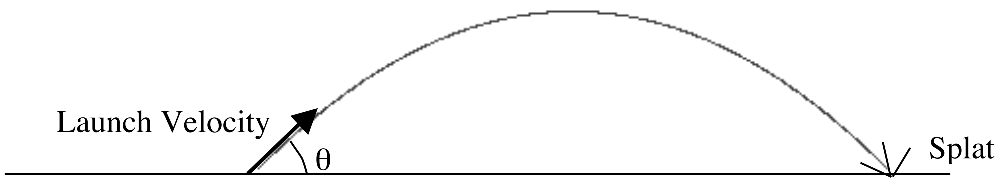
    YES NO

    b. If YES, what kinds of angles can give the same range? Why?
    If NO, why not?

Projectile Motion Predictions Name________________________ Date____________

Key Terms:
ALTITUDE: how high the projectile goes.
RANGE – how far the projectile goes.

A projectile is launched at an angle, θ, to the horizon and lands some distance away, as shown below. Ignore the effect of air resistance.



1. What do you predict will happen to the range if you increase the launch velocity without changing the launch angle or projectile's mass?
   1) The range will increase
   2) The range will decrease
   3) The range will stay the same
   4) Other (explain…)

   Briefly explain your reasoning:

2. What do you predict will happen to the range if you shoot a more massive projectile at the same launch angle with the same speed?
   1) The range will increase
   2) The range will decrease
   3) The range will stay the same
   4) Other (explain…)

Briefly explain your reasoning:

3. For a given launch speed, what launch angle do you predict will give you the largest maximum altitude?
Briefly explain your reasoning:

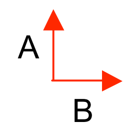
4. For a given launch speed, what launch angle do you predict will give you the longest range (horizontal distance)?
Briefly explain your reasoning:

Name: ______________________ Date:_______________

These three movies are each a simulation of the motion of a projectile. Within the movie, there are a series of strobed snapshots that have captured the position of the ball at equal time intervals. The movie playback has been slowed down enough that we can see the motion clearly.

In each movie, we have added some red markers to call your attention to some aspect of the motion.

Quicktime Simulation #1



1) What do the red arrows indicate about the velocity?

2 a) Which component of velocity does Arrow A give you information about?

b) Is this component of the velocity changing?

3 a) Which component of velocity does Arrow B give you information about?

b) Is this component of velocity changing?

4 a) Does this simulation show acceleration? If so, in what direction?

b) What, in this simulation, lets you know that?

Name: ______________________ Period: ____

Compare Simulations #2 and #3.

Quicktime Simulation #2

1) What does the variable spacing between the red and blue lines indicate about the velocity?

2 a) Which component of the velocity do these lines give you information about?

b) Is this component of the velocity changing?

Quicktime Simulation #3

3) What does the equal spacing between the red lines indicate about the velocity?

4 a) Which component of the velocity do these lines give you information about?

b) Is this component of the velocity changing?

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5 a) Does this simulation show acceleration? If so, in what direction?

b) What, in this simulation, lets you know that?
