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Use of a Computer Simulation to Assist Students in Learning Relative Motion Concepts

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INTRODUCTION

This paper reports case studies from clinical interviews which examined computer simulation use to assist high school physics students in learning relative motion concepts. A brief overview of relevant literature is followed by a description of the study, protocol from two subjects, and discussion.

Previous work, in classroom and interview settings, has indicated that many physics students have considerable difficulty in attaining basic relative motion concepts. Below are listed several authors who have addressed issues associated with relative motion learning.

Camp, Clement, Brown, Gonzalez, Kudukey, Minstrell, Schultz, Steinberg, Veneman, and Zeitsman (in press) indicate that problems which involve motion relative to the ground are easier to some students than problems which involve motion relative to a river. Motion relative to air is considered to be more difficult still. In their book, relative motion instruction is presented that follows the "bridging analogies" strategy. Ueno, et al. (1992) indicate that "'the static ground'" as a frame of reference is tacitly considered as natural." (p.3) Ueno, et al. proposed a "recontextualization" teaching strategy. Metz and Hammer (in press) explored students' problem assessment and response and response to computer simulation feedback in a recent paper. Hewson (1984) has shown positive treatment gains in conceptual understanding of a relative motion concept through subject use of software.

Saltiel and Malgrange (1980) indicate that a preferred frame of reference is implicit in day to day life observation of motion. They hypothesize that there exist spontaneous ways of reasoning (SWR) which are inconsistent with the reasoning of a physicist. The authors further posit the existence of a "natural model" which is in contradiction to a "kinematic model of the physicist".(p. 75) McCloskey (1983), in "The straight-down belief and its origin", investigated subjects' relative motion misconceptions concerning the path of a dropped ball. Bowden et. al. (1990) present a hierarchy of conceptual frameworks which students used to explain instances of relative motion. Aguirre and Erikson (1984) categorized students' responses and spoke about context dependent "inferred rules" applied by students when solving relative motion problems.

The purposes of the study described below were to a.) improve relative motion teaching techniques, b.) study helpful and detrimental modes of thinking that may occur in computer simulation use, c.) identify means to avoid pitfalls associated with computer simulation use.

METHOD

Method overview

Each of the subjects was interviewed during a single class period. Each subject was asked to "think aloud" as he or she solved pretest problems. The pretest was composed of seven content questions and seven "confidence ratings". The confidence ratings requested the subject's confidence in his or her answer to the accompanying content question.

Following the pretest, the subject viewed two computer simulations. The computer simulations were controlled by the interviewer and were presented as interactive demonstrations. During the course of the simulations, the simulation was suspended and the subject was asked to make predictions about what was about to be displayed on the computer. Following the subject's statements, the interviewer continued the simulation. After the subject had viewed this segment of the simulation he or she stated what he or she had seen.

Following the treatment, the subject gave a "think aloud" protocol as he or she solved posttest problems. The posttest and pretest were identical.

Subjects

Subjects were seven junior and sophomore high school students who had just completed a one-year, introductory, algebra based physics course .

All seven subjects were interviewed days before their final examination. During classroom instruction, according to their physics teacher, the students had been exposed to technical language for expressing relative velocities, i.e. , "with respect to" and "relative to" language. The teacher indicated that he had used several methods for describing the velocity of an object. Several students interviewed in this study seemed to prefer the more colloquial "point of view" or "perspective" language. Several students did not readily understand the wording of diagnostic questions which asked for velocity "relative to" another object.

Excerpts from transcripts of two students who engaged in a computer simulation treatment designed to ameliorate difficulties encountered with relative motion problems will be presented. The computer simulation was used in an interactive demonstration format in which a modified form of a predict-observe-explain cycle was used (See Metz and Hammer, in press). Students were asked to "think aloud" during the interview.

Pretest

The seven content questions as well as the accompanying questions concerning the student's confidence in his or her answer are listed in the appendix. Questions had been pilot tested and slightly modified following pilot testing.

Treatment

Two computer simulations were presented to the student as interactive demonstrations. The simulations were created using RelLab, by Bolt, Beranek and Newman (BBN), on an Apple Macintosh Powerbook 160 computer. The interviewer controlled each presentation. During the course of each demonstration, the interviewer asked the subject to predict what was about to occur. Following the prediction, the student viewed an important component of the simulation. After this was done, the student was asked what he or she had just seen.

The first simulation, titled "cars & plane", displayed the relative motion of three objects: a black car, a white car and a plane. The default reference frame was the ground. The interviewer ran the simulation once from the ground frame of reference During this time, the black car moved from the far right of the screen to the left, the white car moved from the far left of the screen to the right, and the airplane appeared from the left of the screen and traveled right.

The simulation was then reset and run until the computer stopwatch read approximately 3 seconds. At this point, the interviewer asked the subject to predict the direction and comparative speed of each of the cars when viewed from the airplane frame of reference.

Figure one below is a "snapshot" of the computer screen at the moment when the frame of reference has been changed to the airplane frame of reference.

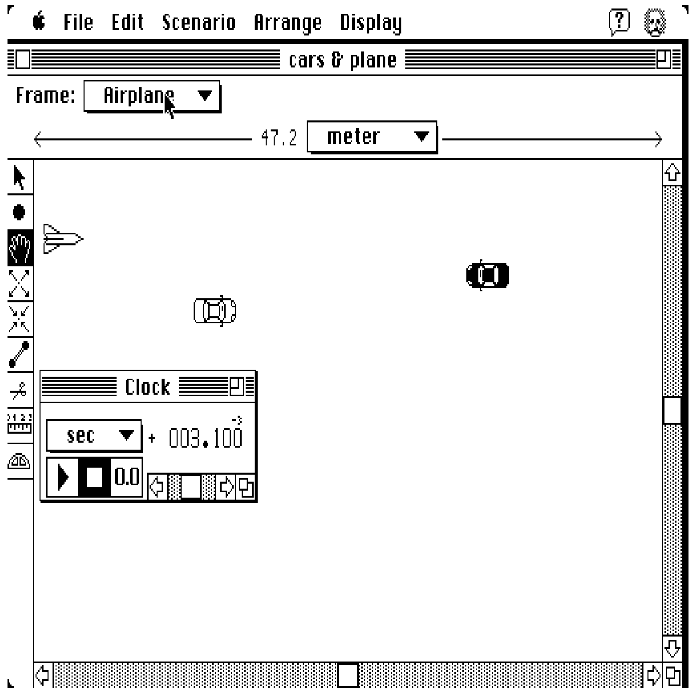

Figure 1

After the subject had viewed the demonstration, he or she narrated what he or she had viewed. If the subject did not spontaneously indicate what he or she had seen, the interviewer prompted the subject to state what had been seen. In some cases, additional probes were asked by the interviewer. These probes included "Is that what you expected?", "Can you explain what you saw?", "What did you see?".

Treatment design issues

The "cars and plane" simulation was designed with the following objectives:

- to assist students in visualizing scenarios involving vehicles approaching each other (when viewed from a particular frame of reference)
- to confront students with the dissimilarity of the appearance of events viewed from different frames of reference
- to assist students in visualizing what events look like from an unfamiliar frame of reference.

Posttest

The posttest was identical to the pretest.

CASE STUDIES

For purposes of anonymity, the two subjects described will be referred to as subjects GS8 and GS11.

Subject GS8

Pretest

Prior to use of the simulation, this subject displayed considerable difficulty with visualization of the physical features of question nine, (truck's speed with respect to the helicopter) as evidenced by the following protocol:

> S: OK, number nine, the white truck is traveling toward you, If the truck's speedometer reads forty miles per hour what is the truck's speed relative to the helicopter? OK, well the truck is now coming in the opposite directions as the helicopter, OK, so I would have to say that the helicopter is going 200 this way and the truck is going 40 this way. Let's see. (pause)
>
> I: What are you thinking.
>
> S: Um, I'm not quite sure because, I don't know, like when the helicopter gets over the truck, right underneath, the truck is right underneath, I'm really not sure what that would cause, like, how it would look.
>
> I: I see.
>
> S: In comparison to the helicopter and the truck.
>
> I: What part is difficult to um, imagine?
>
> S: Just, them coming in the opposite direction.
>
> I: I see.
>
> S: (pause)
>
> S: Well, I would have to say now the truck, the truck is coming toward the helicopter, it looks as if it is going faster, so I would have to just add them. And get 240 and I'm not very confident on this one.
>
> I: Why not?
>
> S: I'm just not quite sure of uh, just how to do this one. (Laugh)
>
> I: Any uh, like what you said before, that was the part that was difficult, like
>
> S: Yeah, like seeing the truck coming at the helicopter, I'm thinking that it would look faster and stuff, so then relative to it it is actually going faster, because they are coming at each other.
>
> I: OK, anything else you wanted to add on that one?
>
> S: Nope.

There is some evidence that suggests that the subject is attempting to visualize the problem yet is having great difficulty doing so. The statement, "Um, I'm not quite sure because, I don't know, like when the helicopter gets over the truck, Right underneath, the truck is right underneath, I'm really not sure what that would cause, like, how it would look" implies that he is truly trying to visualize the problem. In this section of the interview, he also uses hand gestures that appear to represent vehicles involved in the problem. The statement "it looks as if it is going faster", in combination with these non-verbal signs, suggests that the student is attempting to visualize the problem.

Treatment Phase

During the treatment phase, consistent with the predictions of several subjects, this subject incorrectly predicts the direction of motion of the white car (the car whose direction of motion is different depending on whether the motion is viewed from the ground or airplane frame of reference). The student accurately predicts which vehicle (the black car or the white car) would look to be going faster on the computer screen when the simulation was run from the airplane frame of reference.

S: OK. Hum, I think that-- then the cars will look like -- I think, let's see, the black car will still look like it's going faster, because it is moving towards you.
I: OK. What direction will the black car be moving on the screen?
S: It will be moving to the WEST.
I: And how about the white car?
S: To the EAST...
I: To the right?
S: Yeah.

After viewing the simulation, the student acknowledges the accuracy of his speed prediction and the inaccuracy of his direction prediction, when the motion was viewed from the airplane frame of reference:

I: OK. All right. I'm going to change it to the airplane frame of reference.
S: OK.
I: OK. So we did that in about three seconds into the simulation here and now I'll start it.
S: OK.
I: and what I'd like you to do after we do it, is explain what happened. OK?

S: OK.

I: All right. Here we go. (simulation is run for approximately three seconds) OK. what did you see?

S: OK, I saw the black car moving faster than the white car and the white car was moving backwards as if the plane was going past it. And the black car is moved faster as if the plane was going towards it.

I: Is that what you had expected to see?

S: Yes. I did. I didn't, I didn't expect, uh, the white car to be going backwards.

I: OK.

S: but I did expect them to-- the black car to be going faster than the white car.

Posttest

Subsequent to use of the computer simulation, subject GS8 seems to have incorporated a memory of the simulation as a framework for visualization of a target problem done without the simulation:

S: Hm, number nine: (reads question) The white truck is traveling towards you. If the truck's speedometer reads 40 mph, what is the truck's speed relative to the helicopter? OK, in my mind I'm seeing the truck as if it were a black car on the screen, on the computer, and again the helicopter as if it were the plane, and uh, I'm just-- I noticed that the black car was going very fast towards the plane when it remained stationary, so I'd have to say 240 mph for this, and 'D': I'm sure I'm right.

I: OK.

S: Because of-- because of the comparison-- it looked to be going very fast towards the uh, the plane.

I: OK. You changed your confidence to you're sure you are right.

S: Yeah.

I: Why is that?

S: Because a simulation helped me out in seeing that it was going faster than what it looked to be going faster than what it actually was because the helicopter is moving towards it.

I: OK. Can you say more about that?

S: No, just that the helicopter was going 200, and the truck was going 40, and, uh, just if you put the helicopter stationary like the plane was - the truck will look to be going faster than it actually was.

It should be noted that the student is still not using terminology that is consistent with that of the physicist. Use of words such as "the truck will look to be going faster than it actually was." suggests that the student may still strongly prefer the ground frame of reference. Statements such as the latter one are consistent with findings by Saltiel and Malgrange (1983) about students' statements concerning "proper velocity".

Also, in answering posttest question five, the subject displays improved confidence and states: "I'm sure that I'm right, because in the simulation I noticed that the white car looked to be going slower when the plane was going by it, so I compared my car to the white car, and the plane to the helicopter, so, that's how I got my answer." Furthermore the subject states, "I saw -- I saw in my mind, uh, the gray car as if it were the white car, I saw a helicopter as if it were the plane, and, uh, it looked it looked as if, like it was going.--the-- my car looked as if it was going very slow backwards-or uh, very fast backwards, and making no progress forwards."

As displayed by the protocol, the student increases his confidence in his answer. The student indicates that in solving problems he is referring to experience gained while viewing the computer simulation. Thus it appears that the student is able to map visual features of the simulation onto target problems.

<u>Subject GS11</u>

Pretest

Subject GS11 displayed correct reasoning in answering pretest question three.

Treatment Phase

During the treatment phase, the subject incorrectly predicted the direction of movement of the white car when viewed from the airplane frame of reference

Posttest

Following use of the simulation, he inaccurately changes his answers to questions one and three. Below, he describes how he reached his answer to posttest problem three:

> S: (Reads question three) ... you could throw it softer. I'm starting to see this now, I think. And, uh,-- I'll say 'D' - I'm sure, I'm right. [answer is incorrect] Uh -- , I think this because --I'm in one spot throwing it , right. (hand gestures) And uh, and uh I'm moving from that spot, and the chair behind me is going to be - is going towards me, and it is going to be at that spot pretty soon, so I wouldn't, like, I can just like lob it and all

of a sudden the chair will run in to it, because it is going into the snowball, that 's why I thought that. And also I see from watching the computer how you can get that -- just you gotta think it out...

I: OK. Uh, and which, which, uh, simulation or both are you thinking about?

S: Um, I'm thinking of the - the plane.

This student, as displayed above, has regressed in his ability to answer question three. It is worth noting that he was "sure that he was right" in his correct answer to this question on the pretest. Following use of the simulation, his self-report indicates that he is similarly confident in his posttest answer. However, his answer is erroneous. At the end of this section of the protocol, it is worth noting that the student indicates that use of the "cars and plane" simulation affected his answer.

In fact, there was another simulation (not described in this paper) presented to all subjects, including GS11, that was much more appropriate for guiding the solution to question three (one of the two ski-lift problems). Thus, from an expert's point of view, the subject referred to the wrong simulation.

(note: the interviewer's statement before the posttest that he wished to see if using the simulations affected his answers may have prompted the subject to refer to the simulations when providing an explanation for his answers. See Holyoak, 1991)

CONCLUSION

It appears that subject GS8 was better able to visualize problems following use of the computer simulation. This indicates that it is possible for some students to use their memory of the simulation as a framework for visualization of target problems. Additional data suggests that GS8 successfully used the computer simulation to test the accuracy of his thinking. However, protocol from GS11 indicates that our manner of using this computer simulation is certainly not a panacea for alleviating difficulties that students may have in approaching relative motion problems. Indeed, students may actually regress following the use of a computer simulation.

In addition to the aforementioned issues associated with how students use computer simulations, we are currently examining data from other students which address the following questions:

- Could the dissonance caused by a simulation that conflicts with students' expectations be used as a vehicle for conceptual change?
- Do some students attend to a simulation in an fashion unintended by the instructor?
- Do students fail to seriously question the reliability of a computer simulation?
- How can a student's misinterpretation of the meaning of a computer simulation falsely inform the student?

Continuing work is being done to identify and describe additional factors that determine how computer simulations are used by students which affect, positively and negatively, students' ability to solve and to visualize physics problems. Whether experience with a computer simulation can enhance later mental simulation in the absence of the computer is a critical question. The goal of this work is the design of improved pedagogical strategies for using computer simulations.

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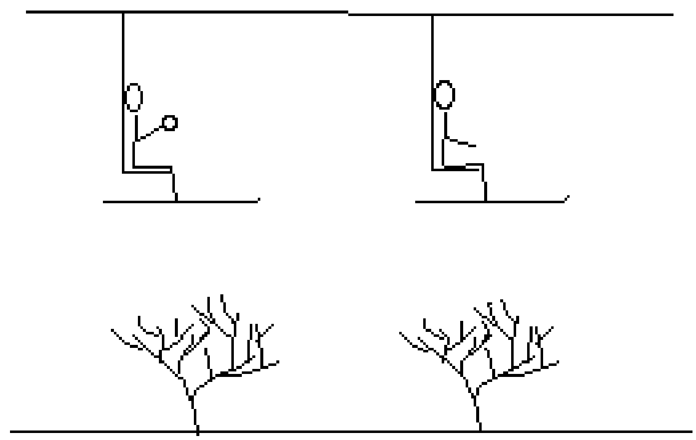
APPENDIX

Pretest/Posttest Questions

Number 1 features the ski-lift shown below:



Assume that if the ski-lift were turned off, you could throw a snowball and hit the person in the chair ahead of you.. Also assume that the ski-lift is over a flat part of the mountain.

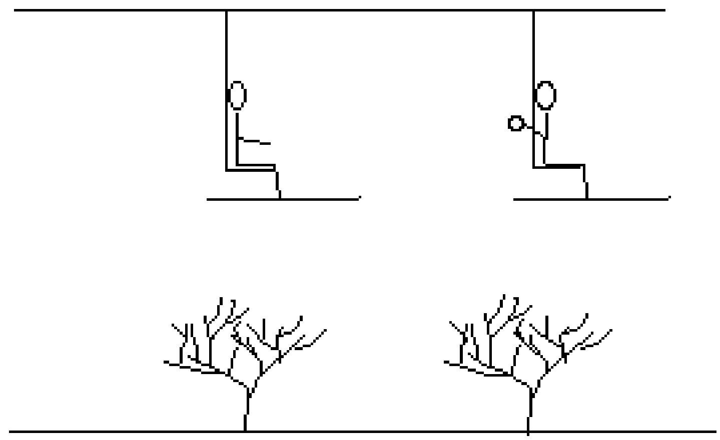
1. How hard would you have to throw the snowball from one chair on a ski-lift to another chair ahead of you on the ski-lift when the ski-lift is in operation

a.) About the same as if the ski-lift were turned off
b.) harder than if the ski-lift were turned off
c.) softer than if the ski-lift were turned off
d.) it's impossible to hit the chair that is ahead of you when the ski-lift is in operation.

2. What is your confidence in your answer?

a.) Just a blind guess
b.) Not very confident
c.) Fairly confident
d.) I'm sure I'm right

Number 3 features the ski-lift shown below:



Assume that if the ski-lift were turned off, you could throw a snowball and hit the person in the chair behind you. Also assume that the ski-lift is over a flat part of the mountain.

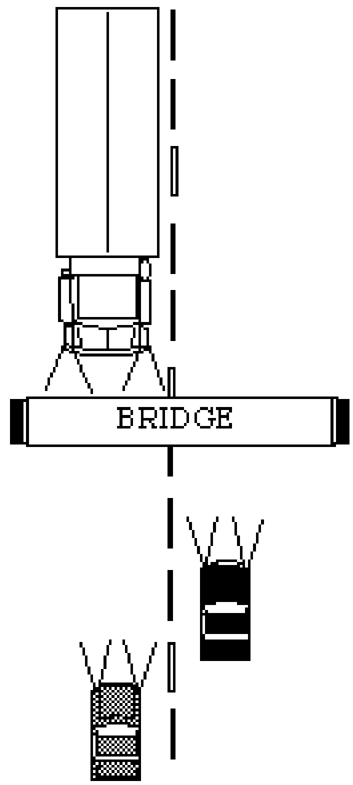
3. How hard would you have to throw the snowball from one chair on a ski-lift to another chair behind you on the ski-lift when the ski-lift is in operation?

a.) About the same as if the ski-lift were turned off
b.) harder than if the ski-lift were turned off
c.) softer than if the ski-lift were turned off
d.) it's impossible to hit the chair that is behind you when the ski-lift is in operation.

4. What is your confidence in your answer?

a.) Just a blind guess
b.) Not very confident
c.) Fairly confident
d.) I'm sure I'm right

Numbers 5-10 refer to the picture below:



In the picture above, you are in the gray car. Your speedometer reads 40 mph.

5. What is your car's speed relative to a very low flying helicopter going exactly the same direction as your car, at a speed relative to the ground of 200 mph?

6. What is your confidence in your answer?

a.) Just a blind guess

b.) Not very confident

c.) Fairly confident

d.) I'm sure I'm right

7. The black car is traveling in the same direction as you are traveling. If the black car's speedometer reads 35 mph, what is the black car's speed relative to the helicopter?

8. What is your confidence in your answer?

a.) Just a blind guess

b.) Not very confident

c.) Fairly confident

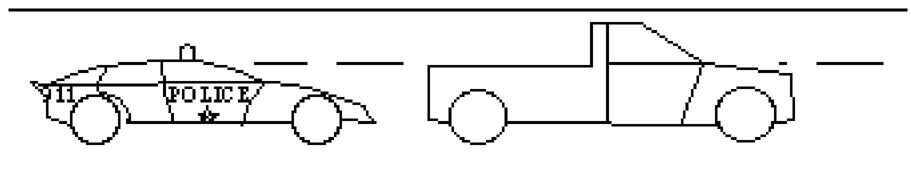
d.) I'm sure I'm right

9. The white truck is traveling toward you. If the truck's speedometer reads 40 mph, what is the truck's speed relative to the helicopter?

10. What is your confidence in your answer?

a.) Just a blind guess
b.) Not very confident
c.) Fairly confident
d.) I'm sure I'm right

For number 11, a police car is following a pickup truck. Both vehicles have had their speedometers checked and they are working fine.

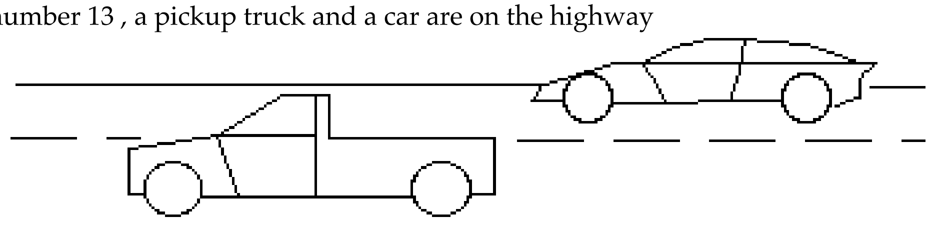


11. If the police car's speedometer reads 75 mph, and the truck's speedometer reads 70 mph, how fast is the truck going relative to the police car?

12. What is your confidence in your answer?

a.) Just a blind guess
b.) Not very confident
c.) Fairly confident
d.) I'm sure I'm right

For number 13 , a pickup truck and a car are on the highway



13. In the picture above, if the truck's speedometer is reading 60 mph and the car's speedometer is reading 55 mph, how fast is the car going relative to the truck?

14.. What is your confidence in your answer?

a.) Just a blind guess

b.) Not very confident

c.) Fairly confident

d.) I'm sure I'm right