

Observing students' use of computer-based tools during collision experiments

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Introduction and background

Studies have shown that introductory physics students have difficulty understanding why and when to use energy and momentum concepts, and especially the conservation laws, to study a phenomenon.^{1,2,3} For example, students generally do not understand why they do not necessarily need to analyze the interaction occurring during collisions but can simply apply conservation principles to the initial and final states of an interacting system.¹ Students also often have trouble deciding when and how to use energy concepts or momentum concepts to analyze a process.² According to Ref. 1, the typical perspective of a student studying collisions emphasizes cause and effect (one object transmitting something to another) and time development (the need to describe what happens during a collision as well as before and after).

Instructional approaches such as microcomputer-based laboratories (MBL) and digital video analysis (video-based labs, or VBL) have great potential to contribute to the development of deeper understanding and conceptual change in science.^{4,5,6} The real-time data collection frees students to think about their experiments,⁷ and the level of information offered by the technology has been found to affect students' understanding of the concepts.⁸ Motion sensors used with MBL provide the possibility of displaying graphs of motion concurrently with the observed phenomenon, a feature which may be

important for learning.⁹ With VBL, graphs are also produced, but with a time delay; on the other hand, the video can be replayed at will and can be viewed frame-by-frame and compared with points on the graph.¹⁰

Because MBL and VBL can provide students with a complete time history of collisions and allow students to look at many different examples of collisions with relatively quick graphical feedback, they hold promise for teaching and learning about energy and momentum in the context of collisions. In particular, these two technologies allow students to examine and explore collision phenomena in a way different from traditional laboratory methods such as photogates. We are investigating the effects of using these different technologies in an undergraduate physics laboratory. We report here some preliminary results from analysis of students' use of MBL, VBL, and photogate tools in a collision experiment in an introductory physics class.

The study

We developed a setup using two carts on an air track or low-friction track, with the capability of having the carts undergo a perfectly inelastic collision and then bouncing elastically off the end of the track. This setup is appropriate for MBL, VBL, or photogate data collection.^{11,12} With MBL and VBL, students can obtain graphs of position, velocity, momentum, and kinetic energy vs. time for the individual carts and also total

momentum and kinetic energy for the system consisting of the two carts.

We have used this setup in three semesters (fall 1999, spring 2000, fall 2000) of an introductory physics course for science majors at Wittenberg University. Approximately thirty students participated in each semester. Because of equipment limitations, the fall 1999 study was significantly different from that in the other two semesters, and will not be discussed here.

Each lab section was scheduled for 90 minutes. Students were allowed to choose their own lab teams of two to three persons. In the second week of the term, lab teams were assigned to the photogate, MBL, or VBL treatment groups. No specific criteria were used in making this assignment except to make the total number of students and the number of men and women in each group roughly the same. Each of the three treatment groups consisted of four lab teams. Midterm exam scores showed no significant differences among these treatment groups.

Students did several labs throughout the semester with their assigned tools, and in the tenth week worked on a one-dimensional collision lab using their assigned tools. For this collision lab, students were asked to conduct several different types of collisions, then to make predictions of the graphs for a different type of collision, and finally carry out the experiment to test their predictions. All the procedures and the questions asked were similar, regardless of the tools used. All teams in this study were videotaped and audiotaped during their lab activities, and their lab reports were collected.

Transcripts of the videotapes and audiotapes were analyzed using two different sets of categories. The

statements students made were coded and analyzed by frequency counting. Students' work events with the computer and other partners were also coded and analyzed by time length. Coding categories were derived from the transcripts and the researcher's field notes documenting observations and interactions occurring in lab. Coding was checked by another researcher; intercoder agreement was 85-90%.

Results and discussion

The time analysis allowed us to evaluate the usage of the tools and students' interaction with the computer. Figure 1 shows the time distribution of the tasks students worked on in the lab in fall 2000. The times shown are averages for all teams in a group. The data for spring 2000 are similar, with the most notable difference being that in spring 2000 all groups spent somewhat more time in prediction and less in discussion than in fall 2000. The data show that it took less time for the MBL teams to conduct one collision experiment than the other groups, and they spent more time talking about the graphs, interacting with the tools, and predicting the graphs. There were fewer interactions among VBL team members than in the MBL teams due in part to the complexity of the VBL software and the time-consuming nature of the tasks related to the VBL technology. There was not much discussion within the

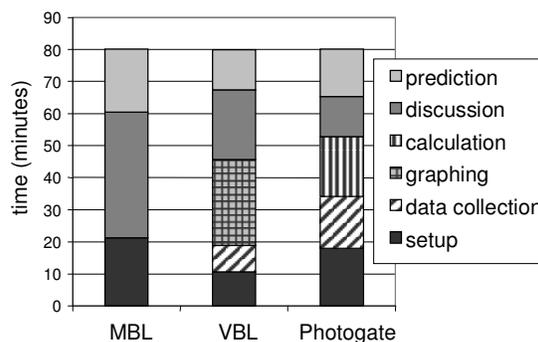


Fig. 1: Time spent on various parts of lab (Fall 2000)

photogate teams during the lab period. In particular, the photogate teams spent less time discussing their results.

In both semesters, the VBL group used less time than other groups in setting up the experiment, mainly because the MBL and photogate groups usually had more problems in adjusting the motion sensors or photogates. The feature of the VBL software allowing the motion to be repeatedly reviewed and compared frame-by-frame with the graphs was rarely used by the students unless they found something wrong in their graphs.

Results from analyzing students' statements in the fall of 2000 are shown in Figure 2. The results for the spring 2000 semester were similar, except that both the MBL and photogate groups made only about half as many conceptual statements in spring 2000 as they did in fall 2000. In both semesters, the MBL and VBL students made more statements in conceptual analysis than the photogate group, probably because the graphs from these two tools provided more information for them to talk about and refer to. VBL students made more statements about the procedure, probably because the software tasks they were required to perform were more complicated.

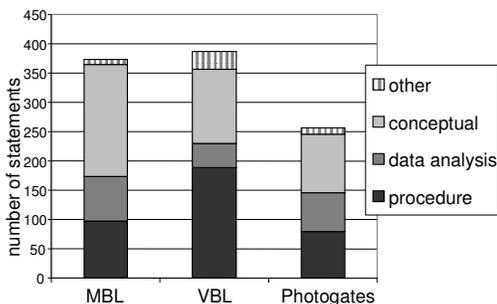


Fig.2: Statements made during lab (Fall 2000)

In the spring 2000 semester, students had not had much practice reading graphs, and so were confused at

first about how to interpret the information in the graphs, particularly in the MBL group. The VBL students could more easily interpret the graphs and identify when the collision occurred because they had edited the video so it ran from just before to just after the collision. In the fall 2000 semester, students had previously performed many RealTime Physics labs with an emphasis on interpreting graphs, and so had less difficulty interpreting the graphs in the collision lab. In both semesters, the photogate group had some trouble identifying which velocities belonged to which cart before and after the collision.

Students' statements in lab and their lab reports showed that the students using MBL and VBL could easily see and describe from the graphs whether momentum and kinetic energy were conserved. The connection between conservation of a quantity and a straight horizontal line on the graph was easy to make for all of the MBL and VBL groups. However, results from the photogate group did not usually agree with the theoretical expectations due in part to poor data collection and incorrect calculations. The spring 2000 semester's results are typical: only one of four photogate teams stated conclusions about momentum and energy conservation that corresponded to their data. In contrast, six of eight MBL and VBL teams drew appropriate conclusions from their data.

Students in the MBL and VBL groups seemed to grasp the idea of momentum transfer. Referring to their graphs, they described what had happened during the process of the collision and how the momentum and kinetic energy transferred from one cart to the other. An explanation of the results in terms of exchange or transfer of something arose spontaneously in several cases. Phrases such as "the carts

kind of trade places,” or “the elastic collision resulted in an exchange of kinetic energy and momentum,” were common in their conversations and lab reports.

Students' statements indicated that they had difficulty with various concepts related to momentum and energy. Many students had trouble understanding the concept of momentum as a vector; for example, carts that moved in the opposite direction with the same speed were said to have the same velocity and momentum. A majority of students thought that when two objects were stuck together and moved together, they become one mass and would have the same kinetic energy and momentum. Student statements during lab or in lab reports rarely showed an adequate understanding of the concept of a system.

Conclusion

Compared to the traditional technology of photogates, the MBL and VBL tools provide more information about energy and momentum in collisions. Our results indicate that students are able to make good use of this information in the lab, and that they respond to this added information by spending more time in lab talking about concepts. Our data also show some of the difficulties students had in learning the concepts of conservation of momentum and energy.

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