Improving College Students Understanding of Time-Varying Velocity during Elastic Collision Using Microcomputer-Based Laboratory

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Introduction

Prior to the instruction of introductory college physics, many students have a set of protoconcepts for interpreting motion in the real world. In observing a large number of college students taking introductory physics, Clement (1982) explained that Newtonian ideas are more likely misperceived or distorted by students so as to fit their existing preconceptions; or they may be memorized separately as formulas with little or no connection to fundamental qualitative concepts. Halloun and Hestenes (1985) also explained that a system of beliefs and intuitions about physical phenomena are possessed by each college student entering a first course in physics and the system is derived from extensive personal experience. This system functions as a common sense theory of the physical world which the student used to interpret what he uses and hears in the physics course.

Understanding of the time-varying velocity that acts between two objects in the collision is the ability to apply them successfully in learning and interpreting linear momentum-impulse theory of introductory physics. In the collision lab, college students will investigate elastic and inelastic collisions between two carts on a frictionless track. Before the collision, cart 1 travels towards the right or left and cart 2 also travels towards the right or left. As the carts are in elastic collision, they bounce off each other during the collision, and they may change their velocities and even reverse their directions. Then, students will be asked to determine the velocities (magnitude and direction) of the carts before and after collision, and construct a graph about the two carts velocities on a worksheet. However, incorrect breaking graphs and zigzag graphs during the collision were presented on students' worksheets, because graphed line about the carts velocity should be smooth and continuous in the process of collision. Some students' making-graphs appear in Figure 1.

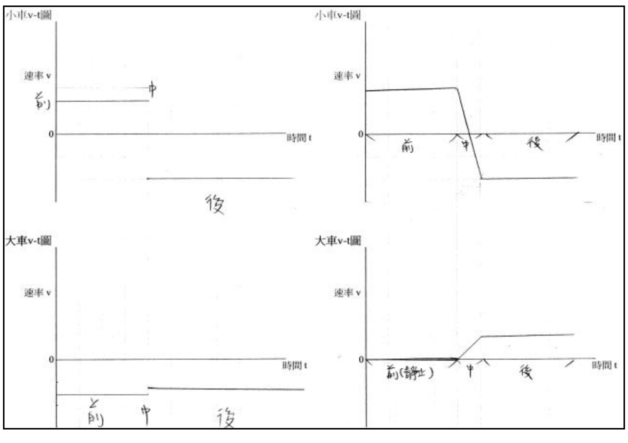

Figure 1. Breaking graph and zigzag graph presented on students' worksheets.

In fact, certain conceptual difficulties occur frequently and predictably among introductory physics in college. Student understanding of physics concepts has been subject to descriptive analysis (Trowbridge & McDermott, 1980). Physics instructors generally share a common interpretation of the kinematical concepts based on operational definitions and precise verbal and mathematical articulation. On the other hand, students are likely to have a wide variety of somewhat vague and undifferentiated ideas about motion based on intuition, experience, and their perception of previous instruction. Thus students often have insufficient qualitative understanding of position, velocity, and acceleration (Trowbridge & McDermott, 1981). Frequently, many students taking introductory physics cannot apply what they have learned about graphs from their study of mathematics to physics. The difficulties experienced by students in connecting graphs to physical concepts include the indecision as to whether to put the desired information in a graph.

Nowadays, microcomputer-based laboratory (MBL) has become an essential tool in physical inquiry experiments. An MBL is that the microcomputer, in combination with appropriate sensors, measures and displays data and graph as the event is occurring. And, MBL provides genuine scientific experiences, accesses data over very short time intervals, has the power to process and display data rapidly, and eliminates the drudgery of graph production (Kelly & Crawford, 1996; Rogers, 1995; Mokros & Tinker, 1987). Therefore, there is a need to examine the effect of an extensive use of MBL on students' critical evaluation skills about time-varying velocity graphs to improve their understanding about linear momentum-Impulse theory of introductory physics.

Research Design

Based on the content of Fundamental of Physics (Halliday, Resnick, and Walker, 2010), two physics experiments of elastic collision were developed on using MBL (MBL Group) or photo gates (Photogate Group) as experimental tools. The MBL Group uses the microcomputer, in combination with two motion sensors and a GLX interface, to measure and display velocities and velocity-time graphs as the carts are running on a frictionless track. The Photogate Group uses photo gates to measure velocities of the carts as they goes through the gates on the same frictionless track. The main concepts of the experiments are velocities of collision carts before, during and after each collision. Also, a physics elastic collision test is a paper-and-pencil test designed to ask students to graph time-varying velocities before, during and after each carts collision and write down the reason of making the graph accordingly before and after different experiments are implemented. The physics elastic collision test was administered before and after the experiments done in the physics laboratory.

Subjects were 48 college students studying fundamental physics in a university in Taipei, Taiwan. In MBL Group, 24 students investigated elastic collision in one dimension used MBL, real-time graphing, in their experiment. In Photogate Group, 24 students investigated the same collision used photo gates as measuring instruments, no real-time graphing, in their experiment. Students were assigned randomly to groups. Four students in Photogate Group did not take pretest, and only 20 students were counted in the Group. The same physics professor taught all groups and the curriculum was identical.

Results

In the study, we examined students' making graphs and the reasons they provided to explain the graphs before and after different experiments implemented. The chi-square test of groups by correct and incorrect making graphs in the pretest yields no significance (Pearson χ^2=.19, DF=1, p=.662). That is, almost all students in the two groups used incorrect ideas in their making graphs about the time-varying velocity during carts collision before them doing experiment.

On the posttest, it is interesting that half of MBL group made the correct time-varying velocity graphs about during collision. Table I summarizes student frequencies of making correct or incorrect time-varying velocity graphs in the pretest and the posttest. A significant difference was found between two groups by correct and incorrect making graphs in the pretest and posttest from the G-square test (L. R. χ^2=20.528, K=2, DF=4, p=.0004) and summarized in Table II. The Chi-square test in Table II indicates that MBL Group on the posttest is more effective in learning time-varying velocity during carts collision than the

Photogate Group.

Table I Student frequencies of making correct or incorrect time-varying velocity graphs

		Pretest	Posttest
Digital Group (n=24)	Correct making graph	2	12
	Incorrect making graph	22	12
Photogate Group (n=20)	Correct making graph	1	1
	Incorrect making graph	19	19

Table II Summarized G-square test between two groups by correct and incorrect making graphs in the pretest and the posttest

	K	DF	L. R. Chisq	Prob
Group*Graph*Test	2	4	20.53	.0004
Group*Test		1	.88	.349
Group*Graph		1	10.49	.001**
Test*Graph		1	9.01	.003**

Conclusion and Suggestion

Experiment through MBL appeared to be a useful vehicle for understanding time-varying velocity during objects collision. Students of making correct graphs in the two groups indicated that MBL real-time graphing accounted for 50% of the improvement within the MBL group relative to the Photogate group. Those students of correct making graphs gave the explanation for the MBL experiment: “I know what is real relation between velocity and time during carts collision”, “I can draw the graphs coming from the computer screen”, and “It is really accurate to show the situation during carts collision”. Therefore, doing experiment through MBL reinforces learning modalities. The physical experience is improved with the visual experience of seeing the time-varying velocity change. Physical experiments results through MBL appear instantly on the graph, it indicates that learning through MBL provides a real-time link between a concrete physical experience and the graphic representation of that experience. It may be appropriate to use MBL in the physics teaching and experiments in order to improve students’ physics understanding of introductory physics.

Bibliography

Clement, J. (1982). Students’ preconceptions in introductory mechanics. American Journal of Physics, 50(11), 66-71.

Halloun, I. A., & Hestenes, D. (1985). The initial knowledge state of college physics students. American Journal of Physics, 53(11), 1043-1048.

Kelly, G. J., & Crawford, T. (1996). Students’ interaction with computer representations: Analysis of discourse in laboratory groups. Journal of Research in Science Teaching, 33, 693-707.

Mokros, J. R., & Tinker, R. T. (1987). The impact of microcomputer-based labs on children’s ability to interpret graphs. Journal of Research in Science Teaching, 24(4), 369-383.

Rogers, L. T. (1995). The computer as an aid for exploring graphs. School Science Review, 76, 31-39.

Trowbridge, D. E., & McDermott, L. C. (1980). Investigation of student understanding of the concept of velocity in one dimension. American Journal of Physics, 48(12), 1020-1028.

Trowbridge, D. E., & McDermott, L. C. (1980). Investigation of student understanding of the concept of acceleration in one dimension. American Journal of Physics, 49(3), 242-253.