George, E.A., Broadstock, M.J., Vazquez Abad, J. (2000). Learning Energy, Momentum, and Conservation Concepts with Computer Support in an Undergraduate Physics Laboratory. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth International Conference of the Learning Sciences* (pp. 2-3). Mahwah, NJ: Erlbaum.

Learning Energy, Momentum, and Conservation Concepts with Computer Support in an Undergraduate Physics Laboratory

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Abstract: The long-term goal of this project is to explore undergraduate students' learning of physics using two instructional technologies, microcomputer-based laboratories and digital video analysis of experimental data. This presentation will focus on the results from a class of introductory undergraduate physics students, regarding their learning of concepts related to collisions and conservation principles, and students' use of the technologies.

Keywords: science education, higher education, pedagogy

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 (Grimellini-Tomasini, Pecori-Balandi, Pacca, & Villani, 1993; Lawson & McDermott, 1987). This represents a significant barrier to learning, because energy and momentum are fundamental concepts in physics, necessary for understanding a variety of phenomena of importance. In addition, the application of conservation laws to solving problems and gaining deeper understanding is also a fundamental part of learning and doing physics. As an example of student difficulties with energy and momentum concepts, students generally do not understand why they do not usually need to analyze the interaction occurring during collisions (Grimellini-Tomasini et al., 1993) but can simply apply conservation principles to the initial and final states of an interacting system. Students also often have trouble deciding when and how to use energy conservation and when and how to use momentum conservation to analyze a process. Simply conducting laboratories need not contribute to students' understanding: indeed, in traditional laboratories students are not given the conditions to inquire sufficiently into phenomena such as collisions that involve mechanical energy and momentum.

Technology-based instructional approaches, such as microcomputer-based laboratories (MBL) and digital video analysis of experimental data (DVA), have great potential to contribute to the development of deeper understanding and conceptual change in science (Beichner, 1996; Tinker & Papert, 1989). Motion sensors used with MBL provide the possibility of displaying graphs of motion concurrently with the observed phenomenon, in addition to storing the data for further analysis (Brassell, 1987; Thornton & Sokoloff, 1990; Trumper, 1997). Although rooted in older applications of videodisks and videotape, the DVA approach considered here is a recent development consisting of capturing and digitizing the image of a phenomenon studied in an experiment, marking points on the digitized movie frames, and using software to analyze the data (Brungardt & Zollman, 1995; Escalada & Zollman, 1997). Both approaches are similar, but offer a complementary potential for learning that justifies the interest in exploring the contributions of both.

These technologies could allow for an examination of interactions and collisions that is more direct and obvious than with traditional laboratory methods. While a "physics view" of such phenomena often calls for implicitly ignoring the specific details of a collision, as mentioned above, it is however a reality underlined by research that students' naive view focuses on this event and questions the validity of approaches ignoring it. By being able to examine the event in detail, and by being able to look at many different examples in order to find regularities in phenomena, students have the opportunity to see explicitly and to come to accept the sufficiency and the efficiency, for conceptual understanding and for problem-solving, of the "physics view."

Because traditional experimental setups for investigating conservation principles are not suitable for the technologies we are using, we have developed an apparatus or setup appropriate for both MBL and DVA in the specific context of an undergraduate learning laboratory on collisions (George, Broadstock, Conway, & Vázquez-Abad, 2000). This setup allows students to graphically display position, velocity, momentum, and kinetic energy for each of two air track gliders, as well as the total momentum and kinetic energy for the system of two gliders.

Students are thus able to examine a time history of these quantities throughout a whole collision process. With MBL, the graphs are displayed in real time, whereas with DVA, the graphs are delayed, but can be synchronized with a replay of the video. Students are asked to carry out several different types of collisions on the air track and interpret the resulting graphs in terms of the conservation laws. Students then make predictions of the graphs for a more complicated collision, carry out the experiment, and compare their predictions with the experimental results.

In order to study real-setting effects and contributions, we are interested in using instructional interventions that can be seen by the students as a legitimate part of the course. We have first used this setup at Wittenberg University during the fall 1999 semester in an introductory physics course primarily for science majors. Very few of the 40 students enrolled had had previous experience with the technologies; some had not taken physics courses before. After a training session with both technologies at the beginning of the term, lab groups consisting of pairs of students were assigned to MBL or DVA groups by their preference for the technologies. Because of equipment constraints, for the collision lab, only four groups were assigned to use MBL and four groups to use DVA, and the rest of the groups used traditional photogate setups. All of these activities were integrated into the course.

All groups using MBL and DVA were video and audio taped during the laboratory session. After the collision lab, students who used these two tools were interviewed using paper-and-pencil tasks, much in the style of McDermott & Schaffer et al. (1998). The rest of the students completed a questionnaire with similar questions. Collected data included video and audio tapes in the labs, lab observation notes, students' lab books, interview tapes, and questionnaires.

Preliminary results from analyzing video and audio tapes of the lab activities show that there are differences in time of using these tools to conduct an experiment, and differences in students' discussion time and their interaction while using these tools. Students' lab books and interviews showed that most students using MBL and DVA technologies can easily describe what happens to momentum and energy during different collision processes. They also indicated student difficulties in understanding the concepts of conservation of momentum and energy, especially in identifying the "system" to which the conservation laws pertain, the meaning of negative momentum, and the nature of energy transformations during collisions.

References

Beichner, R. J. (1996). The impact of video motion analysis on kinematics graph interpretation skills, *American Journal of Physics, 64,* 1272-1278.

Brassell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *J. of Research in Science Teaching 24*(4), 385-395.

Brungardt, J.B., & Zollman, D. (1995). Influence of interactive videodisc using simultaneous-time analysis on kinematics graphing skills of high school students. *J. of Research in Science Teaching 32*(8), 855-869.

Escalada, L.T. & Zollman, D.A. (1997). An investigation on the effects of using interactive digital video in a physics classroom on students learning and attitudes. *J. of Research in Science Teaching, 34*(5), 467-489.

George, E.A., Broadstock, M.J, Conway, T., & Vázquez-Abad, J. (2000). Learning momentum and energy conservation with motion detectors and video. AAPT Winter Meeting 2000, Kissimmee, FL.

Grimellini-Tomasini, N., Pecori-Balandi, B., Pacca, J.L.A., & Villani, A. (1993). Understanding Conservation Laws in Mechanics: Students' Conceptual Change in Learning about Collisions. *Science Education 77*(2), 169-189.

Lawson, R.A., & McDermott, L.C. (1987). Student Understanding of the work-energy and impulse-momentum theorems. *American Journal of Physics 55*(9), 811-817.

McDermott, L.C., Shaffer, P.S. and the Physics Education Group (1998). *Tutorials in Introductory Physics.* Upper Saddle River, N.J.: Prentice Hall.

Trumper, R. (1997). Learning kinematics with V-Scope: a case study. *J. of Computers in Mathematics and Science Teaching, 16*(1), 91-110.

Thornton, R. & Sokoloff, D. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics 58*(9), 858-867.

Tinker, R. & Papert, S. (1989). Tools for Science Education, in Ellis, J. (Ed.) *Information Technology & Science Education*. Columbus, OH, AETS.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. REC-9804922.