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COMPARISON OF CONVENTIONAL AND HIGH-TECHNOLOGY EXPERIMENTS ON GRAPHS

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ABSTRACT: In an in-service upgrading course for physical science teachers, both a conventional and a high-technology experiment were performed to obtain position-time and velocity-time graphs of the movement of a trolley. Graphs were drawn by hand in the conventional ticker-timer and tape experiment. In the high technology experiment a motion-detector connected to a computer sensed the movement of the trolley and graphs were displayed instantly by means of a LCD projector. The investigation compared students' gains in content knowledge in the two experiments, their ideas of the outcomes of the practicals as well as their attitudes. The results indicated that the content was learned more effectively in the high-technology demonstration. Differences in outcomes of the two methods however necessitate that both conventional and high-technology experiments should be included in the course.

INTRODUCTION

In the current postmodern era the principle of purposefulness is emphasised. The purpose of physics laboratory work has recently been investigated, amongst others, by Celliers *et al.* (1999 & 2000); Lemmer *et al.* (1996) and Pedretti, *et al.* (1998). A change in objectives and methods resulted. The establishment of microcomputer-based laboratories (MBL) contributed to these changes.

While the objectives of physics laboratory work previously concentrated on laboratory skills (Celliers *et al.*, 1999), the computer recently made inquiry skills easy to implement (Pedretti *et al.*, 1998). Laboratory related objectives include measuring and observation techniques, graphical representation of data, interpretation of observations, etc. Inquiry skills consist of higher order cognitive skills such as applications of knowledge and skills in unfamiliar situations and problem solving. Although Celliers *et al.* (2000) found that students and lecturers from South African universities still favour laboratory related objectives, she advocated that cognitive skills should also be promoted in laboratory work.

Most of the researchers on the implementation of MBL agree that the computer became an effective tool in the physics laboratory, but that it has limitations (Lawson & Tabor, 1997; McKinney, 1997; Wellington, 1999). Benefits of MBL include time effectiveness, repeatability and accessibility. A major disadvantage is that students are given a misleading impression of science and its nature. Students experiment with a model of reality and not

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reality itself. They do not experience the difficulties and errors that are part of hands-on experimentation.

The aim of this study was to compare the objectives attained by a conventional experiment and an interactive lecture demonstration (ILD) utilizing high-technology equipment. In both cases graphs of the motion of a trolley along a rail were drawn. The investigation determined whether the students' expected outcomes of physics practicals were reached, and whether they gained in content knowledge. A possible change in their attitudes towards laboratory work was also investigated.

RESEARCH METHOD

The survey was conducted among 36 physical science teachers following the Sediba program, an in-service upgrading course at the Potchefstroom University for CHE in South Africa. These teachers have all completed three years of tertiary education at different institutions in South Africa and have a few years of teaching experience in science.

Two experiments were performed to obtain the graphs of the motion of a trolley moving down a rail. Firstly the students performed the conventional ticker-timer experiment. A dotted tape of was produced by a ticker-timer attached to a trolley while it was moving at a constant velocity down a rail. The students measured distances between successive dots, calculated the period of the ticker-timer, tabulated the data and drew distance-time (s-t), speed-time (v-t) and acceleration-time (a-t) graphs by hand.

In the ILD a motion-detector was connected to a computer that sensed the movement of the trolley. The data was processed by the computer and graphs of motion were displayed instantly on a screen by means of an LCD projector.

To enhance student participation during the ILD the POE (Predict, Observe, Explain) method described by White and Gunston (1993) was used. The procedure proposed by Sokoloff and Thornton (1997) was implemented. The students were handed two sets of worksheets: A Prediction Sheet to sketch the predicted outcome of the graph before it is moved and a Result Sheet for observation of the result obtained by the computer. The observed graphs as well as misconceptions revealed by the predicted graphs were discussed.

The students were asked their opinions about the experiments in three questionnaires: A pre-test before exposure to experimental work, a first post-test after the conventional experiment and a second post-test after the ILD. Each one of the tests determined students' opinions about the outcomes of the experiment, their content knowledge and attitudes.

RESULTS AND DISCUSSION OF RESULTS

Outcomes

In the pre-test the students were asked to rank a list of seven outcomes of laboratory work in order of importance. The list of outcomes compiled by Celliers *et al.* (1999) was used with minor adjustments. The students ranked them as follows from most to least important:

1. Interpret experimental data
2. Use laboratory skills in performing experiments
3. Enhance understanding of the theory (content) of physics
4. Use knowledge and skills in unfamiliar situations
5. Design simple experiments to test hypothesis
6. Give clear verbal description of an experiment
7. Solve problems

Practical laboratory skills (1 and 2) were ranked highest, while the higher cognitive outcomes were ranked from 4 to 7. This result concords with those of the lecturers of residential (South African) tertiary institutions reported by Celliers *et al.* (1999). Seemingly the students have adopted the ideas of the institutions where they have been trained.

After each one of the experiments were performed, the students still regarded the interpretation of data and the enhancement of understanding of theory of high priority. They differentiated between the outcomes of the two experiments in the sense that the laboratory skills (1 and 3) were more attended to in the conventional experiment, while outcomes 4 and 5 were utilized in the ILD.

The majority of students indicated that both these experiments should form part of their course and that more practical sessions should be made available. Except for one student, all were eager to learn to handle the high-tech apparatus themselves.

Content knowledge

To determine the effect of the experiments on the content knowledge of the students about graphs of motion, multiple choice items of Thornton and Sokoloff (1990) were used. In the pre-test the students obtained an average of only 36,8 %. This percentage was increased to 43,6 % after the conventional experiment and further to 59,4 % after the ILD. While the conventional experiment could only result in a 6,8 % increase, the IDL caused a further increase of more than double this percentage, namely 15,8 %. From this result may be deduced that the IDL was more effective than the conventional experiment. This is in agreement with the results of Hake (1998), Redish *et al.* (1997) and Thornton and Sokoloff (1990).

It must however be kept in mind that only one movement (namely movement of the trolley away from the origin) could be investigated in the conventional experiment, while a variety of movements were dealt with in the ILD. On the other hand, the large amount of information given in one session confused some of the students.

An interesting result obtained was that in 52,9 % of cases students chose s-t and v-t graphs of identical forms for the same motion. Confusion of position and speed has been reported by Trowbridge and McDermott (1980). The occurrence of this confusion of concepts decreased to 43,8 % after the conventional experiment and further to only 27,4 % after the ILD. The large decrease indicates an improved understanding of the graphs as a relationship between the variables given on the axes.

Attitudes

The students felt very positive about the inclusion of practicals in their curriculum. This positive attitude remained after the practical sessions. This can be due to the careful compilation and proper presentation of both experiments, as required by Lemmer *et al.* (1996) and Thornton and Sokoloff (1997).

CONCLUSIONS

Conventional experiments and ILD's fulfil different objectives. Laboratory-related skills and techniques are learned and practiced mainly in conventional experiments. Since introduced by Galileo, such experiments contributed largely to the development of physics. Inclusion of conventional experiments can therefore contribute to the proper understanding of physics and its methods. For instance, a student pointed out that evaluation of the dots on the ticker-tape enhanced his understanding of the concept of constant velocity as the motion in which equal distances are travelled in equal time intervals. On the other hand, ILD's give opportunities for higher cognitive applications that form the basis of research in physics. Learning of content knowledge were found to be more effective in the ILD due to the variety of cases (and *what if's*) that can be investigated in a short time.

Major disadvantages of the conventional experiment are that it is time-consuming and that measuring errors occur. On the other hand, the results of the ILD performed were sometimes too detailed. Any wobble of the trolley was recorded, which affected the derived v-t and a-t graphs tremendously.

Since different objectives can be reached by the two methods, it is recommended that both conventional experiments and ILD's should form part of the laboratory work of physics. The percentage of each type of experiment that should be included cannot be prescribed. It depends on the study course of the students (e.g. engineering, pharmacy, physics majors or teachers) and the profile of the students (e.g. laboratory experience and computer literacy).

REFERENCES

CELLIERS, J.A, BASSON, I, KIRSCHNER, P.A. & RUTHERFORD, M. 1999. Current views of the purpose of the introductory physics laboratory in South Africa: Part I General objectives. South African journal of higher education, 13(3): 9-17

CELLIERS, J.A, BASSON, I, KIRSCHNER, P.A. & RUTHERFORD, M. 2000. Current views of the purpose of the introductory physics laboratory in South Africa: Part II Specific objectives. Accepted for publication in *South African journal of higher education*, 14(1).

HAKE, R.R. 1998. Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American journal of physics*. 66(1):64-74.

LAWSON, D.A. & TABOR, J.H. 1997. Computer-based experiments in mechanics. (In: Houston, S.K., Blum, W., Huntley, I.D. & Neill, N.T. Teaching and learning mathematical modelling: Innovation, investigation and applications. Chichester: Albion publishing) p 321-330.

LEMMER, M. LEMMER, T.N. & SMIT, J.J.A. 1996. A didactically based approach to the presentation of practical work in first-year Physics courses. *South African journal of higher education*, 10(1):147-154.

McKINNEY, W.J. 1997. The educational use of computer based science simulations: Some lessons from the philosophy of science. *Science and education*, 6:591-603.

PEDRETTI, E, MAYER-SMITH, J. & WOODROW, J. 1998. Technology, text and talk: Students' perspectives on teaching and learning in a technology-enhanced secondary science classroom. *Science education*, 82:569-589.

REDISH, E.F., SAUL, J.M. & STEINBERG, R.N. 1997. On the effectiveness of active-engagement microcomputer-based laboratories. *American journal of physics*, 65(1):45-54.

SOKOLOFF, D.R. & THORNTON, R.K. 1997. Using interactive lecture demonstrations to create an active learning environment (*In:* Redish, E.F. & Rigden, J.S. The changing role of physics departments in modern universities: Proceedings of ICUPE, September 1996) p 1061-1074.

THORNTON, R.K. & SOKOLOFF, D.R. 1990. Learning motion concepts using real-time microcomputer-based laboratory tools. American journal of physics, 58(9):858-867.

THORNTON, R.K. & SOKOLOFF, D.R. 1997. Realtime physics: Active learning laboratory. (*In:* Redish, E.F. & Rigden, J.S. The changing role of physics departments in modern universities: Proceedings of ICUPE, September 1996) p 1101-1118.

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.

WELLINGTON, J. 1999. Integrating multimedia into science teaching: barriers and benefits. *School science review*, 81(295):49-54.

WHITE, R.T. & GUNSTONE, R. 1993. Probing understanding. London: The Palmer Press.