

Implications of Data-logging on A.L. Physics Experiments: A Preliminary Study

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Contents

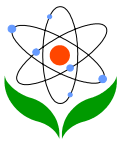
- Abstract
 - Role of Practical Activities in A.L. Physics Curriculum
 - Data-logging
 - The Study
 - Responses and Discussions
 - Implications and Conclusion
 - Acknowledgement & References
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Abstract

The current trend of computer-mediated learning probably implies that data-logger will become an important apparatus in the secondary school physics experiments in Hong Kong. This preliminary study reports and discusses the findings from a trial set of A.L. physics data-logging activities in a secondary technical school.

Role of Practical Activities in A.L. Physics Curriculum

One of the objectives of current A.L. Physics Syllabus is "develop skills relevant to the application of physics, such as experimental design, experimental techniques, problem solving, mathematical analysis, analytical and critical appraisal and communication"



(CDC, 1992). The majority of experiments listed in the Syllabus are taken from the Nuffield Advanced Physics Course. The focus is put on

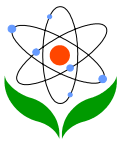
- Techniques (e.g. correct use of apparatus such as vernier, stop-watch and meters etc.)
- Graphical methods (e.g. transformation of formulae into linear graphs)
- Procedures (e.g. measurements and calculation)
- Order of accuracy (e.g. significant figures and error estimation)

Almost every practical activity aims at the verification of some physics laws or physical phenomena. Students are asked to follow the 'cookbook' worksheet to set up the apparatus and take measurement. Some calculations may be needed to manipulate the experimental data. A common practice is to present the data in graphical form from which useful parameters are extracted from the slope and the intercept(s) of the graph. The assessment is mainly based on the experimental procedures and the accuracy of the experimental data. Quite often, the graph is the end product of the whole practical activity.

However, the new Science Education Key Learning Area (KLA) shifts the rationale to "students should be engaged actively in designing and conducting experiments to explore science concepts and develop science investigation skills" (CDC, 2000). The focuses are not only on collecting quantitative and qualitative information with accuracy and generating reliable results, but also on

- Planning and conducting science experiments for solving problems, and
- Collecting information and drawing conclusion for decision-making

This paradigm shift of practical activities is still undergoing consultation. However, it is quite clear that the existing school apparatus and the ways of running a practical session are very difficult to achieve the new requirements. The apparatus available limits the scope of experimental works. For instance, the measurement of speed by the method of ticker-tape can only allow unidirectional motion. The calculation of speed from the separation of dots is tedious. Even worse, the results are sometimes not accurate and discouraging. Besides resources problem, time is also another constraint. Most of the time in current practice is spent on setting up of apparatus and plotting of graph. Not much time is left for the students to repeat the experiment with different settings and parameters, but scientific investigation needs opportunity for experiment repetition. Hence, apart from a change in curriculum, some means of support that can assist the improvement of carrying out experimental activities in terms of time, flexibility and accuracy should be provided.



Data-logging

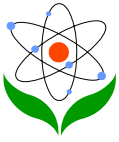
Recently the Education Department has added data-loggers into the standard equipment list for secondary schools ([Science Education KLA, 2000](#)). Data-logging is a trend in practical activities in science education. Its major advantages are the high sensitivity for measurement of very small changes and the ability to monitor changes over a very short or a very long period of time. It can record and store data of one or more parameters. The variations of several parameters can be shown on the same graph for comparison of trends and analysis for inter-relationship. As the recording and the presentation of data are automatic, time can be saved for repeating the experiment with different settings and parameters. That is, it creates a favorable condition for conducting more scientific investigations.


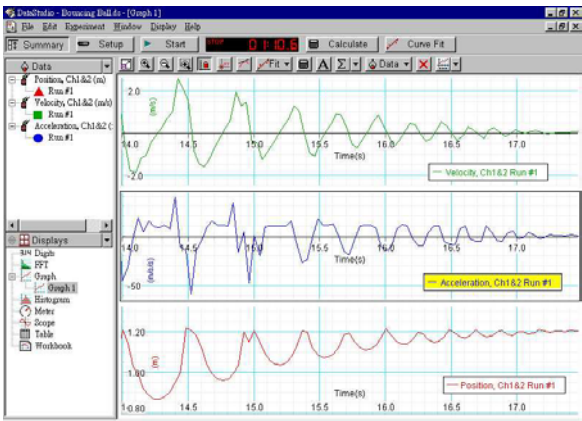
The Study

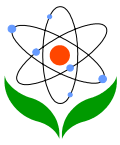
This study is to obtain the views of both the students and a senior physics teacher from a technical secondary school on the applications of data-logging in three physics experiments. For ease of reference, the laboratory worksheets for those three experiments and the corresponding video clips are given in Table 1 below.

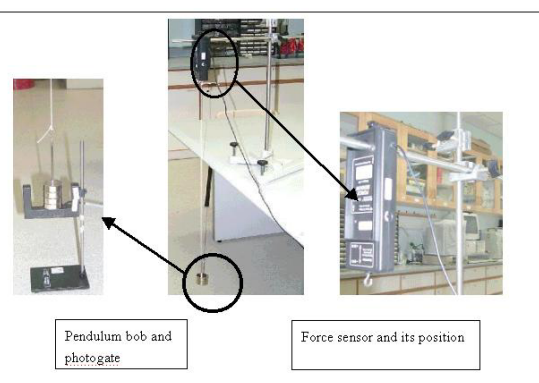
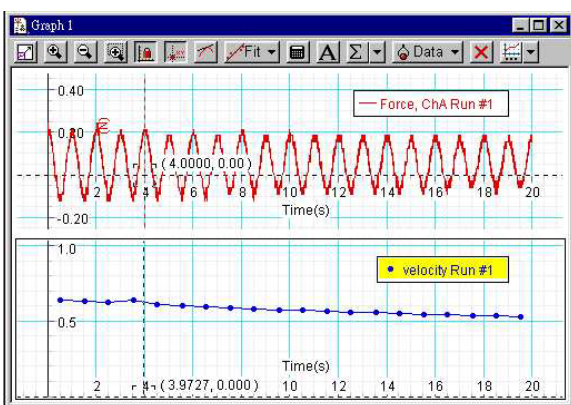

Table 1: Laboratory worksheets (in Adobe pdf file format) and corresponding video clips of three physics experiments

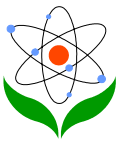
Experiment	Objective	Multimedia materials on the experiment
Bouncing ball	To study the motion of a bouncing ball under the gravitational pull	Experimental Setup

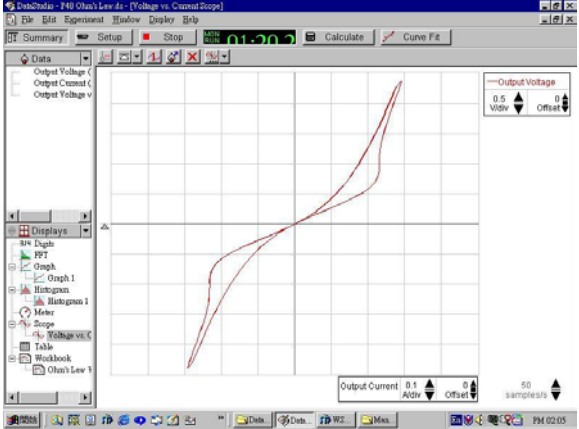


		 <p>Typical Result</p>  <p>Experimental Procedures: video clip (Bouncing.avi)</p>
Centripetal force of a pendulum at its lowest position	To study the centripetal force on the motion of a simple pendulum system.	Experimental Setup



		 <p>Pendulum bob and photogate</p> <p>Force sensor and its position</p> <p>Typical Result</p>  <p>Experimental Procedures: video clip (Centripetal.avi; file size: 1,879kB)</p>
<p>Resistance of a light-bulb filament</p>	<p>To explore the resistance properties of a light-bulb filament.</p>	<p>Experimental Setup</p>  <p>Typical Result</p>



		 <p>Experimental Procedures: video clip (Resistance.avi)</p>
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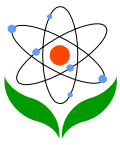
The teacher has 18 years of experience in teaching physics. He is actively involved in designing student activities, and because of this, he is partly seconded to the Education Department. The students are 2 classes of S.7 students. They have more than one year experience in doing conventional A.L. physics experiments. The frequency is at least once every 6 school days cycle and the duration is normally two hours (3 consecutive periods).

Each of the trial experiments had two sets of apparatus and lasted for less than 1 hour. Each class was divided into 6 groups with each group has 3 to 4 students. They did the experiment in a station order. After the first experiment, they were asked to fill a questionnaire to do a preliminary evaluation on data-logging. Two weeks later, they finished the other two experiments and an interview was conducted to obtain further comments.

To avoid drastic change in the style of the experiment, the three experiments also start with verifications of some physical phenomena as the conventional method does. Investigative activities stressing at hypothesis testing and problem solving are introduced at the second half of the experiments. The Table 2 below summarizes the details of the experiments.

Table 2: Physical phenomena for verification and further investigation in the experimental activities

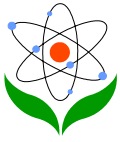
Experiment	Measurement	Physical phenomena verified	Further investigation
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Bouncing ball	View a bouncing ball from the top with a motion sensor.	Showing the interrelationships among displacement, velocity, acceleration and time. Estimation of an average value for g.	To design experiment to verify a cause of energy loss after each collision with the floor.
Centripetal force of a pendulum at its lowest position	Measure the centripetal force F by a force sensor and the speed v by a light-gate as the pendulum passes its lowest position.	Comparing the values of F and mv^2/r where m and r are the mass and the length of the pendulum respectively.	To suggest the possible sources of deviation between F and mv^2/r , and to alter the set-up to test one of their hypothesis.
Resistance of a light-bulb filament	Apply a low frequency signal to the light bulb and measure its voltage and current by the corresponding sensors.	The variation of resistance of the filament with current (temperature).	To explain the occurrence of a loop in V-I plot and to alter the set-up to verify the validity of their explanation.

For example, the details of the laboratory worksheet for usual verification of physical phenomena and for further investigation in the “Bouncing ball” experiment are reproduced as follows:

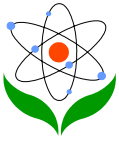
5.4 Choose one segment of motion between two collisions with the wood. Calculate the kinetic energies after the first collision and before the second collision respectively. Calculate the maximum potential energy in that segment of motion as well. Compare their values and explain the differences.



Mass of the ball = kg			
K.E. after the first collision T1	K.E. before the second collision T2	Ratio of the two K.E. T2/T1	Max. P.E.
Comparison and explanation:			

5.5 There are a few factors that will affect the ratio of the two kinetic energies in 5.4 above. For one of these factors, try to investigate it through an experiment. You should make a qualitative prediction of your results first and then carry out the quantitative measurement.

<p>Hypothesis (i.e. the factor and your initial qualitative prediction of its effect)</p> <p>Investigation (brief description of how you carry out or modify the experiment)</p> <p>Findings (numerical results and check if the hypothesis verified or not)</p>
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Responses and Discussions

Like In the first practical session, the teacher (Figure 1) gave a one-hour introduction on the hardware and the software, and demonstrated the important functions of the software with the bouncing ball experiment.



Figure 1: Teacher introducing the usage of the hardware and software for the data-logging system

This practice is quite common when something new is introduced to students. Then the students did their first experiment (Figures 2, 3 and 4). After completing all the three experiments, students needed to fill in a questionnaire.



Figure 2: Students using the computer software to manipulate the data-logging system

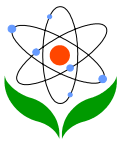
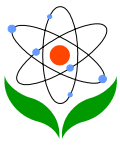


Figure 3: Students doing the bouncing ball experiment
(video clip: experiment.mov; 9.52MB)



Figure 4: Students working on another data-logger experiment

Forty-one students filled the questionnaire. Only one student did not have a personal computer at home but he rated his computer competency to be basic (i.e. knowing Windows and word-processing operation). Hence all students acquired those basic computer operation skills such as mouse operation in the Window environment. Their grades in Physics in public examination ranges from A (excellent) to E (marginally pass), reflecting a diverse background of physics standard. In the questionnaire, the students were asked to evaluate the learning effectiveness and attitudes of data-logging. Most of them (~80 %) agreed or strongly agreed that data-logging could enhance data measurement, data recording and the presentation of results during the experiment as well as could develop their skills in these aspects. They also strongly agreed that data-logging could assist data analysis during the experiment but only 50 % agreed that their corresponding skill could be improved through such process. They also slightly agreed that data-logging could assist the manipulation of apparatus and the observation of phenomena. They were almost neutral in considering whether data-logging had positive impact on making scientific inferences, inducing curiosity, enhancing collaborative learning and developing a sense of achievement. The reason may be owing to the fact that 80 % of them found the software difficult to use. Actually the authors and two officers from the Curriculum Development Institute observed that session and all agreed that the introduction of the software by the teacher was lively, detailed and comprehensive. The teacher had covered all the important and



necessary aspects about the software. The approach on how to guide the students to become familiar with the software needs further investigation.

Another two weeks later, a short interview was conducted separately with different groups of students. They were generally positive about data-logging but some made very perceptive criticisms. They appreciated the powerful features of the hardware and the accuracy, the recording speed and the presentation of the data. Comments included:

The sampling of data is very fast and we can have time to repeat the experiment if the data is not satisfactory.

The sensors are very sensitive and they can measure something we can't measure before.

The plotting of graph manually is really tedious. I like the graphical function of the software and the graph is indeed very smooth.

The data is very accurate and I like the software can present several sets of data on the same graph.

There was a common feeling amongst the students that the experiments were quite different from those they were used to. They were also not used to the investigative approach. Critical comments included:

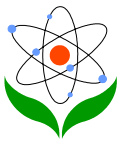
It is boring. There is little thing we need to do as the computer does most of the job.

I still prefer the conventional way of doing experiment. For instance, I like to adjust the voltage gain of a CRO by myself to measure an electrical signal, rather than the data-logging software automatically selecting the gain. Moreover, the A.L. examination requires us to know those skills such as adjusting the voltage gain of a CRO.

Data-logging is helpful in obtaining and presenting the data but do little in developing my experimental technique.

It is always those IT competent classmates to dominate the experiment. There is little chance to work collaboratively.

The authors have also discussed with the teacher about his views on the applications of data-logging in physics teaching. Generally he had quite positive comments on data-logging. As he had rich experience in designing student activities, he had little



problem in operating the data-logger. He raised two worries about the actual implementation of data-logging activities in laboratory:

It is quite difficult to find enough computers for student activities. Discipline is another problem as the students may be distracted to play with other software in the computer.

It is easy to use another stopwatch if it goes wrong in a conventional experiment. However there is little a teacher can do if something goes wrong in a data-logging experiment. He predicted that this would hinder those teachers with low IT competency from experimenting with data-loggers.

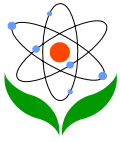
Implications and Conclusion

All secondary schools will be equipped with data-loggers in the coming two years. There should be no doubt that this IT tool can increase the scope of physics experiments. It can measure something that cannot be measured before. However, our focus should be not only on more data recording experiments, but also on collecting data for more investigative activities.

The data collected in this study is quite preliminary but it can still give some insight about the adaptation of data-logging into the teaching and learning of physics.

The approach on how to guide the students to become familiar with the software needs further investigation. In this study, a paragraph supplemented with diagram on how to use the software to record data was given on every worksheet. One student commented that: "The guidelines are useful in doing the first experiment but they become boring when similar description is found in every experiment." Students need to invest a certain amount of time to gain familiarity and confidence in using the software. Rogers (1997) suggested a progression of sophistication approach in which the students are first asked to describe a graph obtained from a very simple data-logging activity. Then the progression moves to a more quantitative approach to measure changes and gradients. At the highest level, groups of observations are linked and relationships are explored. In this approach, teachers don't need to describe and explain too much. They just give some very brief introduction on how to log and present data. They will guide the students to finish the tasks simply by providing some prompting questions.

Some students expressed that observing a data recording process was boring. For this risk to be avoided, there is a clear need for the students' activities to be carefully structured (Newton, 1997). They should be encouraged to develop the habit to think and comment about their data as they appear on the screen, by providing some prompting strategies or activities.



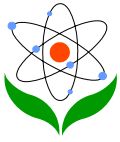
Two students stated that they preferred to use CRO to observe a varying signal rather than using data-logger because the selection of a correct voltage gain is a very common topic in both written and practical examinations. Actually, auto-ranging CRO's are quite common in industrial applications as their prices are decreasing. There is also a trend to use fast interfacing card (with similar function as a data-logger) to replace the CRO. As data-logger is becoming more popular in physics experiments, some 'old' apparatus and techniques should be phased out, particularly in the public examinations. There is a similar case known from a data-logging pilot school. The students performed the motion experiments with both the data-logger (because it gave better results) and the ticker-tape (because this was stated in the examination syllabus). This is a waste of time and resources.

Another implication to the public examinations is what skills should be assessed. The proposed Teacher Assessment Scheme (TAS) still focus on the setting up of apparatus and the recording of data. Quite often, a graph is the final output. However in data-logging, it is almost impossible to assess the data recording skill, and the graph is just the starting point rather than the end-product of the whole experiment. Part of the TAS focus should shift from low level skills such as data recording and graph plotting to higher cognitive skills such as setting and testing hypothesis and problem solving by data-logging investigative activities.

Although data-logging can assist investigative activities, students in this study did not perform well in this aspect. This can be reflected from the interview and the worksheets they have handed in. It is not a surprise to have such result as investigative approach is very uncommon in current ways of teaching physics in Hong Kong. The authors predict that some teachers will definitely have similar problem as the students. There is an urgent need for in-service training of physics teachers on the effective use of data-loggers. Similar findings were obtained from another study by the authors (Yeung & Ng, 2000). Among all the IT tools that can support physics teaching, data-logger was rated as the highest in the need of more in-depth training by a group of physics teachers attending an IT workshop.

Acknowledgement

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