EXPERIENCES WITH CBL AND THE TI-92 IN AUSTRIAN HIGH SCHOOL CLASSES INTEGRATING MATH, PHYSICS AND CHEMISTRY

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Experiments carried out by students are very motivating and lead them to a better understanding of principles and processes in sciences. The main objective is to find functions fitting best to the experimental data and to interpret the special values of the parameters of these functions. The students have to combine knowledge about the different types of functions with the knowledge about chemical and physical facts. As an additional aspect, the students also have to take care of the accuracy in working for obtaining good results. The collection of large lists of data is supported by the TI-CBL system. Mathematical experimenting, complicated mathematical computations and visualization are supported by the TI-92.

We report about first experience of CBL/TI-92 within the final exam at an Austrian grammar school. Basic skills for making experiments, documenting results and using and transferring basical knowledge are discussed in this presentation.

In this presentation we will report about the experiences made with students at the age of 17 to 18 carrying out experiments in chemistry and physics in science courses. We concentrate on how the students can apply their knowledge from mathematics and sciences in these practical situations and how they document their results.

Introduction

CBL is a Calculator Based Laboratory which allows to collect data during physical and chemical experiments. Data are stored directly to a calculator e.g. the TI-92 for graphical visualization and further manipulations. Due to these features experimenting is getting easier. However, this does not mean, that the students can work less exactly. A careful experimenting is absolutely necessary for obtaining good quantitative results. CBL and TI-92 are supporting collecting and manipulating data only.

We report about a project being carried out at the Bundesrealgymnasium Landwiedstrasse, which is an Austrian Grammar school in Linz, in the year 1999/2000. The students are interested in natural sciences. Six different groups of students have been involved in this project consisting of 61 students at the age of 16 to 18 years. About 50% of the students were girls and there was one group consisting of girls only. All of them did not have much basic knowledge in chemistry and no experiences with the TI-92 or the CBL system. Experimenting and working in groups was a new experience for the students.

Experiments

As an example we treat the experiment about "discovering" Boyle´s law in more detail. It is quite easy to understand and the practical execution is unproblematic. However the concept of combing experimental activities and mathematical reasoning using different representation forms (tables, graphs, algebraic expressions) is easy to recognize and can be transferred to all other experiments.

The objective of this experiment is to determine the relationship between pressure and volume of a confined gas. For this experiment we use a syringe which is connected to a pressure sensor (see figure 1). Decreasing the volume in the syring by moving the piston of the syringe, the pressure of the confined gas will increase. The pressure of the gas is collected by the CBL system and stored to a data matrix of the connected TI-92. Using the TI-92 the students can immedeatly visualize the relationship between volume and pressure of the gas and analyze data by fitting suited functions for describing the relationship. We assume that the temperature is constant throughout the experiment.

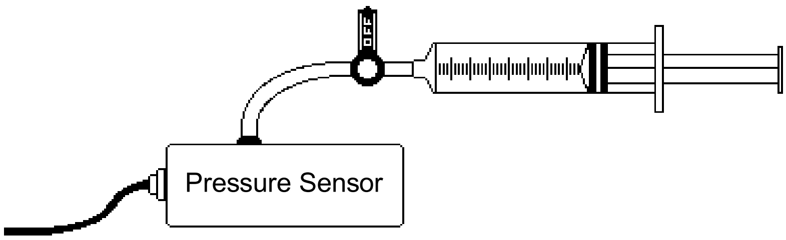

Figure 1: pressure sensor and syringe for investigating Boyle´s Law (from [HOLMQUIST, RANDALL, VOLZ 1998])

After preparing the pressure sensor, the CBL system and the TI-92 the students start collecting data by varying the volume of the gas and simultaneously meassuring the pressure. Both volume and pressure are stored to a data matrix of the TI-92.

By inspecting data stored to data matrix cbldata of the TI-92 the students can find out that the pressure stored in column c2 decrease for increasing volumes stored in column c1. For verifying the assumption that there is an inverse proportionality between volume V and pressure p of the gas, the students compute the product p*V in column c3 by entering the product c1*c2 to the head of c3. The students learn, that they do not obtain exact the same values for all data pairs. It is an important experience for them to learn that experimental data are always affected by an error. This is a good motivation for introducing statistical methods like mean and standard deviation and discussing the meaning of these concepts (see fig. 2).

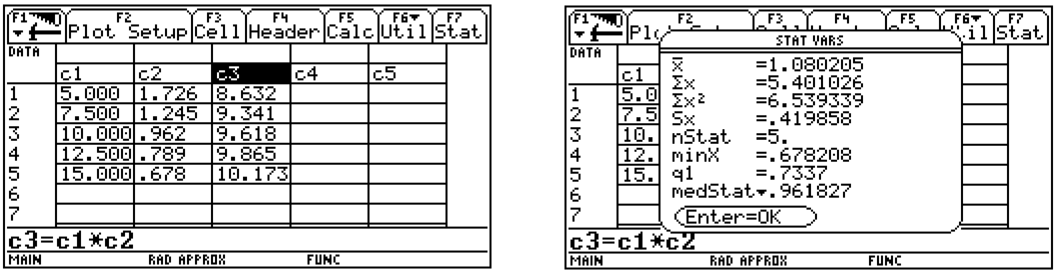

Fig. 2: Collecting data in a data matrix and calculating mean and standard deviation.

The students can define a scatter plot and visualize data in a graph window of the TI-92. The shape of the imaginary line of scatter points is typical for reciprocal functions. The students can try to find experimentally functions that are fitting data best. Maybe they start with the function y1(x) = 1/x learning that the graph of the function is running below the data points. They have to mulitply the function expression by a constant. A good choice is the mean of column c3. The function y2(x) = 9.5/x fits data much better than y1(x). However, even for this function all data points do not lay on the graph of y2. Especially, data points for small volumina deviate from the graph (see fig. 3).

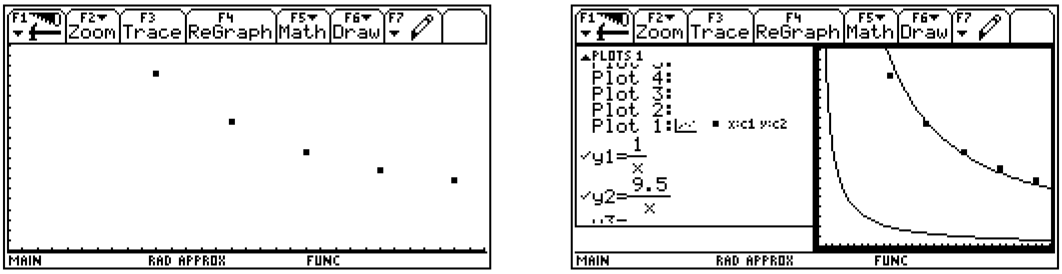

Fig 3: Visualizing data points and fitting them by reciprocal functions

Using the function PowerReg of the TI-92 we can compute a regression curve of the type $a*x^b$ for the given data points obtaining the function $6.9*x^{-0.86}$. We can use a situation like this for intrducing the concept of regression. However, the students at least should be able to interpret the results. For reciprocal functions the exponent b should be -1.

A possible error could caused by neglecting the volume of the tube connecting the syringe with the pressure sensor inside the sensor box. We assume this volume to be 1 ml. We can add this volume to the volumes measured in the experiment before by computing c4 = c1 + 1. We can see that the products p*V with the new values for V do not vary so strong around the mean value 10.6 (see fig. 4) and the function y2(x) = 10.6/x fits the data points quite well.

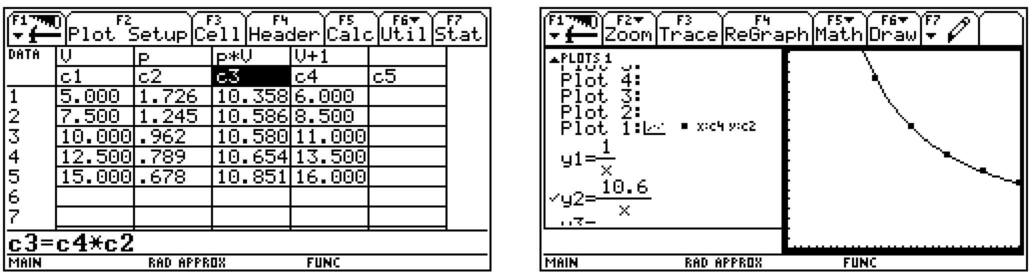

Fig. 4: Investigating new values for the volumes by adding the volume of the tubing

Computing the regression curve with PowerReg of the TI-92 we obtain $6.9*x^{-0.96}$ with an exponent near to -1. Now the regression curve corresponds well to invere relationship and reciprocal functions.

Basic Skills

Experimenting with the CBL and the TI-92 in science courses requires basic skills in different areas, e.g. mathematical skills, verbal skills, practical skills and social skills.

As the main basic skill in mathematics the students should be able to recognize functional interdependences from data. For this reason knowledge about different types of functions is required, e.g. linear, reciprocal, potential or exponential functions. The students should know the typical shapes of the graphs and how the graphs alter if occuring parameters are varied.

As a special case of functions the students should know about direct and inverse relationships. They should know techniques of how to prove which relationship is applicable. E.g. the product p*V is constant if there is an inverse relationship between the pressure p and the volume V of a confined gas. Furthermore the students should be able to recognize e.g. direct relationships form plots of data points in a graph window. There is a strong argument for a direct relationships if the data points lie on a straight line running through the origin.

Concerning the use of the TI-92 during experimenting the main basic skill is a secure handling of the windows for the different representations of data, i.e. the Data/Matrix Editor, the Y= Editor for entering functions and plots, the Graph window and the Window Editor for changing the settings in the Graph window. There is a tight connection of these technical skills to the mathematical skills of interpreting and manipulating data in different representation forms.

A verbal basic skill is the ability of the students of doing experiments by using detailed written instructions. It is surprising how difficult it is for students to read and carry out instructions stepwise without additional explanations of the teacher. A further problem was documenting the results. The students have to learn how to write a technical report. Especially, summarizing the chemical/physical background and interpreting the results is quite difficult.

Finally, the students have to learn some practical and social skills when experimenting in groups. We can not describe these skills in detail, but we have observed that the students had problems in teamwork and experperimenting at the beginning of the project and they mastered these problems at the end.

Experimenting in science courses is a good training for the multiple intelligences [GARDNER 93] of the students.

Final exam

In Austria it is usual to use computers not only in normal lessons but also in our final exam called "Matura". In the verbal part of the final exam students can choose a special topic for one question. In the final exam this year one student choose the use of the CBL and the TI-92 in chemistry courses as a special topic.

It was one task of the student to determine the unknown concentration of a green coloured solution following Lambert Beer´s Law (Light absorption is direct proportional to the concentration). The student had to make a serie of different solutions from a stock solution of known concentration and to measure their light absorbance using a colorimeter. Due to Beer´s Law the concentration/absorption data points lie on a straight line. Measuring the light absorbance of the unknown solution the student was able to determine the unknown concentration of the solution. Furthermore the student gave background information about how a colorimeter works and how to interpret Beer´s law.

Once more a real time problem occured. 20 minutes for preparing the experiment and 8 minutes for presentation were a very short time. It should be mentioned that the show effect helped to attract the attention of the examinators. It was amazing that the experimental data of the student were very accurate. This showed the souvereignity of the student´s work. Nervousity could cause problems in accuracy.

Experiments and the use of computers in final exams can lead to unpredictable situations, especially if there is a break down of the computer. It is recomended to keep an additional TI-92 with some basic data in reserve.

Experiences

The students were really motivated. They spent more time as obligatory in the laboratory and they would like to continue the CBL-TI-92 project. Students being not very good in chemistry and mathematics got a real chance to do it better. Some girls who did not be very interested in these two subjects enjoyed the project. They were proud about their "beautiful curves" and their good results.

According to a questionnaire, which the students answered at the end of the project, they enjoyed practical work. They felt free of the "pressure of learning" and appreciated being independent during experimenting. Chemical and physical laws became more illustrative for the students. Some students also mentioned that it was important to learn using technical instruments and computers for their future life. Only 2 of 61 students would not like to continue this project.

We forced the students to write reports for documenting their work and their results. Most of them were not happy about that, but they accepted the need for doing that. It turned out during discussions that the students understood the background of the experiments after having written the reports and they wished to repeat some of the experiments to obtain better results. Background information before and an intensive discussion and interpretation of the results after experimenting would have been neccessary.

The major problem was the lack of time. We had only 50 minutes per lesson for explaning and doing the experiments. Therefore the discussion and interpretation of the results often had to be deligated to the next lesson. That turned out to be a loose of actuality. A further problem could be the large number of students (~ 30 pupils) in regular science classes. In our project we had only small groups of 10 to 16 students. However, also in this "ideal" situation an additional person was helpful, e.g. when problems with the calculators occured or explanations of mathematical relations were neccessary. Working in chemical and physical laboratories using new technology forced interdisciplinary thinking by the students.

The role of a teacher is going to be changing. Instead of presenting well prepared knowledge he has to assist students during their work. Using new technology it is impossible for teachers to master all occuring situations. Sometimes students know more than their teachers.

It was quite easy for the students to get familiar with the CBL and to apply the CHEMBIO program on the TI-92. However, for further mathematical manipulation of experimental data the students had to learn more about the handling of data-matrices, plotting graphs, defining functions, determining regressions curves etc. This required a detailed introduction of handling the TI-92. This could have been skipped in our project, if the students would have used the TI-92 in regular math lessons. A second obstacle was the simplicity of the CHEMBIO program. It was easy to handle the program for the students, if they did not make any mistakes. However, the program was not "fault tolerant". If the students had entered a wrong value or selected an inappropriate submenue it was very difficult to leave the program or to correct the wrong inputs.

It was new for the students to work in groups. They had to learn to dedicate work to different group members according to their abilities. The second problem was the acceptance of a unique grade for the whole group. Finally, it was quite difficult to find a fair grading for the students according to their individual achievements.

References

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