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Experimental Approach in Physics Teaching – Computer as a Tool in Interaction with Nature

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SUMMARY

We have developed a versatile microcomputer based system including new software and hardware for data acquisition and analysis in science teaching. The hardware is designed to be connected to IBM PC/AT/PS computers. Our software, Empirica 2.0, uses a Windows type of interface and allows several methods of data analysis and graphical visualisation. The data can also be transferred to other programs for further analysis and reporting. Version 3.0 of the Empirica runs under the Microsoft Windows 3.1 Graphical Environment.

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BACKGROUND

Over the last few years many studies have been made on how pupils of different age groups predict and explain natural phenomena (e.g. Driver, 1983). The main result of these investigations is that pupils' conceptions of natural phenomena are markedly different from the concepts which usually underpin teaching programs. Abstract scientific concepts are usually difficult for many pupils to understand. They may know the formulas, equations or mathematical methods but they don't understand what the natural laws really mean.

Interaction between a new situation and present knowledge

Learning is an active process in which the learner constructs his or her own personal world view. What is learned in any new situation depends as much on the ideas the learner brings to the situation as on the learning situation; learning is a result of an interaction between new situations and present knowledge. Learning is a dynamic interaction where pupils continually and progressively construct and reconstruct their understanding of the world.

When we use the microcomputer-based data acquisition we can easily repeat an experiment and investigate how the situation changes when we change one parameter.

Interaction between nature and present knowledge

According to modern learning theory a pupil has to constructs his or her own personal view of the world. In physics teaching this means that we have to use an experimental approach which is the natural way of teaching physics (e.g. Kurki-Suonio & Kurki-Suonio, 1987). The starting point in teaching is the observation of a phenomenon in nature. After recognition of the phenomenon we can obtain quantitative knowledge of the phenomenon by observation or measurements. Concepts and natural laws can be defined by presenting invariances between entities. The theory and the laws can then be applied when we are analysing new phenomena (Fig 1).

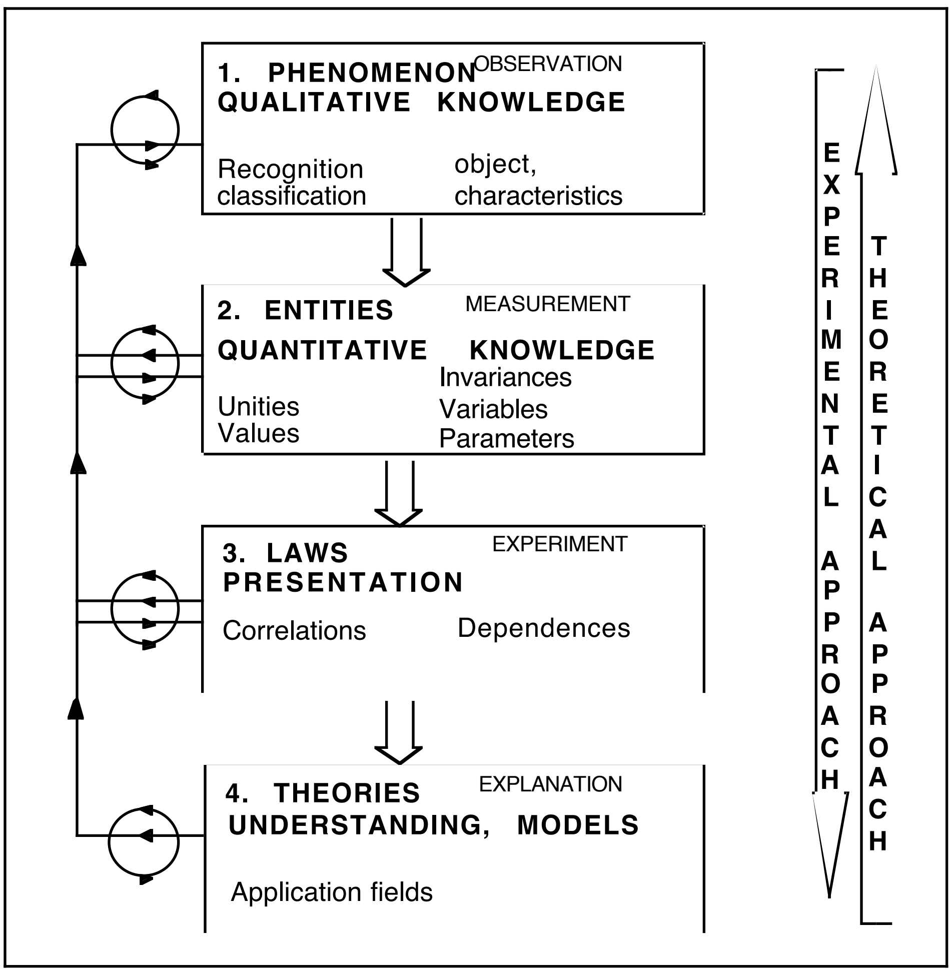


Figure 1. Experimental approach.

The word "experiment" is often used in physics teaching in a way which is synonymous with practical activity. When we teach physics we hope that practical activity leads to better understanding. Practical activity is not pedagogically experimental if pupils don't construct concepts or natural laws. When a teacher is planning an experiment he or she must know how a new concept or law is constructed; how the mind works to process new information, what preconception the pupils have and so on. For example, graphical presentations help pupils to understand new concepts and natural laws.

The computer is an excellent assistant when we want to increase the number of experiments performed during physics lessons. For example it helps in data collection, in the differentiation and integration of data, in the curve fitting of data and in the numerical or graphical display of data. Our software has been designed to help us to present the correlation between entities in many different ways. For example, graphical display of data or curve fitting helps one to analyse the dependence between variables and formulate a mathematical model or the relevant natural law.

Human interaction

When we use a computers in teaching, we have to understand that they are not the single solution to better education. We must understand that when we are interacting with nature, the computer is only a tool. In addition we must remember to communicate with our pupils. When we use microcomputer-based data acquisition we save time in our interactions with nature, and we can thus increase human interactions (see Meisalo, 1987 a, 1987 b, 1991).

When we have more time for human interaction it is easier for pupils to assimilate physical concepts. Arons (1990) suggests that in order for pupils to assimilate abstract concepts of physics they must:

- Describe in simple words their own observations and discuss them with other pupils.
- Engage their minds in active use of the concepts in concrete situations. The concepts must be explicitly connected with immediate or visible experience.

The teacher can increase human interaction by the following methods:

- The teacher must learn to ask questions that lead the pupils to fully articulate the interpretations and explanations in their own words.
- The teacher must demand that his pupils describe their observation in their own words prior to using the terms that science has chosen for these same observations and concepts.
- The teacher should ask his pupils to use the concepts in a more extended manner and in new contexts.

- The teacher has to teach basic skills which can be applied to any scientific investigation. These basic skills are: asking questions, observing, classifying, recording, interpreting, analysing, concluding, suggesting explanations, predicting, making test (fair), applying ideas and so on (e.g. Peacock, 1990).

"EXTENDED MARKET SQUARE" MODEL

When we use computers in science teaching the learning environment can be described by the "Extended Market Square" model (Fig. 2) (Meisalo 1991). Computers are used here mainly as tools as teachers and pupils work towards defined goals. This model illustrates the possibilities for open approaches and creative problem solving. Pupils and teachers should be free to use a wide variety of instruments and tools for their investigations.

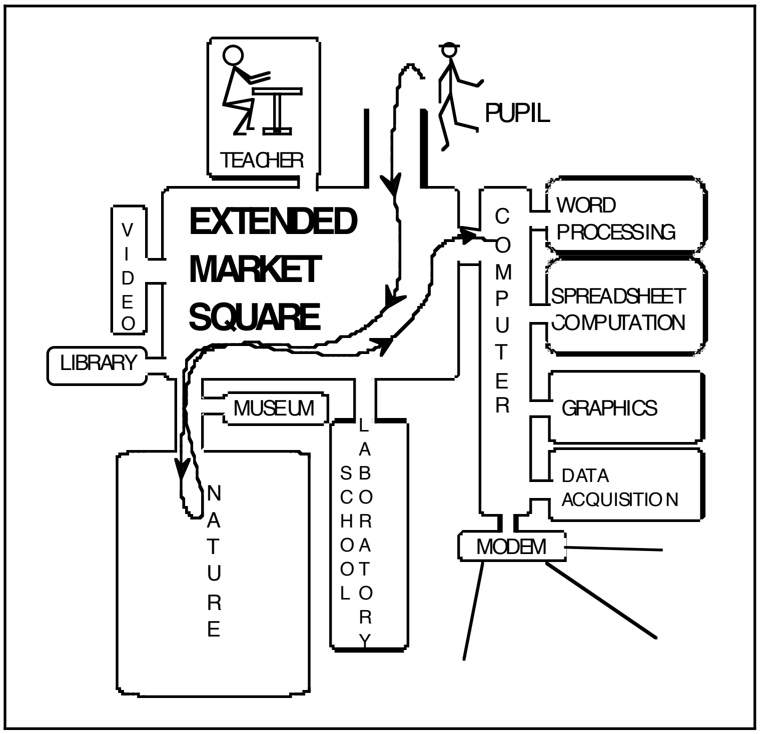
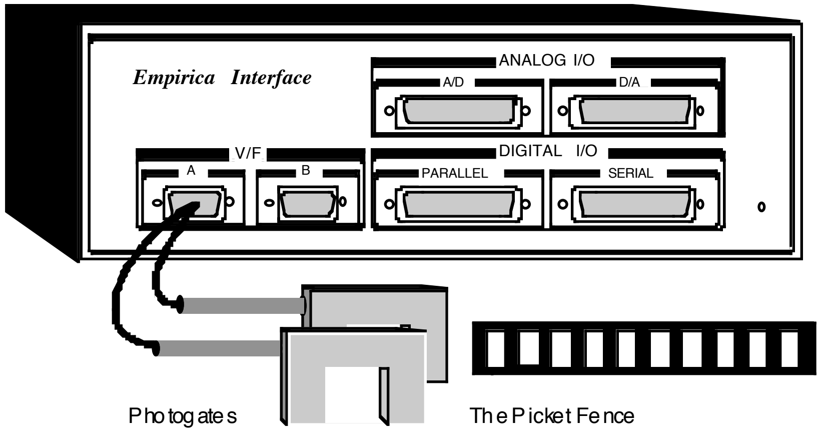


Figure 2. The "Extended Market Square" model.

THE DATA ACQUISTION SYSTEM AND SOFTWARE

In 1987 we began using the computer as a laboratory instrument in our physics courses and started to develop interfaces and software for Compis and IBM microcomputers (PC, AT, and PS/2). The interface is connected to the serial port of the computer (COM1). The measurement unit and the sensors are connected to the interface. A system for photogate measurements is presented in Figure 3 (Lavonen 1989, 1990).

Empirica interface



H Figure 3. The Empirica interface.

Version 2.0 of the Empirica measurement program was completed in 1989 (Lavonen 1989). The software uses a Windows type of interface. With the Empirica measurement system, and an appropriate sensor the following entities can be measured: time, frequency, velocity, acceleration, strain, mass, voltage, current, resistance, electric energy, electric power, temperature, illumination, pressure, pH, conductivity, oxygen content, absorbance, humidity, the density of the magnetic flux, and pulses. It is also possible to define a new entities in the program. For example, using a LED photometer the humus content of water and the concentration of a liquid can be measured. No additional interface cards are needed to collect data. The data is transferred from the measurement sensor to the computer through an *Empirica* Interface connected to the RS-232 serial port.

The Empirica measurement program is an interactive program, this means that the user can choose the most suitable procedure of measurement for his purpose from a menu. The measurement results can be presented numerically or graphically on the screen, or they can be printed or saved. Files can be transferred to spread sheet, word processing or graphics programs.

The Empirica measurement program includes a package of tools, with the help of which results of the following measurement can be dealt with:

- the zooming of graphics and the addition of text to the graphic display,
- curve fitting to the data (ax, ax^2, ax+b, EXP(x), LOG(x) etc.),
- the scaling of axes (LIN, LOG, DIFF, INT, 1/x),
- and the graphic integration and derivation of the data.

In version 2.0 of the Empirica measurement program it is possible to simultaneously examine in smaller windows, many measurements made in different channels.

The resolution of the frequency converter in the measurement unit varies from 10 to 22 bits depending on the sampling frequency. The greatest sampling frequency is about 1.6 kHz. The time of measurement can be chosen from between 0.6 seconds to 41 days. During the allocated measurements 1024 data points will be collected (constant). There are two measurement channels in this measurement unit. It also has a voltage supply of 5 volts.

We are now working on Empirica for Windows. We hope that it will operational by 1993. There are number of new features in the new version. We are also developing the hardware. It will be possible to fit the *Empirica* Interface with an AD/DA-converter. It will have eight measurement channels, a resolution of 14 bits, the sampling rate of 100 kHz, a transient recorder (triggering either from a rising or falling measurement signal with the wanted offset valency), and a DA-converter with two channels (12 bit, +/- 5V) will be available.

EXAMPLES OF USING A COMPUTER IN EXPERIMENTS

In the next sections we will describe two examples of how the computer is used in laboratory work. The description shows how the concept of acceleration is defined with the help of observed invariance in the structure of phenomena. Another example describes how we can increase discussion in physics classroom.

Concept of acceleration

We start the demonstration by discussing moving cars, falling objects and so on. It is best to classify different kinds of movements. Later we start to investigate movements where velocity is changing. With the help of photogates and the "picket fence" we can study how an object moves downhill or falls. We measure in different situations how the velocity of the object depends on time, and present the data graphically. We always get a straight line. The slope of the straight lines is a property of the movement. In this case the property is called acceleration. The data can be studied detail using the spreadsheet Excel.

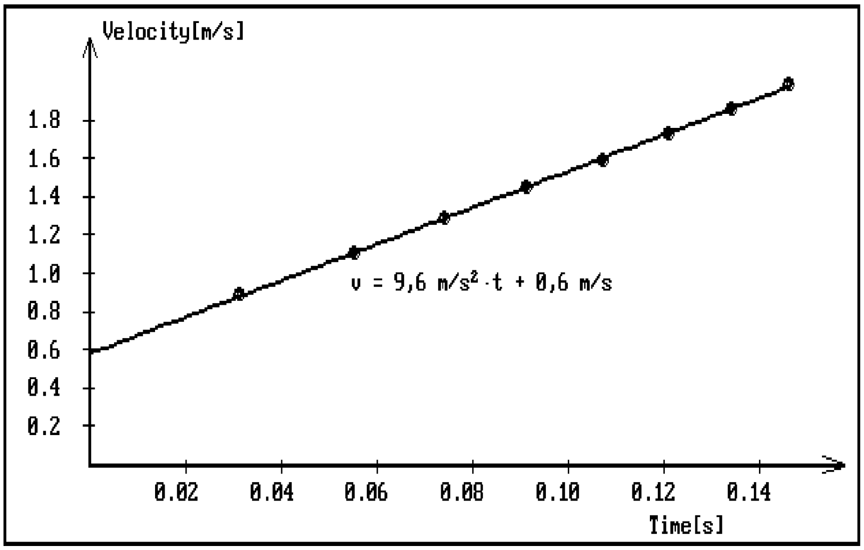


Figure 4. Concept of acceleration.

Internal energy of gases

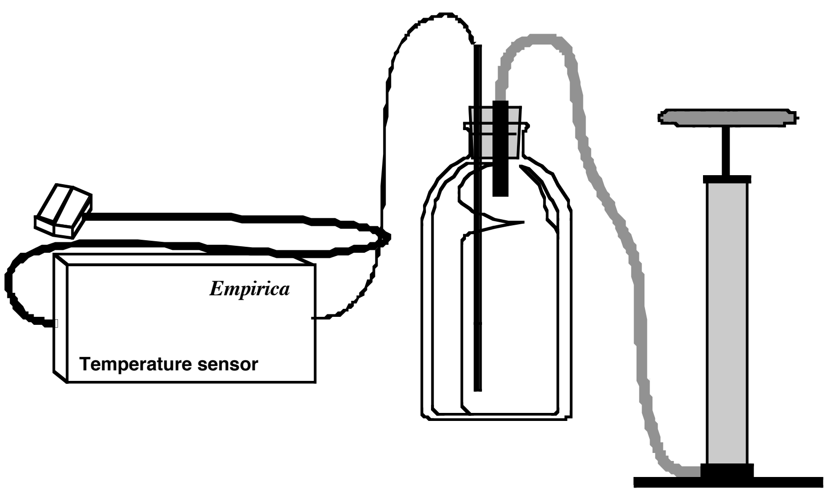


Figure 5. Measurement of air temperature.

Discussion is very important in a physics classroom. If one individual monopolises the discussion pupils usually accept this individual's explanation. The following demonstration, which is illustrated in Fig 5 will highlight this point. A temperature sensor is placed in the centre of glass container (see Layman 1990). We place a stopper on the chamber and use a bicycle pump to pump air into chamber. We measure temperature, and time, and plot temperature versus time as the experiment proceeds.

After pumping for 5 seconds the stopper flows away and the temperature of the air decreases below that of the room temperature (see Fig. 6). It is interesting to discuss with the pupils why the temperature is lower at the end than at the beginning of the demonstration. The teacher must ask questions and show the pupils how they must think as they attemp to solve problem. It is also very important to look at the curve and ask questions about it.

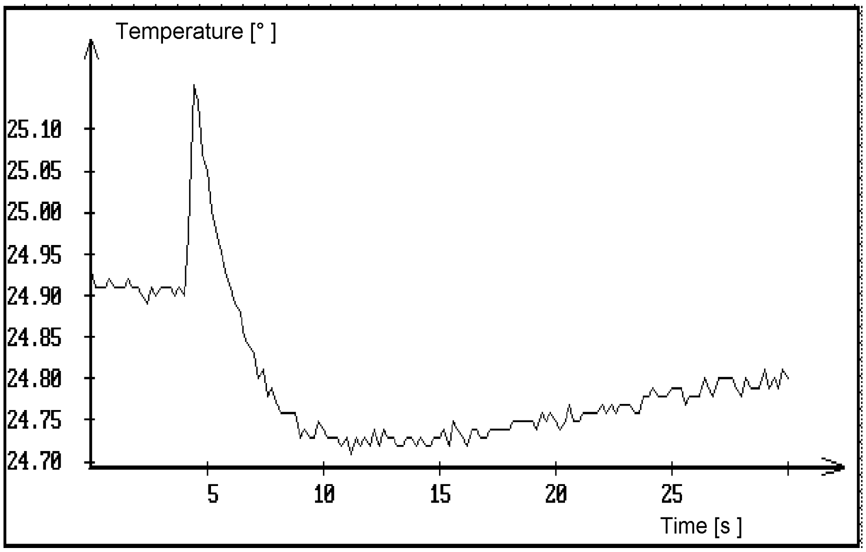


Figure 6. Temperature of the gas.

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