DOCUMENT RESUME

ED 419 709 SE 061 459

AUTHOR	Ahtee, Maija, Ed.; Meisalo, Veijo, Ed.; Lavonen, Jari, Ed.
TITLE	Proceedings of the Finnish-Russian Symposium on Information Technology in Modern Physics Classroom (Halsinki, Finland, April 21-24, 1993). Research Report 123.
INSTITUTION	Helsinki Univ., (Finland). Dept. of Teacher Education.
ISBN	ISBN-951-45-6599-1
ISSN	ISSN-0359-4203
PUB DATE	1994-00-00
NOTE	98p.
AVAILABLE FROM	University of Helsinki, Department of Teacher Education, P.O. Box 38 (Ratakatu 6A), Helsinki 00014, Finland.
PUB TYPE	Collected Works - Proceedings (021) -- Reports - Research (143)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	Computer Simulation; Computer Software; *Computer Uses in Education; *Educational Strategies; Foreign Countries; *Laboratory Procedures; Mechanics (Physics); Models; *Physics; Science Curriculum; Science Education; Scientific Methodology; Secondary Education; *Technology
IDENTIFIERS	Finland

ABSTRACT

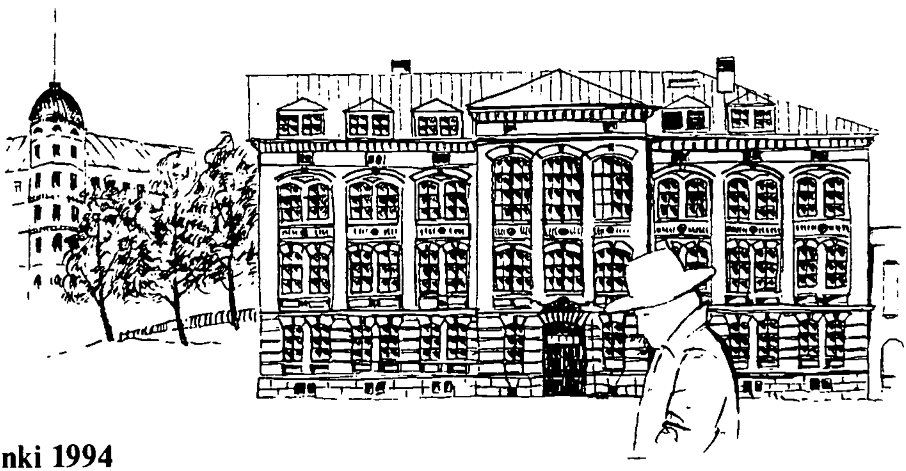
The 15 conference papers in this report address a variety of issues such as computer applications in mechanics and optics, three-dimensional representation in physics teaching, computers in the physics laboratory, information technologies, the perceptual approach in physics education, improving students' conceptual understanding in physics, using computers in teaching physics to medical students, physics curriculum reform, and the examination of two-dimensional motion with video and computer programs. Papers include: (1) "Computer Practical Works in Physics: Mechanics and Optics" (Vasily A. Davydov, Sergey V. Lavristchev, and Alexandre V. Skurikhin); (2) "Animation Programs and Three Dimensional Presentations in the Teaching of Physics" (Jyrki Hokkanen and Peter Holmberg); (3) "Computers in Physics Laboratory" (Ari Hamalainen); (4) "An Approach to Computer Based Educational Environment on Physics" (Vladimir A. Karpov); (5) "New Information Technologies in Education: Mathematical Simulation Processes and Systems" (V.P. Konovalov); (6) "'Physics by Pictures': Simulation of Physical Experiments and Problems on PC in School-Physics Teaching" (Stanislav Kozel and Nataly Soboleva); (7) "Perceptional Approach in Physics Education" (Kaarle Kurki-Suonio); (8) "Using Microcomputer-Based Data Acquisition To Improve Pupils' Conceptual Understanding in Physics (Jari Lavonen); (9) Information Technology in a Modern Physics Classroom" (Veijo Meisalo); (10) "The Renewal of Physics Curriculum in Finland" (Veijo Meisalo); (11) "Computers in Teaching of Physics for Medical Students" (Tiiu Muursepp and Toomas Muursepp); (12) "Computer Models of Physical Processes in School Education" (A.M. Popov, O.B. Popovicheva, and E.A. Volkova); (13) "Examination of Two-Dimensional Motion with Video and Computer Program" (Reima Rouvinen); (14) "An Analysis of Some American and German Simulation Programs" (Martti Vulli); and (15) "Educational Software Package 'Physical Games on the Display'" (M.G. Zaitsev and S.A. Stremyakov). Contains 123 references. (DDR)

RESEARCH REPORT 123

Department of Teacher Education
University of Helsinki

Maija Ahtee – Jari Lavonen – Veijo Meisalo (Eds.)

Proceedings of the FINNISH-RUSSIAN SYMPOSIUM ON INFORMATION TECHNOLOGY IN MODERN PHYSICS CLASSROOM



Helsinki 1994

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ISSN 0359-4203
Helsinki 1994
Yliopistopaino

To the Reader

The Finnish-Russian Symposium on Information Technology in Modern Physics Classroom was held in Helsinki April 21- 24, 1993. The main purpose of the Symposium was to bring together physics teachers and educators interested in developing the use of information technology in physics teaching and finding new ideas and resources for further improvements.

The possibility for organizing the symposium was introduced by Auvo Sarmanto from the Ministry of Education during the visit of professor V. A. Davydov in Helsinki in September 1992. After the Finnish Ministry of Foreign Affairs had promised financial assistance for the participation of the Russian representatives the organization of the symposium was started in January 1993. The organizing and programme committee was selected from the active members of the Teaching Section of the Finnish Physical Society representing the departments of Teacher Education and Physics at the University of Helsinki. The organizers wish to thank the University of Helsinki and especially the departments of Teacher Education and Physics for valuable support and assistance.

The problems in the arrangement of the symposium arose mostly from the shortness of time allowed for organisation. We may have been too careful in announcing the Symposium in Finland as well as elsewhere. Therefore, we hope that this collection of the papers presented in the Symposium will give an idea of the interests of the participants. There are further plans for continuing and broadening the line of the symposium possibly already next year in Russia.

Contents

COMPUTER PRACTICAL WORKS IN PHYSICS: MECHANICS AND OPTICS

Vasily A. Davydov , Sergey V. Lavristchev, Alexandre V. Skurikhin
Russian Physical Society, Kursovoi p. 17, 119034, Moscow, Russia.

Abstract.

COMPUTER PRACTICAL WORKS IN PHYSICS for secondary and higher school are a series of correlated programmes written in accord with concept of PC - simulations of real students experiments in school physical laboratories. COMPUTER PRACTICAL WORKS now contains 30 "experimental" exercises in Mechanics and 15 ones in Optics, many original demonstrations of different physical phenomena and a program Register for teacher. We plan to continue this work and to embrace with CPWP exercises practically all sections of fundamental physics.

It is widely acknowleged that the most direct way to a deep understanding of physical processes and systems is through their practical investigation by means of physical experiment. Such approach is traditional both for secondary and higher school in a form of practical works in physics.

The role of practical works in the course of fundamental physics can hardly be egagerated. At the same time the opportunities of educational physical laboratories (especially in the secondary school) are quite limited, hence almost each physical field has a large number of phenomena and effects that cannot be presented in a school laboratory. Among limitations we can ennumerate sophisticated experimental equipment required for the observation of some phenomena, the study of very long- or very short-living processes, very complicated methods of data analysis, etc.

We believe that an efficient alternative to a real experiment in such cases is a creative work of students with dynamic simulations of physical processes realised as computer programmes. Interactive programmes with visualisation of simulated processes in the monitor screen provide the posibility to study physical processes and phenomena in different conditions and to control them by variations of appropriate parameters.

Pupils are offered a set of original computer exercises based on the simulation of physical systems. Unlike conventional educational programmes our COMPUTER PRACTICAL WORKS are neighther animation of a handbook on fundamental physics nor purely demonstrational programmes made according to the scheme "question- answer". Quite similar to an ordinary laboratory work the pupil will have to select "experimental" conditions, observe the phenomenon and, the most important point, to use the "measured data" for determination of one or several parameters which control the evolution of the studied system.

Besides "experimental" exercises each Section of PRACTICAL WORKS is provided with demonstrations of original and beautiful physical examples allowing to obtain a deeper understanding of the studied phenomenon.

Another characteristic feature of these practical works is presentation of phenomena nonexisting in nature, e.g. the study of sputnik motion around a planet with gravitational field not obeying Newton's law.

The present version of COMPUTER PRACTICAL WORKS is oriented for computers of IBM PC with graphic adapters EGA or VGA.

Application of PRACTICAL WORKS in the educational process does not require special knowledge in programming, computer technique or computational methods. Knowledge of physics and mathematics in the frames of a secondary school is sufficient for succesful solution of problems set by PRACTICAL WORKS IN PHYSICS.

Experience in computer teaching revealed that a simple interface of a computer exercise should assists concentration on the studied problem. This is the reason why the graphics of computer experiments presents only necessary objects.

Issues of practical works envisage exersises and demonstrations in the folloing sections:

Gravity, Friction,Conservation laws, Motion of charged particles, Noninertial systems, Relativity, Mechanical systems, Oscilations, Hydromechanics in part "Mechanics" and: Optics of rays, Optics of waves, Lenses, Mirrors, Quanta in part "Optics".

The programme "REGISTER" is provided with the PRACTICAL WORKS IN PHYSICS" to control the work of pupils. It should be stored in the teacher's computer.

COMPUTER PRACTICAL WORKS IN PHYSICS are intended, first of all, for secondary schools, technical school and other secondary educational institutions as well as for students of technical institutes. PRACTICAL WORKS can also be helpful in preparation for entrance examinations in high schools as well as for those who would like to get a deeper insight into physical phenomena.

COMPUTER PRACTICAL WORKS IN PHYSICS were installed in many Russian educational establishments and are very popular among pupils and teachers. We plan during two years to embrace with "COMPUTER PRACTICAL WORKS" exercises practically all sections of fundamental physics.

ANIMATION PROGRAMS AND THREE DIMENSIONAL PRESENTATIONS IN THE TEACHING OF PHYSICS

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In the teaching process of physics the lecturer can use different aids to reach his goal: to give his students the best possible knowledge of physics. At the teacher's disposal are lectures, exercises, laboratory works, demonstrations, and excursions to factories, laboratories, etc. where the physical theories of the lectures are applied. As the teacher has only a limited amount of hours at her/his disposal for the educational task, the above mentioned different methods of teaching cannot be mixed in an arbitrary way. An instructor has to remember that the fastest way to present a physical law or phenomenon is to deliver a well-prepared lecture. However, from the pupils' point of view this theoretical approach is often not very motivating. The pupils are more interested in the time consuming laboratory works, demonstrations and excursions. Therefore, some of the practical experiences have to be included in the curriculum, too.

At this point the teacher can utilize modern audiovisual techniques. Video assisted teaching (VAT) provides many opportunities today to catch the interest of the pupils and to demonstrate physical phenomena. A video presentation can be delivered in several ways: by directly showing some examples of the phenomenon, by including animations showing only the essential parts of the theory or by including as an introduction some interesting parts from other programs (TV, cinema etc.) on every day life, adventure movies or pictures from nature. This vivid introduction will not only briefly touch the phenomenon under study but it will also catch the interest of the pupils and make them curious to know what comes next and also to know the explanation to the phenomenon they just saw.

While copying programmes from television has become commonplace and making one's own videos tailored to suit the specific needs of particular courses has become possible, copyright problems do arise. Copying and showing commercial TV programmes and video tapes, as well as recording music from records and cassettes for video soundtrack, usually requires a permit. Getting one is expensive, so it pays to be aware of the cases where copying is allowed.

The presentation of a video programme makes it possible for the teacher: to cover the subject in a reasonably short time, to concentrate on essential details of the performance and to zoom in on small scale details which would be difficult to observe otherwise (even if the pupils were on the spot). The teacher can also stop the video or show it in slow-motion and give additional explanations, if necessary.

Video has become an increasingly important aid in teaching not only as a substitute for laboratory work but also as a method in its own right. Graphical and animated presentations directly utilize the capacity of the human brain to process data visually. Animation has previously been limited to professional productions but with the introduction of the new powerful desktop computers and the latest software, it has also become possible for motivated teachers to produce informative and visually pleasing animation. With the help of a video card, computer created animation can be transferred onto video tape for easier presentation and distribution. Live and computer created images can be superposed and mixed.

Next we will focus on three dimensional (3D) animation, made by a computer and transferred onto video. The present day personal computers (PC) are powerful enough to create realistic moving 3D images, and software previously limited to Unix-workstations are now available for these advanced PC's.

The process of creating a 3D object in a computer starts by constructing a 2D object. This object is then lifted into the third dimension along a chosen path. In Fig.1 we have a closed shape and an open shape, the latter representing the path for the former, and a profile along the path for the 3D object-to-be. In Fig.2 a preview of the final object is shown, and in Fig.3 we have the final image. After a 3D object is created, its surface material is chosen from a library of materials or edited from bitmap pictures. The surface material may have bumps and wrinkles and may even be transparent to a desired degree. This will result in an astonishing reality in appearance, and indeed it is often impossible to tell a photograph of a real object from an image created by a computer. Spotlights, cast shadows, and added haze will complete the illusion of reality.

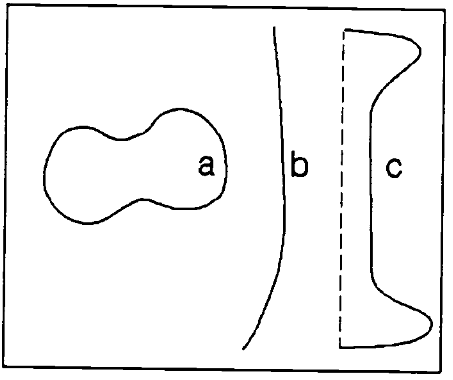

Figure 1. A three-dimensional bone-shaped object is created when the two-dimensional cross-section (a) is lifted into the third dimension along the curved path (b). The profile (c) scales the size of the cross-section.

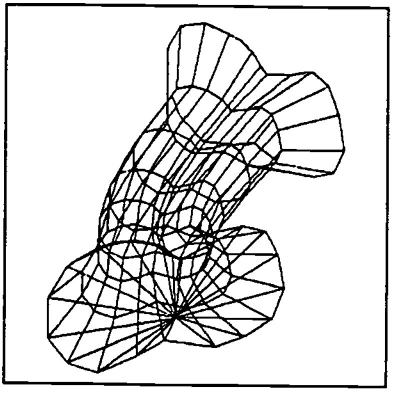

Figure 2. "Wire-frame" created from the elements of Fig.1.

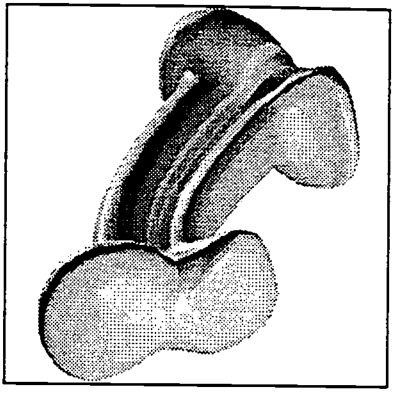

Figure 3. The object completed with a smooth surface.

Earlier, creating an animation meant drawing every picture by hand. Every second of an animation required 10 to 30 separate drawings, and therefore, creating even a short animated sequence took months. Nowadays, however, creating an animation requires only one sceneful of objects and a personal computer. The animation is produced simply by telling the computer where and how to move the objects, and how to transform them.

It does not take a trained graphic designer nor a computer freak to illustrate a principle of physics with a 3D computer programme. Although offering a large number of parameters for completeness, the programme's default settings work for most situations and an object is created with a few straightforward steps. In the programme's library, many useful objects are waiting to be used in animation, so it is usually not necessary for the user to construct complex 3D objects. Simple geometrical shapes are also readily available from the control panel.

Examples of 3D animation programmes running on PC's are Topaz 4.0 and 3D Studio 2.0. Special reduced prices apply for educational institutions, so the investment will be along the same order as for any ordinary computer programme. For transferring the ready animation onto video, a board is needed. Such computer boards are available from several companies and the recommendable ones with flicker reduction circuits cost around 10,000 FIM. However, these can also be used in overlaying text and graphics on live video to give a professional touch to the presentations.

COMPUTERS IN PHYSICS LABORATORY

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Laboratory exercises and lecture demonstrations are integral parts of basic physics courses in the Department of Physics in the University of Helsinki. Computer-aided measuring and data analysis are utilized in both of these. During a one-semester course, student has 1..3 laboratory exercises in which a computer is used as a measuring tool. In lecture demonstrations, computers are in general use. Approximately one half of all demonstration sessions have at least one experiment utilizing a computer.

The benefits of computer-aided measuring in laboratory exercises are:

- working methods in student laboratory have become more versatile
- use of graphics makes the results of the measurements clearer
- when the computer handles the routine manipulations, students have more time for personal interaction with the instructor
- students become familiar with modern instrumentation technology and data analysis

The benefits for lecture demonstrations are:

- several physical phenomena, which are impossible to demonstrate with conventional apparatus, can be presented with the help of computerized measuring devices

- it is possible to make real physical measurements and data analysis within tight time limits
- the results may be represented to a large audience numerically and/or graphically

Use of computers have also drawbacks:

- commercial systems may not be well suited for a task that has not been taken account in that particular system's design phase; systems also have annoying shortcomings and even bugs
- use of computers does not make the preparation for lecture demonstrations any easier; rather the opposite
- sometimes the technology may take the main role from the physics; how much the workings of a measurement system should be explained to the students?
- building own sensors and developing software with general-purpose programming languages is very time consuming

Following general-purpose measurement systems are used:

- Empirica system (one unit)
- Universal Laboratory Interface (three units)
- Digital storage oscilloscope with Matlab software (two units)
- Plug-In data acquisition boards (three units)

In addition to these, a multi-channel analyzer with software is used in nuclear physics laboratory exercises.

Jari Lavonen has an article about the Empirica in this paper. Some notes about the other systems follow.

Universal Laboratory Interface (ULI)

- Made in USA, developed in Tuffs University and Dickinson College
- Microcontroller-based interface unit
- Connects to computer via RS-232 serial interface
- Sensors for distance, force, voltage, temperature, radiation, pH

- Software: MacMotion (force and motion), Event Timer (motion), Data Logger (voltage), Event Counter (radioactivity), MacTemp (temperature)
- Software for Macintosh only at the moment, PC programs under development
- Current software does not include tools for data analysis
- "Open" system, technical data and programming interface are available - user may build sensors and write programs of his/her own
- Is used in students' laboratory exercises and lecture demonstrations
- Has proved to be very easy to use, for students too
- Some of the measuring software is too simple - some integrated analysis tools would be useful
- Does not take negative voltages, standard software does not support high sampling rates - does not fully replace an oscilloscope

Digital storage oscilloscope; data analysis with Matlab

The system is put together at the Department of Physics. It is used in demonstrations and laboratory exercises that require fast acquisition and advanced analysis of analog signals.

Parts of the system

- Digital storage oscilloscope with RS-232 interface
- PC-compatible computer
- Matlab software package for data analysis and graphics
- Serial communications and user interface software written in Turbo Pascal
- Sensors: force probe, microphone

Laboratory exercises and lecture demonstrations with the system

- Measuring rapidly changing force (e.g. fist blow) versus time: calculating the impulse of the force
- Finding equality between impulse and the change of momentum
- Monitoring voltages in AC circuits (RC, RL, RCL)
- Measuring electromagnetic force caused by self inductance
- Examination of sound waveforms from different sources

- Power spectrum analysis of sounds and vibrating strings
- Demonstration of FFT in digital signal analysis
- General enlarging a static oscilloscope display in lecture demonstrations

Characteristics

- Relatively easy to use
- Modular, expandable: for a person familiar with the system, it is easy and fast to write new analysis and graphics modules with Matlab language, and build a new application menu with the user interface
- Oscilloscope is a durable interface for signals varying from 1 mV to 40 V (up to 1 kV with an attenuator box)
- The necessity to transfer data from oscilloscope to PC makes the system more cumbersome compared with integrated systems

Plug-In data acquisition boards

- Boards are designed primarily for industrial and research purposes
- Boards have analog and digital inputs, digital outputs, and counter & timer functions
- Not supported by commercial educational software; high-quality packages for research laboratory and industrial applications are available
- Low cost, high sampling rate, accurate timing functions
- Narrow voltage range, poorly shielded against overvoltages - need to build or buy interface electronics, if used as a general-purpose device
- Own software may be written with high level languages either by writing and reading the registers of the board directly, or by using a subroutine library
- Currently the two boards are used with series of photogates on an air track and on an inclined plane. The third board is used as a voltage recorder with a laboratory exercise about photoelectric effect. Software for these tasks is written in Department of Physics.

AN APPROACH TO COMPUTER BASED EDUCATIONAL ENVIRONMENT ON PHYSICS

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The paper deals with the project called "Science Adventure". The project is oriented on producing the computer based educational environment for school physics curriculum. The project starts in the Institute of New Technologies, Moscow, Russia.

The main components of the educational environment are:

1) hypermedia textbook (with pictures and movies);
2) hypertext reference book;
3) physical laboratory works (models and real labs interfaced to computer);
4) set of tasks.

It is very complex to test the student's knowledge in the modules 1,2,3. The 4 is the base element for interaction and finding out what student have really learn out. So here we will pay attention to the task types and task tree structure in the school physics curriculum.

To build a task tree we have selected the node physical concepts and designed the corresponding node tasks. The tree do not let a student to miss any node task. A node task a set of help tasks and a modeling game form a node task level. The example of a level structure is shown below.

```
                    Game version
                         |
                    Node Task (calculating)  <----------- |
next node <---- OK                                        !
                     | no                                 |
                    Simplified task 1            yes      |
                         OK ------------------------>---  |
                         | no                             |
                    Simplified task 2                     |
                         OK ----------------    ----->--- |
                         | no                             !
                    Explanation of the task solving   ->- |
```

To inforce the motivation, to build a bridge between a life and simplified physical scheme the node level starts with a computer game or toy based on a model of the phenomena. The game lets students to feel the phenomena and the task by their fingers. But student has only 1 or 2 attempts in the game version of the task and it is impossible to reach the exact result without calculations and solving the node task.

After solving the equations and getting the data the student is able to put the data in and observe the game model, what happens. If the answer is OK he can either go to the next node or to play the game during some time period as a prize. If the data is not correct the student gets simplified tasks to solve.

These simplified tasks are to differ from the node task not only by complexity but by their types, by the ways the question is formulated and the way of putting answer. The most popular task type is "Selection" - menu type. Keeping in mind the four components of educational environment and the physical appliance of the tasks the following types of tasks have been selected and designed.

1. What could be determent on the base of the given set known parameters? What parameters are to be given for determination of the physical variable?

Example: select the parameters for determination an acceleration of the body that moves equiaccelerated and rectilinear.

Parameters: Initial speed.
Final speed.
Time interval of the motion. Displacement.
Body mass.

2. Find out the correct paragraph in the reference book describing the physical law for the proposed situation.

3. The student is proposed a physical phenomena and a set of physical parameters. The task is to select from the set those of the parameters that significantly influence the phenomena or on the process.
Example: What parameters are to be taken into consideration for determination free fall acceleration at predetermined point of some planet?
Parameters: Planet mass.
Planet radius.
Distance from the planet surface.
Body mass.
Angular velocity of planet rotation.
Angular velocity of planet revolution about the Sun. Planet surface temperature.

3a. Range the parameters by their influence degree.

4. Why questions.

4a. Menu type. The student is suggested to cconstruct the answer using the sentence pattern with blanks and a set of word menus. The correct answer is not to be single one.
Example: The body rests on the inclined plane. The external force is applied to the body, and it starts motion down the surface. When the force action terminates the body still continues its motion. Why?

Sentence pattern: Because ________ is ________ then
--------------------.

Menus:	sliding friction force	less
	plane inclination angle	more
	rest friction force	equal
	external force direction	

sliding friction force
plane inclination
angle rest friction
force external force
direction

4b. "Free" text type. The student is suggested to answer by typing the text in real language. For restricted number of questions it is possible to build not complex text recognition system that could even dialogue with the student if the answer is not complete.

In the project were included school teachers, physician scientists and programmers. But the task was too complex for small teem. We see the future of the educational environment design in cooperation with other teems. It stands a problem of developing some program interface standard to enable teacher to construct his lesson using modules from different manufactures and using simple scenario language.

NEW INFORMATION TECHNOLOGIES IN EDUCATION: MATHEMATICAL SIMULATION PROCESSES AND SYSTEMS

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Abstracts

Our software and teaching materials complexes based on the complex approach: mathematical simulations and especially work in "on-line" mode. There is a problem in the educational process: conditions of a task and equations are clear for students but methods for analytical solution pass out of the training program, so that big class of tasks quits from consideration.

New information technologies allow to solve this problem. New software tools can to simulate elements of complicated system and processes from different fields of science (physics, chemistry, mathematics, biology, geography, economy, electronics et other). Present software enables (using simple basic elements) to build models without knowledge programming languages.

It is extremely important that the level of student's activity may be changed by teacher from working with prepared scheme to self-dependent training of task and writing of equations and maximal pedagogical effect will be reached.

The main idea in development and practice realization of computer based training courses which are created in our Development Center (ELTI-KUDITS) is the complex approach. This concerns not only the content of our software and teaching materials complexes (STMC), but the hole spectrum of directions in which it is possible to put in the real educational process. In our point of view, maximal pedagogical effect is reached by combination of only computer simulation (i.e. working in the "microworld" of mathematical model) and working in "on-line" mode (i.e. with real objects and systems). Both directions are not except, but supplement each other and common didactical requirement is "activating of student's activity" at the expense of concentration of attention on the essence of the investigating questions (because of the release from routine work) and also at the expense of providing with possibility to intervene both in the work of the mathematical model and in the work of real laboratory equipment.

There is a problem in the training (educational) process: conditions of a task (for example physical task) and equations are clear for students but methods for analytical solution pass out of the training program, so that big class of tasks quits from consideration. In other side, the faculty to write serious simulating program means that user knows well subject, to the right sufficiently is master of mathematical apparatus and knows well programming languages (for example Pascal, C) and, at last, has time at one's disposal for work. All these demands are unreal for ordinary students. Besides that in study of some subject we must to concentrate our attention on the crux kernel of the problem. That's why students have not enough the time for self-dependent building of computer's program. And teacher also has not the time for that.

New information technologies allow to solve this problem. The system of computer's simulation, which was named by authors as "Stratum Computes" represents software tool for simulation of elements of complicated system and processes from different fields of science (physics, chemistry, mathematics, biology, geography, economy, electronics et other). Present software enables (using simple basic elements) to build models without knowledge programming languages.

In this system all models are building from basic elements, original "bricks", named "images". Each image consist of four "logical strata", tied together:

- pictogramm (conventional sing)
- mathematical contents (algebraic or differential equations, operations of conferring, logical operations, algebraic functions etc). It is

possible to enter to 30 equations or variables which describe behaviour or function of this "image"

- commentaries and explanations of mathematical equations
- three-dimensional picture of object, which is simulating in "image", if necessary.

By operating with these "images" which were taken from system libraries or created independently, student constructs scheme of process by connecting "images" with each other in accordance with given task. The method similar to structure schemes methods underlies of this "constructing".

It is extremely important that the level of the "independence" of student's activity may be changed by teacher from working with prepared scheme to self-dependent training of task and writing of equations.

In practical any process may be simulate by this software tool and schemes may be connected with real objects and systems.

In this case computer is the intellectual center of our laboratory equipments. Information from detectors pass directly to the computer and presents for students in more convenient, graphics mode. That permits to concentrate attention on the essence of the problem and, this is more important, to connect "world of abstract mathematical models" with the "real world" of physical, chemical, biologist, economic and others objects.

We suppose that using our methods (especially working in "on-line" mode) maximal pedagogical effect will be reached.

"PHYSICS BY PICTURES". SIMULATION OF PHYSICAL EXPERIMENTS AND PROBLEMS ON PC IN SCHOOL-PHYSICS TEACHING

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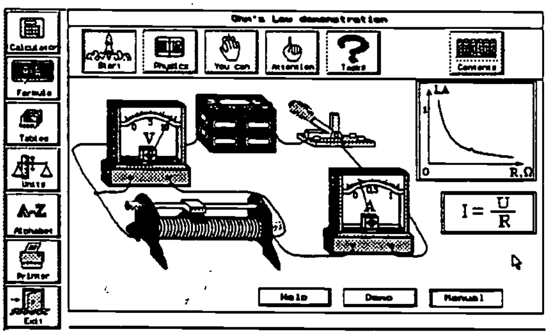
"Physics by pictures" includes many illustrations and colorful animations involving physical devices, schemes, and toy figures to explain and demonstrate different physical phenomena.



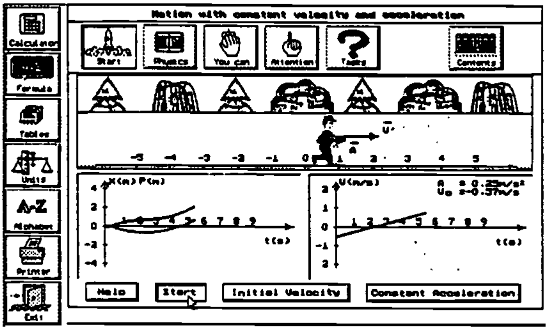
This software contains demonstration of basic laws of Mechanics, Molecular physics, Electricity, Optics, Atomic physics, as well as portraits and biographies of famous physicists, historical experiment examples, etc.

The package also includes some questions and problems for user and the means for solving them and testing the answers.

Some of the examples are designed as a flexible constructor for learning physics in the mode of fascinating scientific investigation.

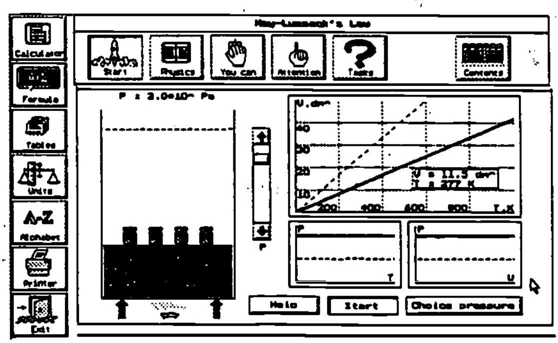
The product has this distinguishable features:

a) a simple in operation icon-interface like in programs for Windows,
b) strongly interactive mode using calculator, list of formulae, different tables, etc.
c) physics examples providing wide possibilities for thinking and investigation,
d) physics problems which can be considered at different levels of difficulty corresponding to user's desire,



This software is designed for:

a) schoolchildren who interested in learning Physics,
b) teachers who need assistance in teaching Physics.



Hardware requirements: IBM AT/286/386 compatibles, EGA or VGA graphic card, Hard disk, Microsoft compatible mouse, MS DOS 3.0 or higher. All text messages are contained in a separate file which can be easily edited or translated into different languages.

PERCEPTIONAL APPROACH IN PHYSICS EDUCATION

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Abstract

Perception is interpreted as creation of meanings. Subsequent conceptualization leads to terms and language. Science can be understood as a great perception process resulting from an expansive development of the primary sensory perception. Genuine learning has the nature of perception and it involves the processual elements of scientific method. It aims at understanding through unifying concepts of increasing generality. The hierarchical levels in the conceptual structure of physics make learning of physics a unique problem. Quantification, the threshold process from the qualitative level to the quantitative one forms the key problem. Learning of the basic concepts of mechanics is discussed as an example. Possibilities to support the perceptional approach with computers are analyzed shortly.

Meanings and concepts

Perception refers originally to the creation of sensations from sensory excitations. It builds up *Gestalts* which become organized into mental pictures understood as representatives of entities and phenomena of the real world. It is the basic process of *creation of meanings* followed by *conceptualization* of the Gestalts which leads to *creation of language*. It is primarily unconscious interaction of observation and mind. Some structure and laws of the human mind control the character of possible Gestalts, but all mental pictures are subordinated to observation. Separation of the mutual roles of the mind and the observation is, however, not possible. There are no pure observations, nor any purely mental constructions. Therefore perception is basically not a logical but an *intuitive process*.

Science is interaction of experiment and theory through the scientific method. It is similarly a process of creating meanings where experimental and theoretical elements are inseparably interwoven. There are neither purely experimental experiments nor purely theoretical theories. Science is a result of a development starting from the sensory perception and expanding hierarchically through learning and studying into research and science. The degree of consciousness increases but the basic nature of the process remains. Science is a highly developed and structured perception process and perception is the seed of science.

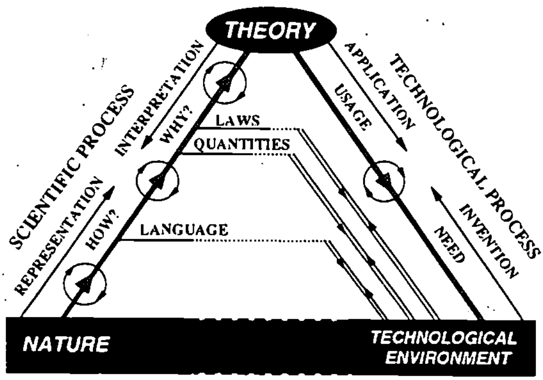

Figure 1 Four-process model of perception.

The process is maintained by two basic motivs, understanding and usage. The questions *why* and *what usage* divide the process into two orthogonal branches, the *scientific* and the *technological* process. Both are one-way processes working between Nature and Theory through two-way dynamics, fig. 1. This four-process structure of perception can be recognized in all stages of the process. The primary excitation of senses, the mental pictures developed, adaptation of behaviour accordingly and trial-and-error type searching of ones possibilities are necessary elements of perception. They are the seeds of science and technology, experimental and theoretical, applied and inventive research.

Science operates from Nature to Theory and aims at understanding. It is the primary prosess of creation of knowledge. *Technology* works from Theory to Nature. It is a secondary process which makes use of the understanding to control the Nature and to elaborate it to meet better the human "needs". The technological process changes the world — the scientific process changes the world picture.

According to the basic idea of empirical science *"how" is the only way to "why". Interpretation* becomes possible through *representation* of Gestalts. Perception is understanding and understanding is perception. The whole structure of physical knowledge is based on unifying ideas of increasing generality, Fig 2. There is no final understanding but a hierarchical chain of more general interpretations.

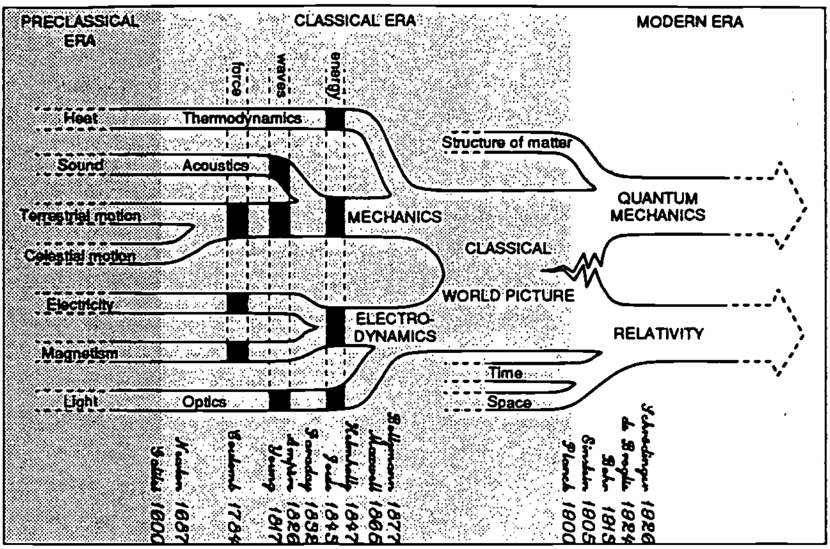

Figure 2. The achievements of science are unifying ideas.

Learning is part of the development of sensory perception into science. It involves all processual elements of science, and it has the processual nature of perception. The core of learning is increasing understanding through unifying concepts. But the key question is not how to introduce concepts but how to help creation of their meanings. Meanings are developing processual elements of mind, Gestalts born first. *Concepts* are introduced as their representations. They are *elements of language* and tools for further perception.

Physics and quantification

On all fields conceptualization of the empirical world leads to increasing generality and abstraction and yields a hierarchical structure. Higher concepts are born as structural Gestalts of lower ones. Transition to quantitative methods and concepts gives this development a new dimension, which is characteristic to physics only. This makes physics different from all ather branches of science and learning of physics different from any other learning. In the *conceptual structure of physics* three successive hierarchical levels can be identified, fig. 3. Learning of physics involves, thus, processes of "normal" conceptual development within the levels and threshold processes from lower levels to higher ones. Creation of concepts on a higher level is based on the lower levels. At the same time it gives new possibilities to proceed on the lower levels and builds thus further basis for perception of higher level Gestalts.

Concept formation of physics starts from the level of qualitative knowledge. In *basic perception basic Gestalts* are identified, classified and connected into mental structures through perception of their mutual relationships. The basic Gestalts include particularly, the *entities* or subjects of nature, the *phenomena* or events of nature and their *properties* and the Gestalts of *conservation or change, dependence, cause* and *influence*.

The empiricalness of this level consists of observations and qualitative experiments supporting the basic perception through variations of the system and surroundings. Its theory consists of conceptualization of the Gestalts, creation of terminology and language using it, and of construction of corresponding mental pictures.

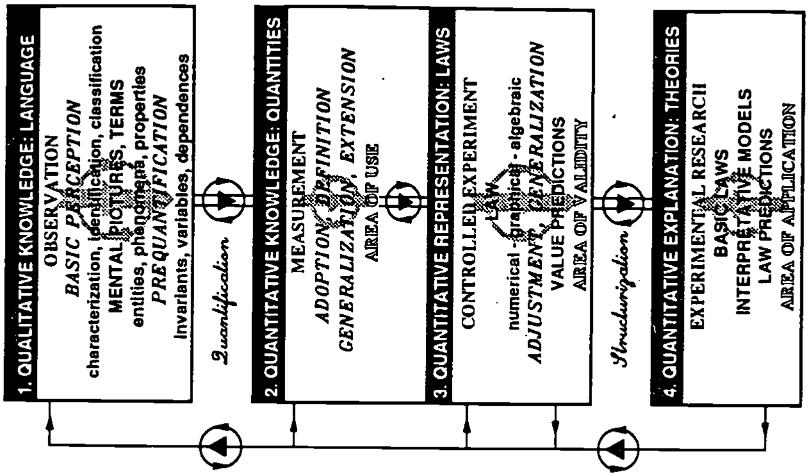

Figure 3 The hierarchical levels of physics.

Quantification is a threshold process which transforms qualities into quantities. It builds a quantitative structure of concepts on the foundation of the qualitative system of Gestalts. The idea of measurement has been introduced also in other fields. But nowhere else does it give rize to representation of properties in terms of quantities which are combinations of units and numerical values, and to quantification of correlations into laws representable as equations between quantities.

Quantification is the first great abstraction. There is an immense gap between qualitative and quantitative thinking. Many difficalties in learning physics trace back to trials to neglect it or to find some short-cut instead of pointing it clearly out. *Prequantification* prepares the way for it. It means perception of *comparative Gestalts* referring to degree or strength of properties. It makes possible to speak about stronger and weaker properties, larger and smaller entities or faster and slower phenomena *etc*. It awakes the questions "how strong, how large, how fast".

Quantities and laws are the quantitative parallels of properties and phenomena -- or actually of the Gestalts of conservation, change, dependence, cause and influence characteristic to the phenomena — respectively. Laws are relations between quantities. In this sense they are higher in hierarchy. However, definitions of quantities are based on laws. Thus, the levels of quantities and laws are tied tightly together.

Quantities form the conceptual basis of whole physics. Quantitative representation is based on quantities. They span the bridge from observations to theoretical models. They tie together the empiricalness and exactness of physics. Empirical information is expressed in terms of them. Theories are defined through basic relations between quantities. Therefore understanding of the meanings of quantities is the key problem of learning physics.

The empirical meaning of a quantity is a Gestalt born before the quantity. It is conceptualized on the qualitative level as a property of some entities or phenomena. Without such *characterization and attachment* the quantity is left without meaning.

The quantity itself is born by the property through a *quantifying experiment* which, at the same time, is verification of the *defining law* of the quantity. This is a narrow gate. It requires *reduction and idealization* in order to invent a simple experimental situation, where comparative Gestalts attached to the property can be given a quantitative meaning, so that quantitative comparison of different degrees of the property becomes possible. This involves always the possibility of choosing a unit either by taking some easily reproducable degree of the property as the unit or coupling the unit to the units of quantities measured in the quantifying experiment. The guiding principle is that *quantities are born as invariants.*

The theoretical meaning of a quantity is born through *structurization*, the threshold process leading to the level of theories. It is expressed by the position of the quantity in the structure of the physical theories. This is a rather late stage in the process of creating the meaning.

Basic definition gives the quantity a restricted meaning, valid in the ideal situation of the quantifying experiment. It is followed by a process of *generalization*, where the meaning is extended to wider classes of entities and phenomena. Definition of a quantity is, thus, not one step from concrete to abstract but a continual process or a bunch of processes. A quantity has a chain of meanings of hierarchically different levels based on each other. Thus, quantities are rather processes than products.

Starting mechanics

Application of these principles leads to *the perceptional approach*. For instance, in *mechanics* the basic perception should lead to identification of three basic Gestalts, the *bodies* as the entities, the *motions* of bodies and the *interactions* between bodies as the phenomena which have a causal relation. *Inertia* of a body, *magnitude of the change of motional state* and *the strength of interaction* are their respective properties. These are easily prequantifyable. Stronger interaction is needed to cause larger change of motional state and larger inertia of a body makes its state of motion more difficult to change. It is concluded that kinematics should not be taught separately from dynamics.

On a qualitative level it is possible to build a mental picture where interactions are understood to be the only causes of changes in the state of motion. As the first step of quantification one is then lead to the idealized concept of a *free body* with no interactions at all and to the *law of inertia*. The existence of an ideal class of even motions is thus motivated and an idealized experiment can be planned to define the *velocity* through the law $\Delta \boldsymbol{r} \sim \Delta t$.

Inertial mass, momentum and impuls or force result from quantification of the three key properties. It is obvious from the basic perception, that the ideal situation for the quantifying experiment must involve two bodies and one interaction. This leads to studies of collisions of free bodies or of bodies on an air table. Collision experiments offer the possibility to compare the inertias of two bodies A and B. After statement of the astonishing independence of the ratio $|\Delta \mathbf{v}_A|/|\Delta \mathbf{v}_B|$ of the nature of collision they can be interpreted as a measurement of the *inertial mass* of B with the mass of A. The *change of momentum* $\Delta \mathbf{p}$, which has equal magnitude for both bodies, follows then as an obvious measure for the change in the motional state. At the same time it yields a measure for the strength of the interaction, which will be called *impuls*.

In the conventional way of starting from one-body motion leaves the concept of force (impulse) is left without meaning. Because its "host phenomenon", the interaction, is excluded from the experimental situation it cannot be seen to represent any property of anything. It is important that the situations where nonuniform one-body motions are studied are understood as idealized limiting cases of two body systems where one of the bodies is very heavy. Then it becomes possible to invent an ideal situation where interaction with a large body acts "smoothly" and to motivate thus introduction of *acceleration* and *force.*

Role of computers

The role of computers in the perceptional approach can be analyzed within the sceme of the hierarchical level structure and the two directions of logics involved in the process. In computer aided measurements, in treatment and analysis of the data, in forming graphical representations of the results to percieve the nature of dependences, in algebraic modelling of them *etc.* the computer supports the primary scientific process proceeding from experiment to theory at different levels. While in simulations and predictions i. e. studies of the behaviour of theories and models, it works in the secondary direction from theory to experiment. Uses of both types can be and have been developed for supporting any of the critical processual stages, basic perception, quantification and structurization.

It is important to realize that perception is the process of the pupil, not of the teacher nor of the computer. Each processual element has to be learned by the pupil. He learns to observe, measure, plan and realize controlled experiments and do experimental researce and to conceptualize observations, represent results, interprete, model, predict etc. Therefore computerization should not proceed too fast. Only processes already learnt by the pupil can be automatized without violating the natural learning.

USING MICROCOMPUTER-BASED DATA ACQUISITION TO IMPROVE PUPILS' CONCEPTUAL UNDERSTANDING IN PHYSICS

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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.

A pedagogical research and development program has also been initiated to produce teaching materials as well as different practical approaches to the problems of teaching-learning situation in schools. Here, we have utilized the "Extended Market Square" model developed by Meisalo (1991) and the idea of "Perceptional approach in physics teaching" emphasized in Finland especially by Kurki-Suonio & Kurki-Suonio (1987). The qualitative results of the evaluation of our approach support the claims of the pedagogical versatility of our approach. Our system is already in use in several Finnish schools.

1 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).

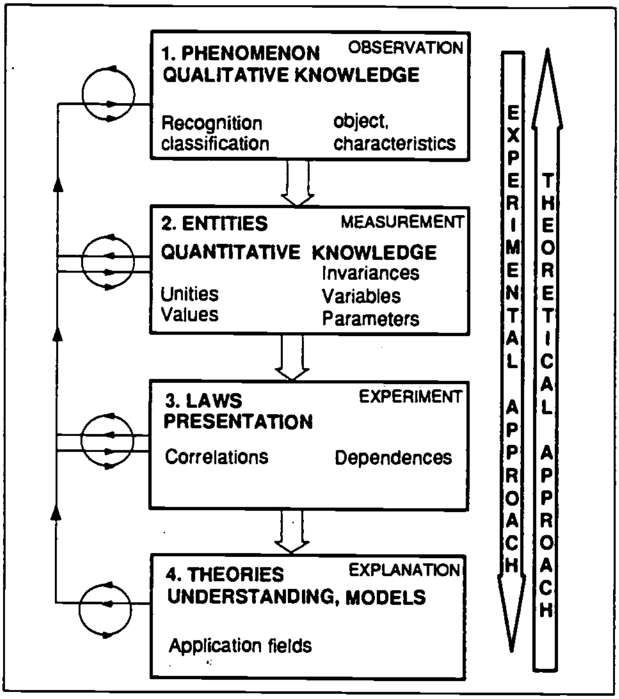

Figure 1. Experimental approach.

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.

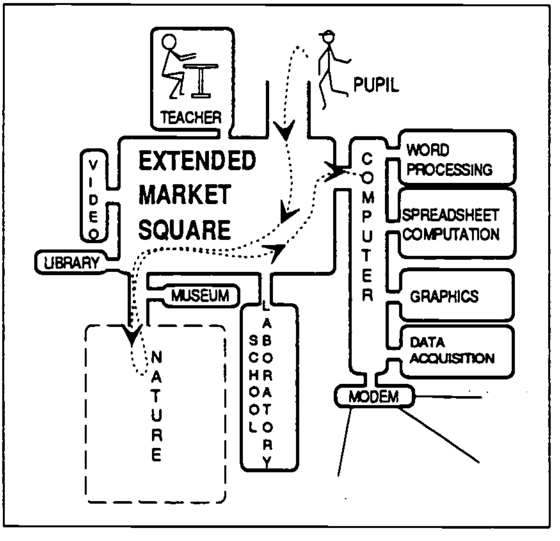

Figure 2. The "Extended Market Square" model.

2 The Data Acquisition System and Software

History

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).

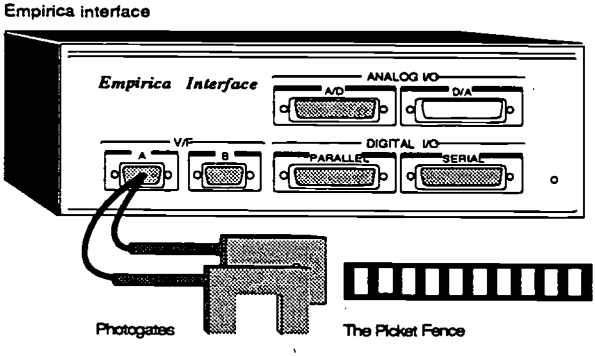

Figure 3. The Empirica interface.

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.

The Future

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.

3 Example 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.

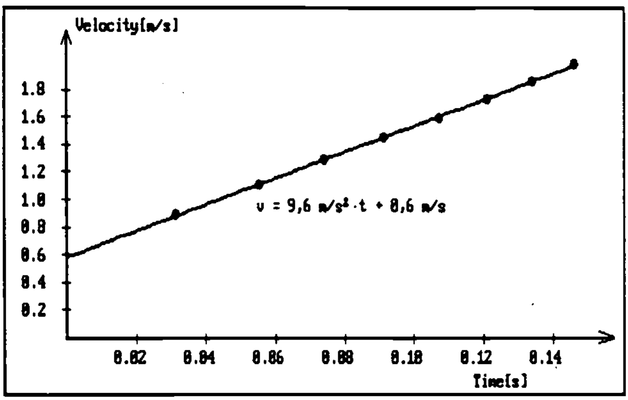

Figure 4. Concept of acceleration.

Internal energy of gases

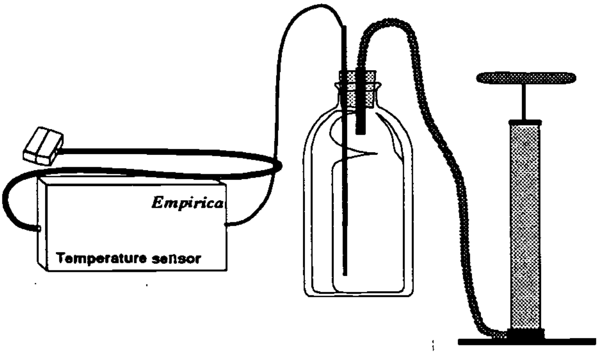

Figure 5. Measurement of air temperature.

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.

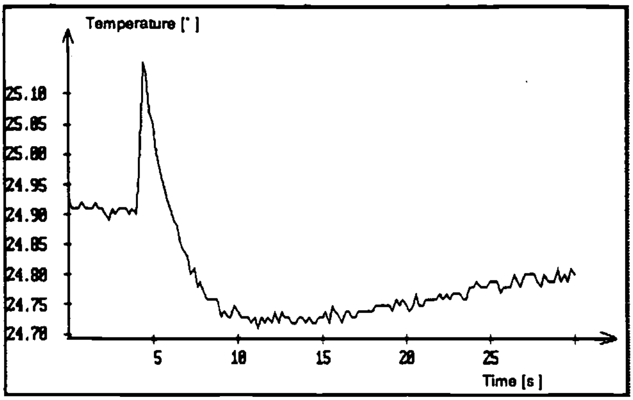

Figure 6. Temperature of the gas.

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INFORMATION TECHNOLOGY IN A MODERN PHYSICS CLASSROOM

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Abstract

This report describes and analyses shortly the Extended Market Square Model developed at the Department of Teacher Education of the University of Helsinki. This model emphasizes, that in science teaching we have to observe the experimental nature of sciences and avoid the idea of any virtual world replacing the real nature. It also helps to understand the central role of each student in the learning process. In this connexion we discuss some new ideas on the relation of student autonomy and social interaction as described by our model.

Introduction

The computer is today a common tool in our society in general as well as specially in the modern educational environment. For instance in Finland all secondary schools had already several years ago the possibility to teach informatics using a hands on approach (cf. Meisalo 1989). It has been considered important already in the present curriculum of Finnish secondary schools and it is emphasized even more in the suggested new curriculum, that computer technology shall be applied widely in all school subjects. Astonishingly enough, informatics as such will apparently not prevail as an autonomous subject in the national curriculum (Meisalo 1993). Most schools will probably offer a workshop type of elective course, where the use of a computer as a tool in school activities will be trained.

The Nordic countries have been cooperating for several years in producing materials for computer assisted learning (anon. 1991). There was a need to find a breakthrough application, which could help in introducing coputers in all classrooms. In the Nordic project the central idea was to design programs following the so called Market Square Model (cf. Minken & al. 1988). These CAI programs have the principle, that when working with a simulation model the student may select a number of tools offered by the program like vendors offer their products and services on a market square. The use of these tools makes possible solving of different kinds of problems encountered with the simulation. There are many good features as the student has wide intellectual freedom in comparison with old Skinnerian CAI. This approach can obviously be developed in the direction of virtual reality. However, we want to open the design principle to include some essential features of modern science teaching and avoid the illusion that the Nature itself can be simulated faultlessly and contained in a computer.

The Extended Market Square Model

We feel stronly, that in science teaching emphasis has to be put on direct observations and experiments instead of simulations or even far developed virtual world. Thus physics teaching should be based on direct observations and experiments while the computer has to be included as an integral part of the school laboratory, connected through electronic mail to data banks, to other schools and libraries, co-operating local industrial laboratories etc. The Extended Market Square is not restricted to a computer, but widens to include the Nature herself even outside the school as experienced during field trips and other practical activities and projects. It is easy to extend to contacts even over national borderlines, if necessary. The ideas of an autonomous student selecting appropriate tools for solving problems and learning about physical phenomena can be included in this wider context. The teacher neither remains as a principal source of information nor is put aside as an outsider, but has an essential role as an expert and a consultant for the pupils. These ideas we try to visualize in Figure 1.

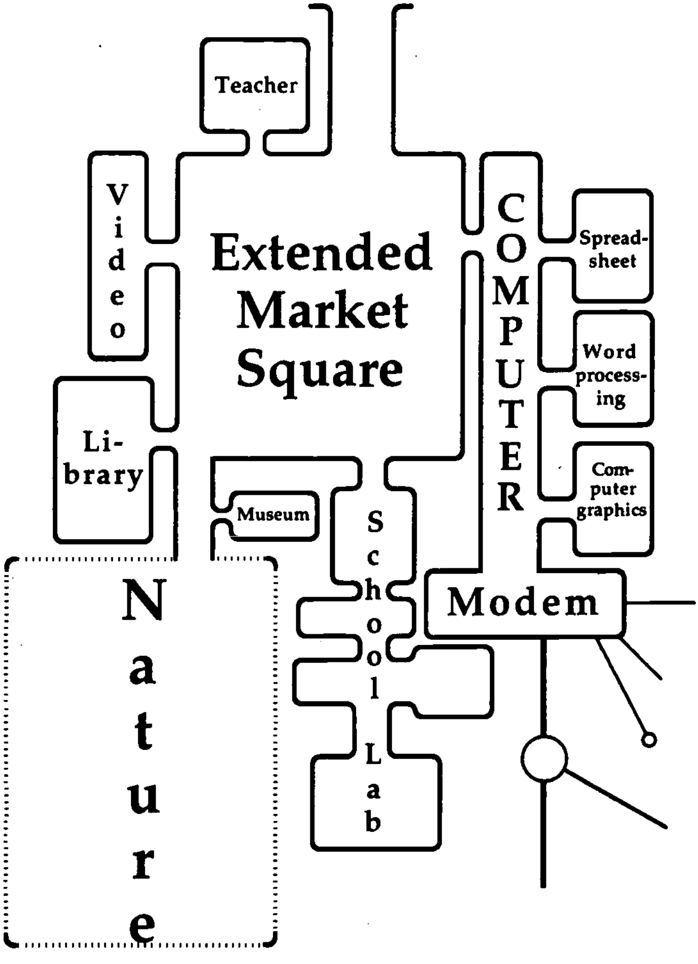

Figure 1 Extended Market Square

A student enters the market square of the model "through the channel" and follow individual paths around the square. A student may start consulting the teacher, proceeds according to the needs of the individual problem or other task, possibly to see some videos or books in the library, etc. The school laboratory with different experimental setups is available as well as, of course, a computer with a variety of software. The use of computers is very important also in the analysis of experimental data and producing the reports of laboratory experiments and projects.

It is to be noted, that although we emphasize the autonomy of each pupil, the market square idea actually brings forward also the possibility of social interaction between students. Like a market place in a busy town, even a physics classroom and the whole schoolhouse with their modern facilities will activate many discussion seeking and giving advice, debatting, reporting interesting results, etc. Practical experience shows, that when the idea of the Extended Market Square Model is followed, pupil to pupil interaction grows quite naturally in the actual learning situations. The Extended Market Square Model has the Square as the place, where the paths of different pupils are crossing, inviting for various kinds of positive intellectual interaction.

At the Department of Teacher Education of the University of Helsinki we have also worked for developing sowtware to be used when following the ideas of our model. It is important, that the man-machine interaction is smooth, since a clumsy interface distracts the interest of a student. This is one of the reasons, why we have found it advisable to design programs for Windows.

The EMPIRICA project organized by Lavonen (Lavonen 1989; 1991) is a good realization of these principles.

Conclusions

We have worked in different subject areas furthering the above ideas for getting good results. This model has also been used widely in teacher education helping students to grasp the essential principles of usinf modern technology in physics education. There have been e.g. a number of seminar projects at our Department applying and testing this approach. However, we feel that a lot of practical educational research and development work has to be done, before we can utlize fully the powers offered by new and rapidly renewing technologies.

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THE RENEWAL OF PHYSICS CURRICULUM IN FINLAND

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Abstract

This report analyses the current process of curriculum renewal for secondary schools in Finland and the presently available draft of the new physics curriculum, which is expected to be put into effect from autumn 1994. There are are several changes to the present curriculum. The renewal was demanded originally by a State Committee, which had to make proposals to promote Basic Scientific Education. However, the changes we see in the new curriculum do not mean any major favours to sciences. In the upper secondary school there is a short physics course, which is compulsory for all students. According to the present curriculum all students who so wished, could decide to take no courses in physics. On the other hand, far more freedom is offered to the local school administration and schools. Physics teachers have to be prepared to make advantage of the new possibilities. The use of information technology for teaching all subjects is emphasized, but it is problematic, that the national curriculum does not have information technology as an official subject area.

Introduction

The present structure of the Finnish school system with the comprehensive school of nine years was created about twenty years ago. The curricula for its primary and lower secondary stages are equally old. The general goal of the comprehensive school has been to develop the full personality of its pupils. One of the problems of these curricula was, that the general goals were very broad and idealistic, while the subject oriented aims and goals were detailed and rather narrow. On the positive side was the emphasis given on practical work in science teaching. Nevertheless, according to the feedback collected by the National Board of General Education even science teaching was too much teacher centered and based on rote learning in many schools.

The original comprehensive school curricula have been gradually amended by the National Board of (General) Education. In the search for new pedagogical approaches in science teaching the activities inspired by the Science and Technology Education Programme of UNESCO through its Network (INISTE and its national branch FINISTE) were important (cf. Meisalo 1989). More modern editions of the curricula were published in 1985. Then even the curriculum of the upper secondary school (Gymnasium) was rewritten in a similar form. However, many teachers and educational specialists felt that this renewal was more of technical nature, and that a more thorough renewal was needed.

The process of curriculum renewal

The current process of curriculum renewal started as a result of discussions in public, where demands for more effective teaching both in sciences and in foreign languages were expressed. These voices were heard from business and industry as well as from institutions of higher education. A State Committee, which had to make proposals to promote Basic Scientific Education, started its work, and its recommendations (anon. 1989) were accepted by both the Parliament and the State Council. The Ministry of Education collected feedback and and the National Board of (General) Education was supposed to start the necessary renewal process in practice.

The National Board of Education initiated the work for curriculum renewal by nominating in September 1991 expert groups in different subject areas. Physics and chemistry were assigned to a single working group chaired by the present author. The other members represented the Department of Chemistry of the University of Helsinki, the Teachers' Union, industrial organizations, and different school levels. This group studied trends in curriculum development in different countries studying available information in literature, through personal contacts and visits. Previous studies on the analysis of aims and goals as well as development of pedagogical approaches related to the work of FINISTE were utilized as a basis for the work. Brainstorming sessions were held to find out new ideas for curriculum development. There were also common seminars with other groups (biological sciences and mathematics).

According to the instructions given to the expert groups the new curricilum was to be written on a rather general level. Much weight was put in our work on the analysis of aims and goals in science teaching. These were divided in four groups: A. Kognitive skills, B. Laboratory skills (including skills of field work), C. Skills of human interaction, and D. Skills of an autonomous personality (cf. Meisalo 1991). The analysis emphasized the interrelation to the general aims an goals of education, having subject matter more as a medium to introduce problem solving skills, readines to team work, critical analysis etc. Subject oriented goals were presented in relation to the skills and knowledge needed of a physicist on the other hand, of a civilized citizen on the other.

The subject matter was analyzed and structured in relation to the aims and goals of teaching. According to the general instructions, the content matter was not to be assigned to a certain grade level, but only for the junior secondary school (grades 7 to 9) or to the Gymnasium (grades 10 to 12). This left the order of different courses open, and gave each teacher the possibility of creating his/her own approach.

The number of teaching hours in the school in each subject is in the Finnish system decided by the State Council. At the beginning of the curriculum work a preliminary number of hours was given for each subject as a guideline. It was suggested, that more freedom should be given to each school and to individual pupils and their parents in comparison with the present quite fixed system. For instance, it was also suggested, that in the Gymnasium School there would be two physics courses (about 32 net teaching hours each) common to all students and each student could then take one or more elective courses of the list of five in the nationally recommended list. It was planned, that the common courses in physics, chemistry, biology, geography and environmental science were to form a coordinated basis for science education. Schools could have also have some extra courses tailored according to the local needs and interests. For the moment it seems that after some debate there will be a change to a single commom physics course and that there will be no course of environmental science. Other major amendments concern mainly teaching of Swedish (the second official domestic language) and religion. Final decisions are expected in near future. The expert groups have felt very unfortunate to plan the curriculum with no exact knowledge on these details.

The expert groups had to give their reports in the beginning of February 1992 to the National Board of Education. After that the proposed subject oriented curricula have been fused by NBE to a complete proposal for the curriculum of the comprehensive school and Gymnasium, the first (A) version being distributed widely in October 1991. The proposal has been again commented officially and inofficially by a large number of different institutions as well as private persons. There have been major amendments to the form of the document, but the main ideas have remained through versions A, B, C and D, which were produced by officers of the NBE. The presently available draft of the curriculum is yet expected to be amended at least to some extent before it will be officially introduced. Since the comments on the first drafts have been partially contradictory, it is not easy to see, what kind of amendments there would yet be necessary. However, it is probable, that there will be more detailed treatment of the contents of different courses in the final curriculum. It is expected to be put into effect gradually, first schools applying it by autumn 1994. Of course, there are already several experimantal schools testing the ideas presented in the proposals.

The new curriculum in physics

The new curriculum in physics will follow, according to the presently available draft, largely the ideas suggested by our expert group. The experimental nature of sciences and the role of physics in relation of other sciences is emphasized.

In the lower secondary school the number of teaching hours in physics as well as in chemistry is expected to remain on the present level. There are two levels of aims and goals: On the qualitative level the goal is that

- pupils learn basic concepts, principles and laws related to physical phenomena,
- can discuss matters related to physics and use this information in problem solving and decision making,
- can make observations, and
- understands the importance of physics to the development of our culture and solving of environmental problems.

On the qualitative level the goal is that each pupil

- can make quantitative measurements, report and evaluate them,
- can apply physical information in soving environmental and other problems, and
- can use different kinds of models in explaining physical phenomena.

The most important content areas are according to the curriculum

- Structures and systems
- Interactions
- Energy
- Processes

This presentation of subject matter allows many different approaches on the school level.

In the Gymnasium school there will be one physics course common to all students. It is called Physics as a Science. Each school has to offer at least seven elective courses, whose topics include Physics in the Society, Mechanics, Heat and Energy, Wave Motion, Electricity, Electromagnetism, and Modern Physics. If the school has necessary resources, it may offer even several other courses, like Electronics, Experimental Physics, etc. By the time of writing this text, it is not known how the subject oriented aims and goals as well as the contents of different courses will be written in the final version of the curriculum.

Discussion

The new curriculum is very general and open giving great deal of opportunities to each school and each teacher. It means also, that substantial work has to be done in developing local curricula on the basis of this national framework. This work has been started in many schools, and in fortunate cases they will be mature to introduce the new curriculum already in 1994. We have started this work also with the Second Normal Scool of our University and we are writing also a guidebook for other schools to help them in this task. However, it seems that many school will go to the new system somewhat later. The present economical situation makes the renewals even more difficult on the local level, when reduction in salaries are endangering the positive working atmosphere in schools.

The renewal was demanded originally by the State Committee on Basic Scientific Education. However, the suggested changes do not mean any major favours to sciences. Of course, one may note, that in the Gymnasium school there is a short course in physics compulsory for all students, when earlier no physics was compulsory. On the other hand, far more freedom is offered to the local school administration and schools. It is generally considered as a threat to science teaching, but it can also be turned as an advantage. The physics teachers have to be prepared to make advantage of the new possibilities. The use of information technology for teaching all subjects is emphasized, and in science teaching there could be good possibilities for utilization of modern technology in the school laboratory. However, it is problematic, that there are no national guidelines and no time is allocated for informatics courses in the national curriculum.

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COMPUTERS IN TEACHING OF PHYSICS FOR MEDICAL STUDENTS

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At the University of Tartu the course of general medical physics delivered to the first year students consists of 64 hours lectures and 96 hours of laboratory work.

The choiceprocess of students to the University of Tartu does not include an examination in physics and the pupils entering the medical faculty do not prepare themselves especially in this subject. Therefore they have forgotten a considerable amount of knowledge in physics and this must be taken into consideration in the lectures and laboratory works.

The main purpose of our course of physics for medical students is to show that physics is natural science that gives a fundamental method for obtaining knowledge in different fields of human activities, including the medicine. This method is based on measurements, data analysis and the theoretical interpreting of results.

Therefore we consider the practical works very important because during these works the students have to conduct their own measurements and calculations. The number of students in a group is about 10, so discussions about the results of measurements of physical principles and medical applications can provided individually.

Introducing the computers in teaching of physics for medical students we are interested to show them that computer can be very effective tool in all stages of the scientific method. This idea is realized step by step according to our financial and other possibilities.

The use of computers in our laboratory works can be classified as follows.

1. We have planned a series of teaching programs about physical principles and methods in medicine. This series includes programs about the properties of radioactive radiation and dosimetry, about the principles of bioelectrogenesis and electrical properties of living tissue, and about the various electrical methods in therapy. In the present stage these programs may be named as "theoretical", that means that measurements are made corresponding to themes listed above, but experimental data are not put in a computer in context of these programs. Students get a review from about corresponding principles and methods and at the end of every program they have to answer to a series of questions checking the understanding of the topic.
   The programs described in this item are planned to develop further.

2. Another type of programs help the students to make necessary calculations with the results of measurements. For example, a simple program enables to approximate measured relationships between two physical quantities with the method of least squares. The linear and exponential relationships, with or without a fixed point, can be treated by this program. A statistical estimate of errors is also included into this program and the regression coefficient is calculated. For example, the measurements of the absorption coefficients of light in a series of solutions with different concentrations, or the dependence of the absorption coefficient of ionizing radiation from the thickness of various materials and several other measurements can be treated with this program.

The program, calculating from the results of measurements the dependencies of the electrical impedance and of the capacitance of living tissue from the frequency of alternating current can also be classified into present item.

3. We have begun to work out programs in which computer controlled automatic recording of experimental results is followed with data analysis and corresponding theoretical explanations. Following two examples can be given in this field of our activities.

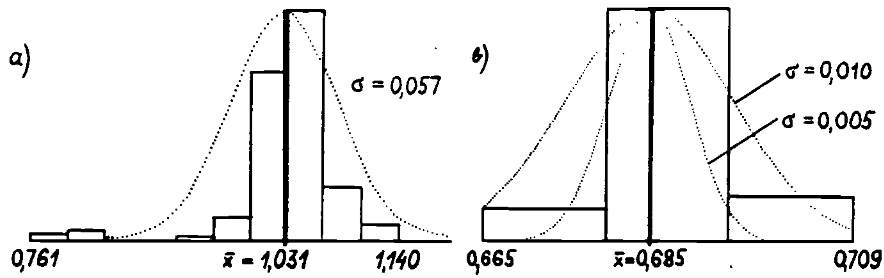

Figure 1 Frequency histograms of time intervals between two consecutive heart pulses before (a) and after (b) a physical exercise.

3.1. An experimental setup is constructed with consists of a special sensor, computer and interface. The sensor is worked out in the laboratory of biophysics of our University by physicist V.Reeben, and it consists from a light source and a photoresistor.

In the experiment, tip of the finger is fixed in the sensor. During the heart cycle the filling of the fingertip with the blood will have periodical changes in time and the optical density of the soft tissue of fingertip will follow these changes. Reflected from the soft tissue light is recorded with a photoresistor and an electrical signal is formed. Time dependence of this signal is principally similar to an electrocardiogram. In the process of electronic treatment of signals, finally time intervals between two consecutive heart pulses are recorded. The number of recorded heart pulses can be varied up to five hundred.

After the recording of a fixed number of time intervals between consecutive heart pulses, a statistical data analysis follows and on the screen of the display this analysis is accompanied with explanations of the meaning of following fundamental terms of elementary statistics: frequency histogram, average over the whole population and over a sample of values, variance and standard deviation for a population and for a sample, confidence interval, Gaussian distribution, etc. As an example a part of a computer outprint is given on figure 1.During the data analysis the students can vary the number of intervals of the histogram, they can change the variance and look at the corresponding change of Gaussian curve.

The experiment can be provided before and after a physical exercise and, in this way, the recurrence of the heart work can be investigated.

The program described above is intended to develop further for measurements and analysis of human reaction time to the light irritation.

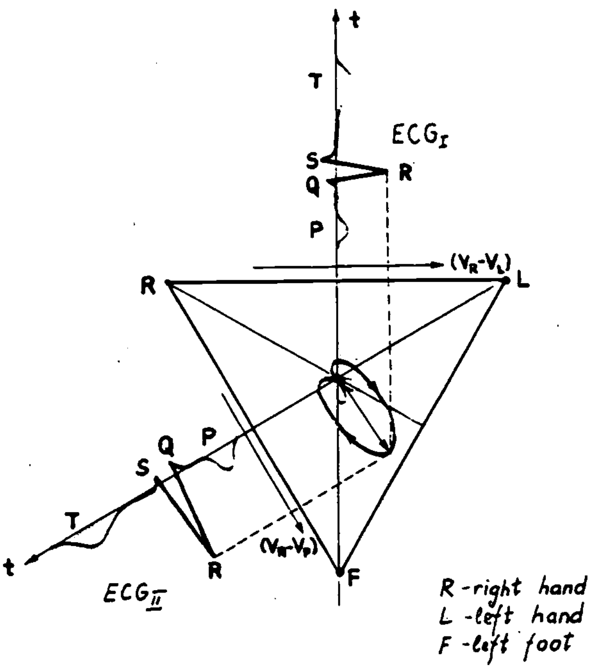

Figure 2 Einthovens triangle

3.2. The theory and methods of electrocardiography was founded by Dutch physiologists William Einthoven, who was awarded with Nobel prize in 1924. According to Einthovens theory the electrodes are located on the surface of the body at the points which are assumed to be equipotential with the vertexes R, L and F of a equilateral triangle (fig. 2). Beginning point of the electric vector of heart is fixed at the center of the triangle. During the cycle the projection of the endpoint of this vector to the frontal plane describes a curve which consists of three loops. An approximate shape of this curve is shown on fig.2, in the center of Einthovens triangle.

In our laboratory work we simulate the principles of Einthovens theory in following way.

Experimental setup consists of a vessel which is filled with tap-water. Through the plastic cover of the vessel 35 needle electrodes are fixed. These electrodes are situated along the three loops formed by the electric vector endpoint on frontal plane. All the loops with electrodes can be turned together around the vertical axes through the central point of Einthovens triangle. A current dipole is generated between the central electrode and in turn with every particular electrode on a certain loop. The switching of current dipoles and the measurement of corresponding time dependencies of voltage between the two vertexes (leads I and II) of Einthovens triangle is controlled automatically by a computer system.

On the screen of the display the spreading of the excitations wave through the heart atriums and ventricles is visualized by a series of pictures, explanations are given for every stage of excitation and the corresponding forming of the parts of a ECG is also illustrated. In addition, on the basis of electrocardiograms in two different leads of Einthovens triangle the VECG is constructed and visualized for different angles of rotation of loops around vertical axes. Some typical outprints are presented on fig. 3.

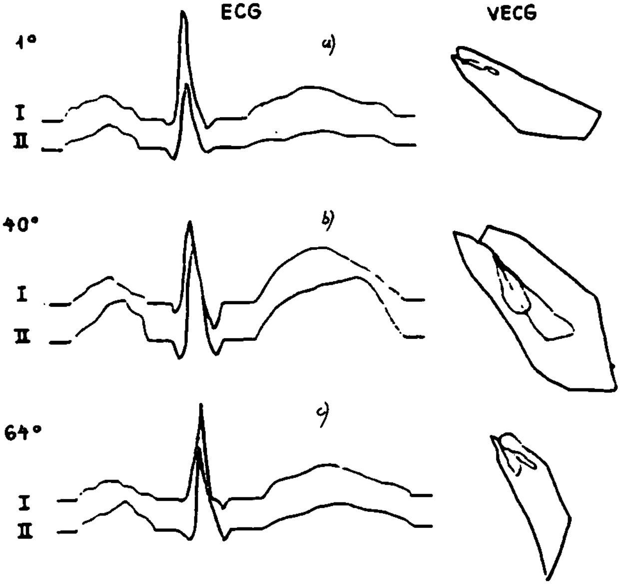

Figure 3 Examples of outprint: a), b), c) correspond to the different angles of rotation of loops around the vertical axes through the center of triangle. I-ECG of the first lead, II-ECG of the second lead. VECG - vector-electrogardiogramm.

We should like to express our thanks to engineer Aivar Tensing, who worked actively constructing the experimental setups and writing the programs.

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Tiiu Müürsepp, Toomas Müürsepp och Peter Holmberg: "Experimentell undersökning av hjärtats elektriska aktivitet." Dimensio, N° 4, 1993.

COMPUTER MODELS OF PHYSICAL PROCESSES IN SCHOOL EDUCATION

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The computer application in school and college courses of Physics allows to achieve the qualitatively new education level. In comparison with the traditional approach based on a number of problems for analytical solution and laboratory exercises the computer can enlarge the number of problems to be discussed.

A lot of different physical processes are based on a number of general physical laws (for example, the Newton laws in mechanics, The Coulomb law in electrostatics an so on). The meaning of these basic laws is usually very simple, but there is a few of physical phenomena, which can be considered in the analytical way. That is why the computer appli- cation in physical teaching is of great importance.

The main advantage of the computer application is the possi- bility to observe in real time right on the monitor screen the spatial and temporal system evolution. The user can vary in wide ranges a number of parameters which influence the material point movement; to include or to exclude external forces and interactions and so on. For every process user can get the time dependences for main particle characteris- tics: space displacement, velocity, energy, etc.

For some input parameters the discussed physical processes can be studied by user also in analytical way, other can be investigated only with the help of computer. This allows user to check up himself his own physical knowledge and to apply these knowledge for more difficult from mathematical point of view problems. In any case we propose that the main physical features of the processes to be discussed are clear enough for qualitative understanding.

Special efforts were turned to clarify the physical meaning of such mathematical procedures as differentiation and inte- gration.

The computer laboratory works can be developed on the base of such computer models. Some of them for Mechanics are discussed in the report.

The Computer Laboratory Manual on Physics (Mechanics).

The laboratory manual on physics is one of the basic part of physical education. The package "The Computer Laboratory Manual on Physics (Mechanics)" which was created in Moscow State University allows to emulate almost all features of the real physical experiment.

Almost all physical concepts concerning the motion of a body (both translational and rotational) can be studied by using the Computer Manual.

Laboratory Manual consists of a number exercises on the different chapters of Mechanics.

The Manual includes the following exercises:

1. Free motion under the action of gravity;
2. Motion along the inclined plane (sliding, rolling off); 3. Motion along the horizontal plane (sliding and rotating); 4. The Hooke's law;
5. The balls collision;
6. Garmonic motion (Pendulum);
7. Frictional force motion in the viscous fluids.

For all named above exercises user have to carry out "the experiment" on the screen of the monitor. The result of the "experiment" is the array of "experimental data", i.e. the dependence of the body (ball, cylinder, bar) displacement on time. As a result of "the experiment" analysis some important physical values and dependencies can be measured in the Manual. The acceleration under the action of gravity, the friction coefficients for sliding and rolling, the elastic constant are the examples of such values. Time dependencies for different physical values (velocity, acceleration, mo- mentum, kinetic and potential energy, etc.) for both motion with constant velocity and the accelerated motion are inves- tigated. The energy and momentum conservation laws can be examined for different situations.

Some mathematical aspects of experimental data analyzing are clarified and widely used in the package.

All results of the experimental work and of its analysis are fixed in the electronic text-book for teacher control.

The package is supported by the Manual Text-Book which in- cludes the theoretical chapter being directed to the clari- fying of the discussed material (both physical and mathema- tical) and the laboratory works description.

The package can be used both in school and in colleges.

The computer IBM PC AT-286/287 (386/387) or compatible with EGA (VGA) monitor is needed to run the package.

EXAMINATION OF TWO-DIMENSIONAL MOTION WITH VIDEO AND COMPUTER PROGRAM

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Examination of two-dimensional motion with video and computer progMm was started filming curvilinear motion of a body on an air cushion table where the motion is almost frictionless and almost in a plane. The position of the body at a certain moment was measured from a stillpicture using transparent millimeterfilm. With the videocamera making 25 frames in one second, the duration between two successive videoframes is accurately 0,04 seconds. Thus the instant of time was determined by counting frames between the measurements. The measurements of time and position were fed to the computer program that was programmed to analyse measurements from the videoframe.

Two-dimensional motion can be treated as two independent one-dimensional motions. The measured rectangular coordinates of position were fed to the computer program and graphs of displacement and average velocity of rectangular components of motion were represented with this program. The measurements were represented numerically and graphically and also analysed graphically comparing measurements to curves representing uniform and uniformly accelerated motions. The program also represents the measured path of the body which can be compared to paths of uniform and uniformly accelerated motions.

The uniform and uniformly accelerated two-dimensional motions can be simulated choosing coordinates of the initial position and components of initial velocity and the acceleration of simulated motion. The program represents the graphs of displacement, velocity and acceleration of component motions in one frame. if necessary, any of the graphs can be enlarged. The program can also present a 'real time simulation', that is, image of the body moving along the path of simulated motion showing the position of the body at a simulated instant of time.

AN ANALYSIS OF SOME AMERICAN AND GERMAN SIMULATION PROGRAMS

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Computer assisted learning/instruction (CAL/CAI) programs for physics studies and teaching at university level are nowadays available in several places.

The American Institute of Physics has recently published seven programs in its series Physics Academic Software. These programs can be ordered at The Academic Software Library[1)] and can be viewed at CSC[2)] in Finland. The programs are following:

ORBITS

A program for illustration of planetary motion of planets, space vehicles and stars under Newton's gravitation.

PHYSICS SIMULATION PROGRAMS

Demonstrates wave motion, chain reaction, Maxwell's daemon, electric field of moving charge, radiating dipole and a system of thin lenses.

RELATIVISTIC COLLISION

Considers relativistic processes between different elementary particles in 1- or 2-dimensions.

SPACETIME

Demonstrates relativistic phenomena according to special relativity.

THERMODYNAMIC LECTURE DEMONSTRATIONS

Presents basic thermodynamic processes and their application in heat engine processes (Otto- and Diesel-prosesses).

CHAOTIC DYNAMIC WORKBENCH

Simulates chaotic dynamic systems (for students having basic knowledge in this field).

CHAOS SIMULATIONS

Represents chaotic systems like double and quadrupole pendulums, N-particle gravitational motion etc.

All these programs have been analysed as students' exercises in a computational physics course arranged at TUT. A corresponding finnish report has been published at Technical University in Espoo[3)].

Every program includes a diskette and a program handbook, which describes the physical phenomena treated in the program as well as the use of the program. The five first programs are suitable to illustrate corresponding physical phenomena for first year students. Of course all these programs can be used by a teacher for the class room demonstrations. The two programs for chaos simulations will require more knowledge on computational and statistical physics.

Just briefly these programs are simulators to demonstrate and illustrate physical phenomena which are difficult to represent by other ways. They don't unfortunately have very much user interaction, test for user etc., and so the possibility to a cognitive learning process is lacking too.

The second set of simulator programs can freely be drawn from a German ftp site[4]. This ftp archive has 24 programs which could be used as simulators for students or for demonstration purposes of a teacher. The following PD or shareware programs are available in this ftp site:

3kugel.arc: scattering of particle on three hard spheres which are freely located

billards.arc: simulation of billard ball on a table with convex edge

chaos_generator.arc: simulates electrical oscillator with adjustable parameters

duffing-oszillator.arc: Duffing oscillator with adjustable parameters

dynlab1.arc: examples of dynamical systems and basic phenomena in mechanics

ellipsenstreuung.arc: collision of a particle on a hard ellipsoid

feigenbaum-szenario.arc: iteration of a real function (mathematical feedback)

felder.arc: field and equipotential lines for a given electrode configuration

fft.arc: carries out Fourier transformation of complex data

h-atom.arc: presents wave function of hydrogen atom for given quantum number

ising-modell.arc: Monte-Carlo simulation of 2-dimensional Ising Model

keil.arc: chaotic motion of a particle under influence of gravitation

lamda.arc: detection of light diffraction with a diode array

mandelbrot.arc: generates images of different areas of the Mandelbrot set

membrane-vibrations.arc: damped oscillations of 2-dimensional membrane

moldyn.arc: simulation of motion of 2 dimensional many particle system

nil-fit.arc: nonlinear fit of data according to Levenberg-Marquard method

optische_bank.arc: interactive study of optical system on optical bench

perpot.arc: energy bands in a 1-dimensional periodic potential

pia.arc: interaction of particles under a given radialsymmetric potential

siphex.arc: simulation of wave motion in 2- and 3-dimensions

statphys.arc: examples of statistical physics like chaos, Ising model etc.

wellenpakete.arc: dynamic of wave packets in a binding potential

wkb_quantisierung.arc: eigenvalues of linear Schroedinger equation

The programs have mainly been developed in connection of a Computer Supported Physics Teaching Workshop" which was organised at University of Kaiserslautern although other german universities participated on this work as well. There are no handbooks or manuals for programs but there is a textfile describing every program. Textfiles are written in german or english. The menus in the programs are often written in german but so much german can be easily learned.

Only some of the programs have been tested and analysed by us. Our general remarks concerning these demonstrations and simulations are

- programs are relatively easy to use
- colours could be adjustable

- no bugs detected so far
- interactive usage gives more motivation for the user
- clear and easy user interfaces
- suitable for student and teacher demos and illustrations
- PD and shareware distribution conditions
- don't provide a cognitive learning process
- some programs require knowledge on statistical and computational physics

These programs are anyway suitable for classroom demonstrations but maybe useful in a computer network for students' usage.

In addition to these two sets of programs there are many other ftp sites where CAI programs can be copied with "ftp anonymous" action. Some ftp directories will be given in references[5)]. All the program files are compressed and can be uncompressed with pkunzip program. The textfiles are not compressed. The shareware conditions if any are given, should allways be concerned.

References:

1) Ordering address: The Academic Software Library, Box 8202, North Carolina State University, Raleigh, NC 27695 - 2682

2) For viewing please contact Mr. J. Korpela, e-mail: jkorpela@csc.fi

3) J.E. Korpela: Tietokoneavusteinen fysiikan opetus, Teknillinen korkeakoulu, Fysiikan laboratorio 1992

4) ftp address: 192.67.194.33 (new internet number 129.13.200.33, askhp.ask.uni-karlsruhe.de), directory pub/education/physics

5) some useful ftp addresses: nic.funet.fi; garbo.uwasa.fi; wuarchive .wustl.edu

EDUCATIONAL SOFTWARE PACKAGE "PHYSICAL GAMES ON THE DISPLAY"

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The proposed software package is designed to be used in the classrooms equipped with the computers IBM-PC by students studying the subjects "Kinematics" and "Dynamics" of the high school or introductory colledge physics course.

The package contains 18 instructional programs and 6 tests.

All the instructional programs are based on computer simulation of various mechanical motions, with the motion being visually displayed on the screen and with the students' conducting the active dialog with the computer.

The instructional programs include computer demonstrations, laboratory works, "animated" problems and physical games.

The computer demonstrations and the laboratory works help study such physical processes that are difficult, and sometimes even impossible, to demonstrate or study in a school physical laboratory. The conmputer presents the accurate scale of the physical parameters characteristic for the experiments being simulated, while maintaining the correct spatial and temporal relationships between various motions.

Another aim of the computer demonstrations is to show that one and the same motion can be described by various methods (mathematical equations, graphs) and that each of these methods can evoke in the students's memory the visual image of a certain motion.

Of interest is also the role played by the computer simulation in the mode termed "the animated" problems in physics. The main idea of these programs is as follows: once the question or problem is formulated, the computer requires that the student should give the numerical answer which would serve for the computer as an input parameter for simulating the motion and depicting it on the display. Normally, the computer requires: "Set the speed (acceleration, coordinate, etc.) so that the motion of a certain object would be so and so". While observing the motion on the display the student can see it for himself to which extent his (or her) answer is correct (or incorrect). If the answer is incorrect, the comparison of the obtained motion with that present in the question helps the student to introduce proper corrections in his (her) answer.

The ingenuous physical games presented in the package serve, on the one hand, as a powerful instrument for stimulating the study of the mechanical motion theory and, on the other hand, as an ideal means of developing intuitive understanding of physics by the practical application of the obtained theoretical knowledge in the game.

The checking programs are designed for rapid routine testing of the students' knowledge. Being mainly in the form traditional for. One of the major pedagogical aims intended to be achieved by the use of this educational software package is the humanitarization of teaching of physics.

Having worked with our programs all children, without regard to their talents and aptitudes, shall form the visual image and intuitively clear idea of the mechanical motion laws in their memory.

The relativity of motion, the motion and its graphical representation, the Neuton's laws of motion, the motion of artificial satellites and heavenly bodies, the weight and weightlessness, the non-inertial reference frame - studying of all these difficult and abstact problems becomes an absorbing game.

The mathematical formulae and abstract notions become closely associated with the visual images of the motion. The intuitive interpretation of the laws of motion makes lengthy and sophisticated explanations and calculations more lively or, sometimes, may replace them altogether.

In working out the present software package the use has been made of the following original software tools presented to the authors by the "FITEC" Ltd.:

- the functional windowing program allowing visual and compact representation of information and enabling the friendly dialog of the computer with the user (author S.L. Trishkin);
- the graphical editor and animator (author A.A. Ovechkin).

CONTENTS OF SOFTWARE PACKAGE "WATCHING PHYSICS ON THE DISPLAY"

PART 1

1. "ON THE RIVER" - the animated problem.

The program is expected to give the student initial ideas on relativity of motion. The motion of several bodies (the house on the river bank, the raft and the motor boat) is simulated on the display. First, these motions are demonstrated in the bank-fixed reference frame. Then, the computer (in the image of the famous hero of the Disney's animated cartoons) formulates the questions of the following kind to the student:"Set the motor boat speed in such a manner that the raft and the house move in this or that way in the motor boat-fixed reference frame".

The student must set the required speed on the boat speedometer, following which the computer shows the picture of the motion corresponding to the selected motor boat speed (view from the boat). As a result the student sees it by himself whether or not he has given the correct answer.In the case of incorrect answer the computer allows another two speed-setting attempts.

Since the computer questions are qualitative in character, different values of the motor boat speed may turn out to be correct. The computer shall assess the answer of the student in its essence and, depending on whether the student gives correct answers or makes many mistakes, offers him from 3 to 9 problems.

In formulating the questions the computer uses the random numbers selector. Therefore, generally speaking, the set and the sequence of the questions shall be different on different displays in the classroom.

2. "CORRECT COURSE OR AIRPLANE" - the animated problem.

Intended for training students in the rule of summation of velocities. The student is the pilot of the small airplane transporting mail between various European towns. In selecting the correct course of the airplane the pilot must take into account the direction and the velocity of wind. The computer offers a few tasks beginning from simple problems where the direction of wind coincides with or is directly opposite to the correct airplane heading, and shifting gradually to more complex cases where the wind direction is arbitrary. The calculation of the course, speed and duration of the flight in simple cases is performed analytically by means of the screen calculator and in more complex cases - by means of the graphical summation of vectors.

Once the student has calculated the airplane course and introduced it in the computer, the azimuths of the course and wind are marked on the compass depicted on the screen, and the airplane is flying moving over the map of Europe in accordance with the selected course of the airplane and the direction and velocity of wind. If the problem is solved correctly,the airplane shall arrive at the point of destination at the preset time. If not,the error shall be evident from the results of the flight and from the readings of the airplane instruments displayed on the screen. In the case of the incorrect answer, the computer shall allow another two attempts to introduce the correct course of the airplane.

In formulating the questions the computer utilizes the random numbers selector.

3. UNIFORM MOTION AND ITS GRAPHS

4. UNIFORMLY-ACCELERATED MOTION AND ITS GRAPHS

The computer demonstrations the aim of which is to create in the student's mind the wholesale picture of simple mechanical motions by combining the visual image of these motions with their abstract descriptions by math equations and graphs.

The motion of the car (in the case of uniform motion) or the spaceship (in the case of uniformly-accelerated motion) is displayed on the screen and, at the same time, the graphs of the coordinates and velocities of these objects are being plotted.

The provision is made for a few stages of the work with the demonstrations. At the first, familiarizing, stage the teacher must draw the students' attention to different methods by which the motion of an object may be represented on the computer screen and to the interrelationship between the character of the motion and the initial conditions which are selected randomly by the students themselves (or following the teacher's instructions).

The stages that follow in addition to the acquisition of knowledge presuppose a certain element of its checking. The computer requires that the initial conditions be set in such a way that the desired initial position or character of motion is obtained. In addition, the computer attracts the students' attention to certain specific features of the graphs of coordinates or character of motion of the object and to their interrelationship with the mathematical equation describing the motion.

5. FIGHT AGAINST SPACE RUBBISH - the physical game

The student is the pilot of the patrol spacecraft whose task is to catch up with the uncontrolled object (rubbish) moving towards the space station - Base. The acceleration of the spacecraft can be varied by means of the direction keys. The catching can be accomplished only when both the coordinates and the velocity of the spacecraft coincide with those of the uncontrolled object.

In addition to the picture of the motion the computer display shows the numerical information about the coordinates and velocities of the spacecraft and object and depicts the constructed graphs of their coordinates and velocities.

The pedagogical objective of this game is to demonstrate how practically useful and convenient it is to describe mechanical motion by means of graphs. It turns out that the only way in which the student can achieve the success in this game is to control the spacecraft by orienting himself to the graphs of the coordinates and velocities. But this way is not imposed on the student whatsoever. He ought to find it himself while solving his clear-cut task in the game.

6. MOTION OF ARTIFICIAL SATELLITES

The computer demonstration of the motion of sattelit in the central field of gravity of heavenly bodies. The following two modes of demonstration are proposed.

Mode 1 - frontal demonstration. The teacher selects one of the heavenly bodies of the Solar system, and the computer demonstrates the motion of the satellite on closed orbits at various initial conditions. The initial satellite's speeds higher and lower than the circular orbital speeds are considered. The values of the semi-major axes and orbital periods are displayed. This demonstration is performed in the automatic mode.

Mode 2 - intended for individual student's work with the computer. The student can select various heavenly bodies, introduce initial conditions and observe the character of the body's motion using the motion parameters shown on the display.

After setting the initial conditions the student may either instruct the computer to select the most convenient spatial and temporal scales by itself and display the trajectory on the blank screen or may retain the previously selected scales and display on the screen sequentially several different motions while maintaining the correct temporal and spatial relationships between them. If in the latter case the screen turns out to be too small to show the entire trajectory, the computer shall offer to alter the scale and repeat the observation.

This mode may be used as a labaroratory test where the student, for instance, may be instructed to analyse the character of the motion under various initial conditions, to find the relationship between the orbital period and other orbital parameters, etc.

7. RUSHING AFTER SPACE STATION - the physical game

The student is the spaceship pilot whose task is to approach the space station placed on the stationary circular orbit as at a minimum possible distance for a limited period of time. Initially, the manned spaceship is located in the diametrically opposite point on the same orbit. The spaceship control is accomplished by means of the direction keys each depression of one of which increases or decreases the tangential or normal component of the spaceship velocity by 2% of its speed on the stationary orbit.

In the course of the game it turns out that many seemingly commonsense ideas do not correspond to the actual motion in the gravity field. For instance, it turns out that in order to catch up with the station the spaceship speed should be decreased rather than increased, or that it is more dangerously to decelerate the spaceship when it is at a large distance from the heavenly body rather than close to it, etc.

This game is intended to help students to develop the intuitive understanding of the laws of motion in the field of gravity and serves as a powerful stimulus for them to set to studying the physical fundamentals of maneuvering of spacecraft on orbits close to heavenly bodies, which is a subject of the special laboratory work.

8. SPACESHIP ORBITAL MANOEUVERS - the laboratory work

The major aim of the test is to familiarize the students with the fundamentals of spaceship orbital control. The computer formulates simple tasks: to increase or decrease the tangential speed component in one or another point on the orbit by means of the direction keys (and observe the resultant changes in the spaceship orbit), transfer the spaceship to the circular orbit of a larger or smaller radius, etc.

The computer continuously monitors and assesses the student's actions after each manoeuver. If at some or another stage the student has made an error, the computer shall demonstrate the correct sequence of actions and allow him to make another attempt.

9. TEST 1: UNIFORM MOTION .

10. TEST 2: UNIFORMLY-ACCELERATED MOTION.

The computer offers four problems in either of these tests. In the formulation of the problems a wide use along with the texts is made of the graphic representation of information and the computer simulation of mechanical motions. The computer requires that the student should either introduce the numrical answer or select the correct answer out of the several offerred ones. The computer allows the student to select by himself that sequence of the solution of the problems which he reckons to be the most convenient for him. The necessary calculations can be performed on the screen calculator.

All the numerical data are selected by means of the random numbers selector and are different for different displays. The provision is made for four versions of tests differing from one another in the degree of complexity.

The computer monitors the correctness of student's answers, informs him about the result at the end of the test and submits this information to the teacher.

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ISBN 951-45-6599-1
ISSN 0359-4203
Helsinki 1994
Yliopistopaino

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