

Coach: an environment where mathematics meets science and technology

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Introduction

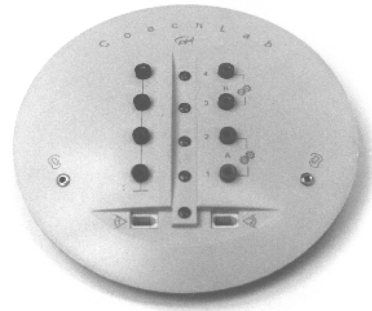
In today's education, pupils play an active role in their learning process. The active pupils need tools to do their work. Every field emphasizes different tools: in science education these are tools for doing measurement experiments and running simulations, in technology these are design tools and tools that combine measurement and control, and in mathematics these are computational and modeling tools. The computer and Internet are often used by pupils in activities, e.g., to collect and process data or to find information about subjects of study. The AMSTEL Institute at the University of Amsterdam has developed in the last decade a computer environment, called Coach, that provides pupils with tools for active, self-responsible study of natural and mathematical phenomena. A few examples: sensors can be used to collect real-life data in measurement experiments, actuators allow process control, interactive video extends the means to collect data, and modeling tools enable comparison of mathematical models with reality. At present, the Coach environment is mostly used in science and technology, where it is employed to carry out measurements, to display directly results of measurements, to process data, to set up computer models, to investigate relationships between physical quantities, to make predictions and compare these with real-life data, to control apparatus, and much more. Work is in progress to extend the mathematical facilities of Coach so that it becomes a more complete educational environment for exact sciences. In this paper we shall describe the software product.

Bird's-eye view of Coach

Hardware

Connecting sensors and actuators to a computer requires interfaces. These can be dedicated cards

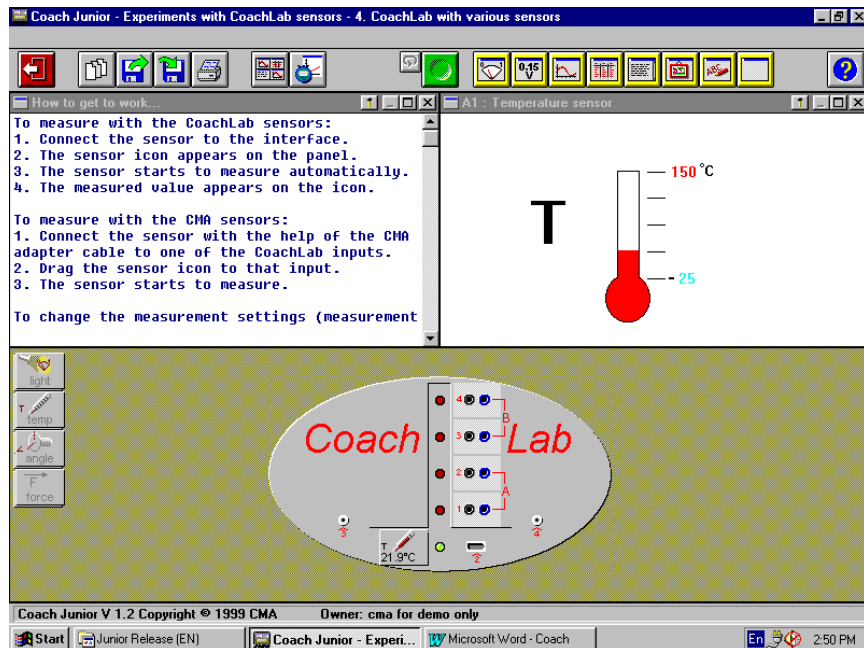
inside a computer as well as external interfaces, which can be directly connected to the serial or parallel ports of the computer. Both approaches are supported in the Coach environment: in addition to the use of interface cards inside a computer, a measurement interface for the serial port (SMI), the LEGO DACTA[®] interfaces for control, and an interface for measurement and control via the parallel port (CoachLab) are available among other interfaces. The EcoLog of Fourier Systems and the CBL[™] - and CBR[™] - dataloggers of Texas Instruments can also be connected via the serial port so that out-of-classroom measurements can easily be carried out. The CoachLab interface has been especially developed for uncomplicated real-time measurement and control activities, which do not require a steep learning curve or extensive reading of the manual. CoachLab includes three standard sensors, viz., temperature, light, and microphone, but others can be connected as well.



The CoachLab Interface

Software

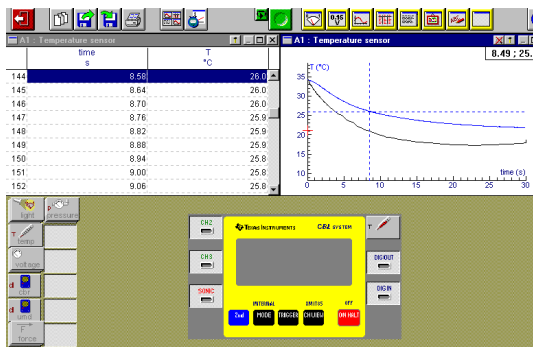
Several interfaces are represented graphically in the software. What you do in the experimental setup corresponds directly with the activities in the software. Measuring boils down to connecting a sensor to the interface and dragging the corresponding sensor icon in the software to the corresponding channel on the computer screen. The sensor immediately displays the measured value. CoachLab can recognize the attached sensor so that default sensor settings are known and no calibration is required anymore and so that a pupil can be warned if he or she connect an inappropriate sensor to the measurement panel. The following screen dump shows a CoachLab panel with a temperature sensor icon dragged to the lower left channel and a window that displays the current temperature value graphically in a meter window.



Measuring with CoachLab in Coach Junior

Measurement features

What distinguishes the Coach software from other measurement programs is that it offers integration of several tools in one environment: a text window may contain explanations for or instructions to the pupil and a plot window can immediately display the diagram of measured data. Below you see a screen dump of an activity in which cooling of a cup of warm water is investigated via the CBL™-datalogger.



Sample activity of predicting and measuring

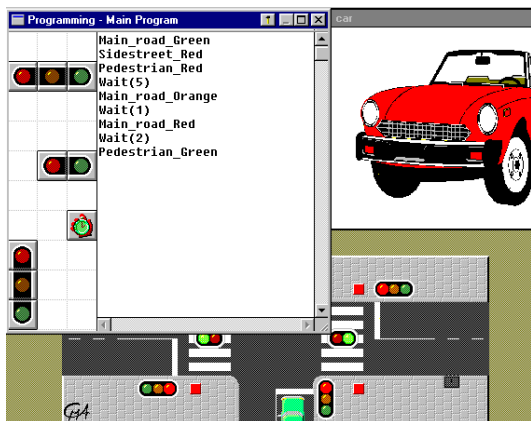
During 30 seconds the temperature is measured. First the pupil has predicted in the plot window what he or she expects (lower curve). Then the measurement takes place and the data are plotted

(upper curve). Afterwards, the zooming facilities can be used or the measurement can be replayed, at slower speed, as many times as one wishes, for better understanding of the experiment. The measured data are simultaneously tabulated in the upper left table window. A direct link between graph and table exists: the highlighted row in the table refers to the same datum as is marked in the graph window as the intersection point of the dotted horizontal and vertical lines. Further processing of measured data by means of formulas (entered via a Calculation Wizard) is possible.

Control features

The control environment of Coach offers several levels of programming with increasing stages of difficulty:

- **manual control mode:** the pupil can read connected sensors and control actuators by simply clicking on the on-screen panel to find out their behavior.
- **instruction mode:** pupils can make programs by manually controlling a system of so-called "instruction buttons" on the screen. Pupils learn that systems can be controlled by commands.



Example taken from the Crossroads Project showing manual control mode for traffic control.

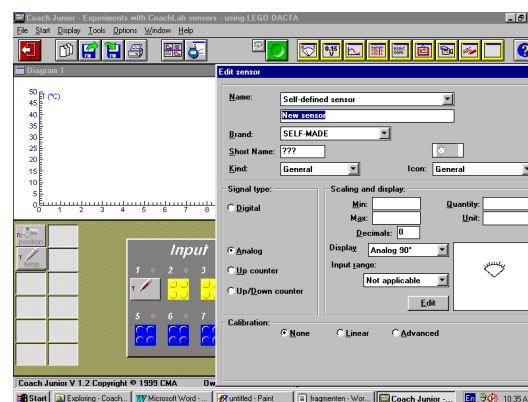
- **microworld programming mode:** a microworld consists of pre-defined set of commands tuned to a particular model. Pupils learn to write control programs by selecting statements from a command list on the screen.
- **free programming mode:** experienced pupils can program freely, i.e., by choosing commands from the complete list of available Coach Language commands, or by typing commands.

Coach Junior

The above screen dumps show Coach Junior, the version of the software that is meant for pupils in the age group of 10 – 15 years. In this version, the computer screen has a fixed structure of four tool windows in quadrants plus a background that can display the experimental setup, i.e., the measurement or control panel plus the palettes for sensors and actuators. The tool windows can be plot windows, table windows, text windows, annotation windows, meter windows, videos, and so on. Coach Junior has been optimized with respect to ease of use in education by young pupils. It is used in almost every Dutch secondary school in physics, chemistry, biology, and computer science lessons. Furthermore, it has been completely translated (menus, help, and programming language included) into seventeen languages. The software won in 1998 the Worlddidac Award in the category of informatics and multimedia technologies.

Authoring

Coach Junior offers authoring tools for teachers or curriculum developers to prepare tailor-made activities, ranging for very closed to very open (fixed, flexible and own lab modes), organized in projects which can offer progression from a simple introduction to an advanced data acquisition or programming. The author decides what kind of windows the pupil will find in an activity: whether the windows will contain text, graphs, tables, control programs, pictures, video, a place for pupil notes, etc. The author also decides which tools specific for a chosen window will be available to the pupil. Of course, the author can specify which interface for measurement and/or control and which sensors and/or actuators can be used in the activity. The author can also change existing or create own sensors/actuators with an editor. In this way, Coach Junior allows authors to design applications for pupils exactly as they like the projects and activities to be.

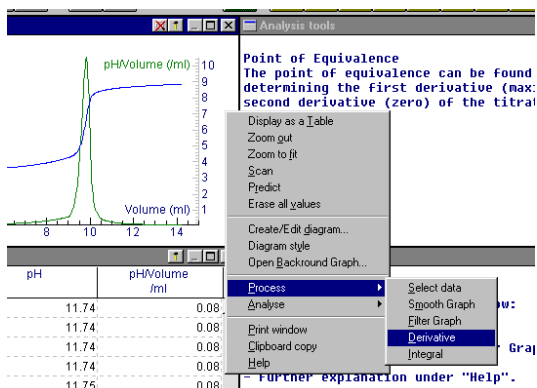


Creation of an activity in progress

Coach 5

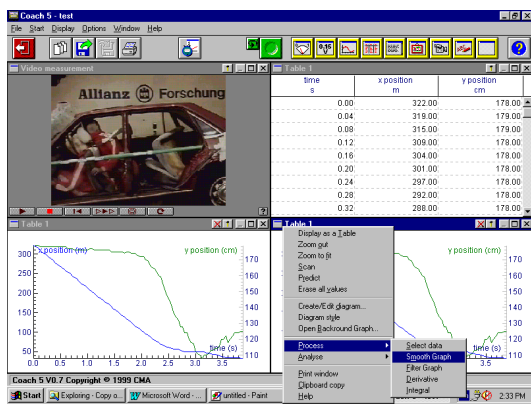
Coach 5 is the successor of IP-Coach 4, the DOS version of 1994, and it is meant for students in the last years of secondary school education and in the beginning years of higher education. The software offers the same intuitive and versatile facilities as Coach Junior plus

- **mathematical tools for data processing:** processing of the tables and graphs of measured data includes zooming in, reading and selecting data points, smoothing and filtering data, determining the slope of a curve or the area under a curve, mathematical manipulation of measured values in tables, function-fit, formula editing, etc.



Processing in action

- **modeling tools:** mathematical models can be constructed graphically or textually via an elaborate programming language. The results as calculated by a mathematical model can be compared with graphs that stem from a measurement. Parameter estimation for best fits to experimental results is also supported.
- **interactive video,** which offers possibilities for measurements with digital video-clips, like measurements of the movement, velocity, and acceleration of moving objects. This usage of real-world shots brings into vision realistic mathematics and science.
- **control tools:** for technology applications.
- **Internet communication:** built-in tools for importing and using Internet sources (data, text, pictures, video clips) in investigations and design projects.



Video measurement of a car crash

Most facilities have already been realized, others will be released in the fall of 1999. Detailed information about products and releases can be

found the website of the enterprise arm of AMSTEL: <http://www.cma.beta.uva.nl/english/> Demonstration versions can be freely downloaded from this website. Computer requirements for the software are: PC with 386 processor or higher and 4 MB RAM, 5MB of free disk space, Windows 3.1x, Windows 95/98, Windows NT.

The near future of Coach

Coach Junior and Coach 5 have been developed with the help of teachers as learning environments for students and teachers in science and technology education, which support inquiry-based, self-responsible learning via measurement and control experiments. In mathematics education, the computer and mathematical software like a computer algebra system start to play an important role as well. Problematic for secondary education is that there seems to exist for almost every mathematical topic another piece of software: Cabri for geometry, Winplot, GrafEq, and the graphic calculator for plotting graphs of functions, Dynasys for simulations of dynamical systems, Derive for working with formulas, and many more could be mentioned. They form a grab bag of packages that do not work well together. The situation gets worse when mathematical software is used in activities in natural sciences and technology: for example, mathematical analysis of measured values is frustrated by the limited possibilities to import data and by the unnecessary difficult steps needed to obtain the desired result. Students may even get the impression that the mathematics and the mathematical tools used in natural sciences and technology are totally different from the subjects and tools in mathematics education.

The current trend in mathematics education to focus on self-reliant, inquiry-based learning of “realistic mathematics”, which is tied to other science fields and which emphasizes skills and ICT usage and de-emphasizes factual knowledge, makes the need of one software environment for natural sciences felt. A one-sentence description of the envisioned all-in-one learning environment is the following:

“Coach is a set of tools for the study of natural and mathematical phenomena that is integrated in an open environment for the educational setting”.

Like in today's Coach, a tool is materialized by a window with its own objects and operations. The tools can be organized according to functionality:

- set-up/definition: set-up for measurement and/or control, interactive video measurement, mathematical set-up like defining functions and relations.
- manipulation: run controls, digital and analog meters, graphing, tables, data processing (smoothing, filtering, fitting), calculations, (graphical) modeling, etc.
- reporting and support: text (also multimedia and HTML), pictures, notes, and so on.

Depending on the subject, the student can make a choice of tools. For instance, for mathematics a natural choice would be a function definition window, a plot window, a table window, and the calculation window. For an experiment where physical quantities are measured, a choice would be a set-up measurement window, a processing window, a plot window, and a table window. Beside the toolkit, a database of resources for learning must be available. Resources can be present in the classroom, on the computer, but may also be external, e.g., come via Internet.

Coach will stay an open environment in the sense that it is

- a multi-purpose tool.
- an environment for solving open problems, that need definition, set-up, exploration, etc.
- free of didactical contexts or principles.

The fact that Coach is designed for the educational setting makes that the software will be perceived at two distinct levels.

- The student regards the software as a set of tools for measurement, analysis and control. Moreover, the software offers possibilities for receiving the texts and assignments, and for writing a report on the results obtained.
- The teacher perceives the software as an environment where the student can define a set-up and explore the phenomena. Hopefully understanding will arise and this can be expressed in a report. The teacher can use the software to design/adapt the environment in such way that it is best for the subject and for the student. Part of this design can be the choice of texts that

introduce the topic, contain the assignments, etc. For an inexperienced student, the teacher can prepare the materials together with a lay-out of tools. For the more experienced student, the choice of tools is part of the study-activity, so it should not be prepared by the teacher.

In fact there is a third level: it is the level of the author of the materials. For instance, the author can be a teacher, a course-book author, an educational publisher, or a more experienced student. The authoring environment offers an extension of the functionality directed towards the creation and inclusion of texts, pictures, videos, data. This comes together with the possibility of a choice of lay-out of tool windows. This combination of resources forms an activity. Many sample activities are included.

In short, the Coach environment helps students master concepts in mathematics, science and technology, improve their problem solving skills, access teacher-prepared course material, and create their own activities. It encourages students to explore the real world and to investigate mathematics and science ideas.

Further information

For further information about educational research related to Coach we refer to the following websites

<http://www.wins.uva.nl/research/amstel>

<http://amstel.wins.uva.nl/~cmulder>