This paper describes an experiment in introducing informatics into basic education. This operation, developed in the context of the IRIS project, in coordination with the European Centre for Education, entailed the development of a teaching unit designed for the first two years of high school. The experiment is illustrated both from the point of view of the content and from that of the methods used, and the framework within which it was conducted, the working plan followed, the first results and prospects for the future are also described.

In particular, the robot Martino is introduced. This is a software instrument aimed at introducing the main basic concepts of the study of informatics.

1. INTRODUCTION

It is a widespread belief today that informatics is not only a specialized technical discipline, but also - and perhaps even above all - a method of thought to be put to use in a wide range of subjects and activities. To this concept of informatics, an educational value of great importance is attributed. There are, however, contrasting points of view as to what the educational content of informatics actually is, and how it should be included in basic education.

The purpose of these notes is to describe a specific experiment in introducing the basic concepts of informatics into a high school context. The experience is described on the basis of the choice of contents and the means by which they may be transmitted, possible ways of conducting the experiment and the difficulties encountered, the first results obtained and future prospects. Within the framework of the experiment, the software instrument utilized was the robot Martino, a modified version "Karel the Robot" by R. Pattis. The experiment was developed and put into practice by the Istituto per le Tecnologie Didattiche (Institute for Teaching Technologies) of the CNR (Italian National Research Council), in the context of the IRIS project, coordinated by the European Centre for Education, and conducted in several Italian schools. The IRIS project (Iniziative e Ricerche per l'Informatica nella Scuola - Undertakings and Research for Informatics at School) includes a series of parallel activities for introducing informatics into school at various levels.

2. PERSPECTIVE OF THE EXPERIMENT

2.1 Analysis of the context

It is widely believed today that an organic introduction to informatics is more and more urgently required in basic education. (19)
structures. This field, too, therefore, has to rely on the initiative of single teachers, spurred on by their own personal interest and by pressures from their students. Difficulties of a technical nature are to be found in introducing informatics into the official basic school programs, and are created by the lack of uniformity of the economic situation from one school to another.

2.2 Aims

The experiment under reference had the scope not so much of training specialists as of introducing informatics into basic education. The aims are therefore easily identified in those aspects of informatics which have a particular educational value, and make it easier for young people to fit into an informatics-minded society:

a) Encouraging the development of logic and cognitive capacities.

The constant application of the informatic method encourages the acquisition of the capacity to face reality systematically in an organic manner, both as far as concerns problem solving and in order to develop learning potential. In particular, the hierarchical decomposition method and the use of formal methodologies for describing realities increase the capacity to communicate, while the formulation of models and the abstraction of functions and data constitute the basis of abstract thought.

b) Improving the quality of learning.

A large number of proposals and experiments carried out by teachers and research workers have contributed towards highlighting a wide range of educational advantages, some of which still undoubtedly remain to be discovered, to be achieved by introducing informatic methods and means into the teaching of non-informatic subjects. These advantages concern the possibility of widening and renewing the contents of each discipline, the possibility of giving knowledge a more concrete and operational form, and finally the possibility of improved, easier and more incisive communication in teaching, above all when referred to complex subjects. This object is of necessity complementary to the first, as problem solving and abstraction capacities, as a mental attitude systematically adopted by the student are of course applied to any real context.

c) Educating towards life in an informatics-minded society.

This objective implies the acquisition of a certain familiarity with the use of informatic means and their possible applications, spreading the concept of the computer as an instrument to exploit rather than to submit to, and debunking the idea of informatics as an inaccessible discipline.

2.3 Content

In line with the objectives stated above, it is possible to identify (24) a set of contents, based on the criteria already indicated above of privileging methods of thought of a general capacity rather than technologies of a contingent value.

Of course, varying degrees of completeness, of thoroughness, and of complexity, and a series of considerations which may condition a further selection within the framework of these contents, correspond to each scolastic level. Two classes of contents are illustrated in greater detail, and the choices made are motivated herebelow.

a) Structured construction of algorithms and programs.

Mastering the concept of an algorithm is a necessary condition in order to know the potentiality of the computer; acquiring the capacity to synthesize algorithms means a great increase in one's own problem-solving capacities, in a general purpose sense, and consequently is particularly educational. But so-called structured programming is something more than the mere construction of an algorithmic and its coding in a programming language: it is a method of thought based on the capability to discover and build up the structure of what is real, and it uses definite techniques in order to dominate the complexity and to guide organically the invention process. The pivots of this method of thought, intimately linked to one another, are the algorithmic concept, hierarchical decomposition (called "top-down") and function and data abstraction.

b) Education to access to information and to its handling by didactic use of preconstructed programs.

In addition to the construction of algorithms and programs, also the use of preconstructed programs, such as data base, simulation programs, graphic editors, games and in general any didactic "environment" may constitute an educational factor of great importance. It entails, in fact:

- getting used to considering a computer an instrument of work able to facilitate, improve or speed up production and cognitive activities;
- getting used to modelling and formalizing situations and ideas which allow communication with informatic means and their functional integration into the activity being carried out;
- the enrichment of teaching with computational capacities and the handling of otherwise inaccessible information;
- a creative stimulus, thanks to the
fact that the student is able to make use of means which strengthen his or her expressive capacities.

As already stated at the beginning of this paragraph, the experiment under reference did not cover the whole area of content described here. Within the framework of the two classes mentioned, taking into account the scolastic level of the intervention and the requisites of compactness which the course itself had to comply with, a selection was made which led to a more detailed and restricted set of points, calibrated as far as concerns the degree of completeness, thoroughness and complexity, motivating factors, cultural links and links with the real context.

The first class of contents is present integrally in the course, since the algorithmic approach, the top-down process and functional abstraction were all considered to be indispensable and fundamental.

The second class is represented by the use of an operative environment and of a facilitated teaching environment in which the student may develop his first programs.

2.4 Methodological aspects

Coherently with the objects and contents described, it was decided to set up a teaching unit in which the main characters were not, as is almost compulsory today, the structure of the computer and Basic language. This does not mean "poor" informatics, limited to the use of pencil and paper: all the conceptual aspects of the informatic method may take shape only by applying them to the solution of specific problems, and in conclusion through the construction of programs coded in a specific language and their execution on the computer.

The choices made as far as concerns the environment for the student to operate in are: Pascal language, the UCSD operative system, the robot Martino as the facilitated teaching environment, and the use of personal computers as a hardware support.

a) The language.

Many factors conditioned this choice: availability of the language, the age and scolastic level of the pupils, the knowledge of the teaching staff and so on. But rather than to these prevalently technical aspects, preference was given to the fact that each language has its own philosophy and subtends a different way of thinking, and Pascal in particular does not constitute merely a coding instrument, but even more an instrument of thought and ideaion; it does not allow any elements to appear which depend on the specific architecture of the computer, and does not force the user to implement intrinsically simple logic structures in ways which are complex to carry out and to understand. Rather it adapts naturally to the application of the conceptual instruments referred to.

b) The hardware and the operative system.

The lack of uniformity in the economic situations of the schools involved prompted the use of personal computers as a hardware support, so as to allow schools with a limited investment capacity to acquire a smaller number of work stations, but not of a lower quality, as compared with schools having a higher budget.

The choice of the UCSD operational system followed naturally the choice of a language and a hardware support to communicate it through, making it a de facto standard; it is also easy to learn and to use, even without being experts.

c) Martino the robot.

In order to temper down the difficulty of the contents, it was decided to utilize a software instrument such as the robot Martino, based on a variation of R. Pattis robot, Karel (17), able to facilitate the acquisition of informatic concepts and to strengthen the motivation of the students, thanks to the presence of play elements. The role of Martino is that of supplying a concrete reference at the moment of acquiring new concepts, and of inventing abstractions for the solution of a problem; an instrument for checking out the correctness of the solutions adopted; and finally a motivating play element.

The world within which Martino moves consists of a network of "roads" orthogonal to one another (fig. 1).

Figure 1.

The robot is represented by the arrow which indicates the direction in which it points. At the crosspoints there may be objects of a general nature (represented by a small full square) which Martino may pick up or put down. There may also be obstacles of various shapes and lengths,
which represent limits to Martino's movements. The only way for the student to communicate with Martino is to write a program according to which he carries out a specific task; in particular, it was decided to include in the Pascal language some robot control primitives: there are instructions which make Martino perform certain operations (forwards, right, left, pick up, put down) and predicates which provide information on Martino's situation (object present, free ahead, free right, north, south, and so on). It should be noted that, unlike Karel the robot, a real language and programming environment are used to program Martino: UCSD Pascal. In this way, it is possible to make Martino carry out certain specific operations in a particular "world", suitably configured by means of an actual Pascal program. For example, the task "go along the corridor, picking up any object present" may be resolved by a simple program such as the one illustrated in figure 2.

In this way, the teacher may guide the students in programming Martino to resolve more and more complex tasks, and supply them with the "worlds" in which these tasks are to be carried out. The students build up Martino's programs in the form of normal Pascal programs and while they are being executed, Martino's actions are visualized by effect of the program they have built. Martino's world is an extremely concrete reference for a gradual introduction of the various concepts of informatics: algorithms, functional abstraction, procedures, control structures and top-down development. It is important to note that all these concepts may be introduced and made operational even without data. These are introduced during a later stage, with reference at first to Martino, and subsequently to problems of the real world. This represents a further simplification of the learning process, as it allows separate concepts to be learned in successive stages.

The structure of the contents reflects their conceptual priority criteria, introducing first of all, gradually, the elements considered to be more educational. Martino's world allows these concepts to be isolated, and permits the student to concentrate on them without being distracted by elements of a different nature and of lesser importance. For example, functional abstraction and the use of procedures are introduced almost immediately, even before control structures, while data is not introduced at all, thanks to the self-consistency of Martino's language, which allows a "clean" approach to the concept of algorithms as a sequence of steps required to carry out a predetermined task. This type of content structure is definitely different from the traditional sequence of introduction of contents: variables, control structures and finally procedures.
Introducing the Basic Concepts of Informatics

3. CONDUCTION OF THE EXPERIMENT

3.1 Course material

The experiment under reference constitutes, as already stated, a teaching unit of the IRIS project, and as such, it was developed in conformity with standards preestablished by the European Centre for Education: among these the modular structure of the course material should be mentioned, as well as the presence of a sequence of cards for the students and a teacher's guide.

The course material consists of a student's manual, a teacher's manual and several disks containing Martino's software, plus some test cards.

Martino accompanies the introduction of the basic concepts of informatics in five stages, each identified by a logically correlated set of contents:

Stage 1: Preliminary notions on computers
Stage 2: The first steps
Stage 3: How to define new instructions
Stage 4: If ... then ...
Stage 5: Repeat ... until ...

Each stage is articulated over activities framed in three differing contexts: in the class-room, at home and in the laboratory. While in the class-room the teacher introduces the new concepts, possibly utilizing the machine for short demonstrations, the activity at home consists of individual preparation of exercises to be carried out in groups, on the computer, in the laboratory.

The subdivision into stages is present both in the students' cards and in the teacher's guide. The former, in line with the authors' conviction that the active participation of the students is necessary, really constitutes an interactive course, with frequent stimuli to perform exercises and maintaining an interlocutory structure even when introducing new concepts.

The teacher's guide, which is indispensable considering the difficulties already mentioned in bringing teachers up to date, gives general indications with reference to the scope of the course, the contents, the times and means required, a plan for use of the material and the formalities for carrying out each stage. These five stages form the first part of an introductory informatics course, of which the second part, prepared by the Institute for Applied Mathematics of CNR (the National Research Council) leaves Martino's world to introduce data structures by means of a real example.

3.2 Characteristics

The experiment was carried out in a limited number of classes, in schools in various parts of Italy (Genoa, Turin, Naples and Pavia). The students were first and second year high school students, and the average age was therefore about 14. It should be pointed out that the official study program for these classes did not include any subject of the informatics area.

The teachers involved in the experiment lent themselves on a voluntary basis, and with great enthusiasm. They already knew the students, as they are already teaching them various subjects within the normal study program, and got on well together. Generally speaking, none of the teachers had any previous experience of teaching informatics, indeed for some of them it was an experience quite out of their usual fields of interest: the teachers present were in fact from various fields, such as mathematics, physics, business administration, but also arts and history.

The problem of training the teaching staff was therefore particularly delicate, due to the fact that they did not possess the necessary knowledge and cultural background. The subject was confronted along two separate lines. On one hand, refresher courses were organized (lasting one week), utilizing as teaching material the unit which they would subsequently use with their own students. On the other hand, the "Teacher's guide" was prepared with particular care, and constitutes a real form of "direction" of the single lessons and exercises, complete with suggestions for facing any critical situation and tips for possible applications. The hypothesis, which still remains partly to be verified, is that a guide of this type would make it possible even for teachers without any specific training to put the course into practice, turning it into a real self-refreshing instrument.

3.3 Control

Within the framework of the experiment, instruments were provided and used for collecting data as objectively as possible concerning the progress of the students' learning:

- a questionnaire at the beginning of the course supplied useful information for classifying the students on the basis of their previous experience with computers;
- a "popularity" test compiled by the students at the end of each stage stressed elements of incompleteness, ambiguity or redundancy in the structure of each lesson;
- a rating test at the end of stages 3 and 5 was used to check that the basic contents of the course were being correctly acquired and consolidated by the students;
- a final test, consisting of the production of a program of a certain complexity and generality and put to the students in the form of an individual competition, in which the winner will be the author of the most correct and elegant program, allowed global evaluation of the progress of the whole course for each single participant.
Side by side with these systematic controls, another less formal but directed form of check was implemented:

- before, during and upon completion of the experiment, meetings of the teachers involved with the authors of the teaching unit were held, leading to useful exchanges of opinions, suggestions, criticism;
- the course was run in some cases by the teachers, in other cases the authors worked side by side with the teachers, and in yet other cases replaced them completely.

This made it possible to evaluate the incidence of the "teacher" factor, and to obtain an immediate feedback of the impact on the students.

3.4 The first results

The control mechanism prepared beforehand, together with the sensations of the authors and teachers involved, provided a sufficiently accurate method of measuring the results of this first experiment.

The questionnaires filled in at the beginning of the course showed that none of the students had any previous knowledge of informatics or programming. The "popularity" level of the various stages was in general very high, and increased considerably when Martino, the robot, was introduced, clearly due to the "play" motivations. The laboratory activities were also very much enjoyed, and the groups formed for these generally got on very well together. The only difficulties were noticed in groups containing too many students (due to the small number of machines available to some schools), or in situations where one of the elements of the group tended to emerge and become the leader of the group, monopolizing the use of the machine. In general it was found that the ideal group size was three people; however it must be kept in mind that one teacher alone cannot follow too many groups at the same time.

The rating tests, together with the final test, showed very good language learning level and use of the operative system and of the computer in general. The rapidity and enthusiasm with which students of this age group acquire the capacity to operate microcomputer were surprising. Their problem-solving capacities were undoubtedly strengthened, even though the short duration of the course did not permit, in some cases, a systematic method consolidation.

Separate thought should be given to the estimates which, in the teacher's guide, indicated the time necessary for the various types of activity. While these estimates proved to be mostly correct for class-room and home activities, the same may not be said for the time allocated to laboratory exercises, which were often underestimated, particularly in the case of numerous groups or hardware subject to frequent breakdowns.

4. CONCLUSIONS AND PROSPECTS

To conclude, it may be said that the teaching unit under reference met with considerable success, both from the point of view of its impact on the students, who acquired rapidly the contents put to them and developed problem-solving capacities which they did not have at the beginning, and from the point of view of the teachers, and in spite of the absence of any form of official recognition of this activity, motivated not only by their personal interest but also by the pressure and enthusiastic responses of their students.

Some indications for second thoughts about the course material and content of the courses resulted from this experiment, and these are articulated along two different lines according to their incidence in time.

A series of very relevant suggestions put forward by the teachers or which came up during the direct meetings with the authors in the classrooms or in the questionnaires and tests shall constitute the input for a review which should be completed within the end of the next academic year with a more complete and efficient edition of the material. Examples of these revisions are the extension of the functionality of the operative system, the use of interchangeable pages according to the type of computer utilized and so on.

As far as concerns the content, the intention is to lengthen the teaching unit, including, after the fundamental control structures, the data concept. This should allow, on one hand, a natural completion of the abstraction concept adding data abstraction to functional abstraction, and on the other hand an extension in time of the use of top-down methodologies, applying them to the data structuring process. This should provide a remedy to the problem already mentioned of the students not all getting used in a well-rooted manner to this method of thought.

At the present time, it is believed that the course modified as indicated above may be experimented during the 1984/1985 school-year, on a wider scale.

There are longer term prospects for the creation of a development and testing environment for concurrent programming, very similar to the present world of Martino, but containing more than one robot: Martino and his brothers.

5. REFERENCES


(2) Various Authors, Introduzione all'informatica, Unità didattica sviluppata dagli Istituti Tecnologie Didattiche e Matematica Applicata del CNR: 1984.


(21) The Open University, Micros in school: an awareness pack for teachers, Case studies, (The Open University Press, 1982).

