INTEGRATING THE USE OF EDUCATIONAL SOFTWARE IN PRIMARY SCHOOL TEACHING
BY SHAPING LEARNING ITINERARIES

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In this paper we argue how to improve the integration of educational software in elementary school by building “learning itineraries”. This entails first of all a careful choice of software tools, based on the analysis of what cognitive tasks come into play in each exercise, and hence what cognitive abilities are implied. Then the selected activities must be organized into self-standing itineraries suitable for fulfilling the educational objectives posed and at the same time apt to facilitate learning. We exemplify our approach by making reference to an experience we carried out in a second grade of primary school.

1 Introduction

Often software tools appear to be of limited use for most school teachers since they do not provide adequate support for their individual didactical planning, only proving suitable for carrying out short, limited experiences; these tools are therefore unable to support the articulated and systematic path of cognitive growth entailed by the school experience. In order to integrate the use of technology in the school curricula in an effective, non-superficial way, rich and ductile software tools are required. Unfortunately, educational software tools are often inhomogeneous collections of exercises on different topics (e.g. arithmetic, logic, reading and writing all bundled together) and sometimes are not even targeted to a specific age level. While this is less true of products for high school level or of direct-activity learning environments, it applies in particular to drill-and-practice software for primary school, possibly as a result of the idea that at this age level exercising a wide range of abilities is preferable to developing one specific ability in depth.

In this paper we describe an experience we carried out in elementary school concerning the selection and organization of meaningful software exercises to support teaching. We explain how we dealt with this matter by structuring learning itineraries, based on selecting, from a variety of different software tools, suitable exercises on different aspects of a same topic.

2 Description of the experience

Our project was carried out during the 2001-2002 school year with two primary school classes, respectively comprising 17 and 20 children, which were involved in the experimentation for a whole morning every week. The classes were subdivided into groups of 4-5 children so that each could work on the computer individually and could be directly followed by one of the experimenters. The basic idea of the project was to support learning in the logical-mathematical area using educational software. We decided to centre the experience on activities that were parallel and complementary to those in the regular curriculum. We dealt in particular with the logical area, deliberately excluding activities involving numbers. This gave us the opportunity to substantiate further a hypothesis that emerged during a previous experimentation about the relative independence of logical and reckoning abilities [5].

The project was designed to pursue three objectives:
• to gain precise, detailed understanding of children's capabilities and difficulties with logical tasks;
• to draw up measures for fostering existing abilities and capabilities and for stimulating any deficient cognitive functions that may have been detected;
• to evaluate the appropriateness of using educational software tools to support a systematic logic path in primary school, possibly identifying the software tools’ peculiarities, limitations and best modes of use.

A further, implicit, objective was to understand if specific interventions in the logical field can bring about, in the long run, concrete improvement in learning abilities, as well as lead to better approaches to tackling problems and finding solution strategies, not only in mathematics but also in other curricular fields.

In pursuing these educational objectives we focused on three basic sets of abilities in the field of logical thinking: selection and classification of characteristics, forms and constructions and verbal logic. Based on an analysis of the software tools at our disposal (described in Section 3), we checked which logic exercises could be considered valuable from the cognitive point of view and from these we selected those most meaningful with respect to the three mentioned sub-areas. This gave rise to three systematic learning itineraries, which are detailed in Section 4.
3 Choosing educational software

In order to locate suitable software tools to use in our experience, we analysed those available in the Educational Software Library at ITD-CNR in Genoa, Italy [2]. The titles available for the considered age level were mostly general purpose systems, which often covered both logical and numerical aspects (such as arithmetical operations, building of logical sequences, management of shapes, etc.), sometimes even mixed together inside the same exercise (e.g. determine to which set an element belongs, where the element is a number and the set is characterized by means of some numerical property, like even or >10). This makes it difficult to understand whether the difficulties children encounter lie in the logical or the numerical component, so we disregarded all such exercises as well as those dealing exclusively with numbers. Another drawback fairly common among educational software is that the same package may include exercises for different age levels; subsequently we made sure to omit activities which were not suitable for the age level considered.

The initial selection turned up a good number of logical exercises. At this point, we made a further selection to check quality and to identify what cognitive abilities were called into play. This second selection proved more difficult than the first, in that it entailed three distinct problems.

The first was to determine what cognitive abilities actually underlie the activities involved in solving each given exercise [3]. This is not immediately apparent from the software presentation and description; it requires careful analysis of the mental activity called upon during the solution process, which means actually trying out the software, ideally with someone belonging to the target age group. The outcome of this selection is a classification of exercises, and a subdivision of the initial set into groups of finely related content.

The next step was to check that the proposed exercises made sense, were correct, meaningful and engaging, in order not to mislead or demotivate the children. The need to check these aspects may appear surprising, since we were dealing with widely available, commercial software, but unfortunately our experience shows that not all packages currently in use meet these requirements.

Finally, we checked that the cognitive area covered by each exercise was not too limited. This is again a widespread problem, especially with drill-and-practice exercises at elementary level, which often tackle just a very limited aspect of some conceptual field, hence leading to a fragmentary view of the topic. By contrast, the educational literature confirms that most topics are better learned if tackled from different points of view [4]. This last consideration, in particular, made us feel the need to select several exercises dealing with related content from different software tools, so as to obtain an articulated view of each topic. This gave rise to the design of the learning itineraries described in the next section.

The steps for software selection described in this section are not dependent on the particular field of logic, but may be taken into consideration and fruitfully followed by teachers of any subject interested in integrating their teaching with the use of software tools.

4 Designing learning itineraries

A learning itinerary is a specialized educational unit made up of several tasks devoted to developing a limited number of well-defined cognitive abilities, through the completion of several intermediate steps. These intermediate steps may be part of the goal or may be intermediate achievements which facilitate, or are necessary for, the attainment of the final goal. Organizing several logically related tasks into a learning itinerary is usually worth the effort, since this makes presentation more organic and helps establish mental connections between different aspects of the same topic, thus facilitating and improving learning.

The word “itinerary” recalls the image of a one-way path leading to a final destination by way of some sequential, obligatory points. This type of organization, which is schematized in Fig.1(a), sometimes actually corresponds to necessary learning priorities: for instance, understanding first the meaning of addition is a natural way to introduce the concept of subtraction. In this kind of itinerary, omitting any intermediate step can severely hinder the possibility of successfully managing the following ones, and hence of reaching the final goal.

In many fields, however, the abilities necessary to achieve a didactical objective do not necessarily need to be ordered in a hierarchical or sequential way: sometimes different abilities are relatively independent of each other and can be tackled in any order. Such structures are better represented by means of a graph, like the one depicted in Fig. 1(b). This is exactly the case with the logical knowledge with which we were dealing in the reported experience. Not only were the three basic areas approached (selection and classification of characteristics, forms and constructions and verbal logic) relatively independent of each other, but also within each of them it was possible to detect sub-areas which could be tackled in random order, as shown in the detail of the three itineraries in the tables below.

This does not mean, however, that all the selected exercises could be proposed to the children in any order, both because most exercises require more than a single logical ability, and because some of them are intrinsically more difficult than others, though centred on the same abilities. It is rather difficult in any context to find exercises dealing only with a single cognitive ability, and this is especially true in the field of educational software. Nevertheless, careful analysis of products mostly reveals the main ability being exercised.
This is clearly evident, for instance, in the exercises of the Selection and classification of characteristics itinerary. Exercises 1 and 3 explicitly make use of logical connectors, but in the former only the AND connector is used, while in the latter AND, OR and NOT can be mixed in the same assignment; Exercise 1 is not a necessary precursor for Exercise 3, but it is certainly easier and would make a more suitable starting point for introducing logical connectors. Similarly, Exercise 2 proves to be easier than Exercise 3 as concerns the detection and selection of features, since in the former the features can be analysed one at a time and independently of each other, while in the latter it is necessary to check if several of them coexist. On the other hand, Exercises 1 and 2 can be considered more or less of equivalent difficulty, since the former is centred on the explicit coexistence of at most two features, while in the latter the features to be selected are more numerous but do not need to be explicitly associated.

Even more independent of each other are the exercises in the second itinerary, Shapes and constructions, all of which are centred on different types of manipulation and reconstruction of shapes of various kinds. The leading thread which conceptually connects these exercises is the cognitive balance between intuition and reasoning, and the need to set up a solution strategy based on a careful analysis of the elements at play whenever the exercises were too difficult to solve exclusively by intuition. In this itinerary, no exercise is strictly propedeutic to any other, so that in principle they could be proposed to the children in any order, as underlined by the fact that the children who skipped a program for some reason did not encounter any particular difficulty when tackling the subsequent exercises. Hence we simply ordered the exercises within the itinerary according to their intrinsic difficulty.

As concern the third itinerary Verbal Logic, again all the exercises are conceptually independent of each other. They share the requirement of understanding and dealing with the verbal meaning and interpretation of words and whole sentences, assigned visually or verbally.

The composition of the three learning itineraries realized is detailed in the tables below.

### RECOGNITION AND SELECTION OF CHARACTERISTICS

<table>
<thead>
<tr>
<th>EXERCISE / SOFTWARE</th>
<th>SUMMARY</th>
<th>COGNITIVE ABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exercise</strong></td>
<td></td>
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<tr>
<td><strong>A ogni scimmia la sua banana</strong></td>
<td>A number of monkeys are scattered in a garden; the student has to point out which of them has one or both of these features: a T-shirt, a hat. To solve the test it is necessary to be able to use the logical connector AND. At the higher level the monkeys hide and it is therefore necessary to remember their position on the screen.</td>
<td>• Understanding a task verbally assigned and completely described. • Associating two characteristics chosen from a small menu; ability to use the logical connector AND. • Aural and visual memory at the higher level</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td></td>
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<tr>
<td><strong>A SCUOLA CON ADIBÙ</strong></td>
<td>Preschool 4-5 y.o.</td>
<td></td>
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<tr>
<td><strong>Publisher</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Coktel</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Exercise</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Costruisci un amico pennuto</strong></td>
<td>The task consists in completing a sequence of goslings by constructing a gosling whose attributes (at most four) agree with the given sequence. The task is assigned implicitly, in that it is left to the student to understand the structure of the series to be completed.</td>
<td>• Understanding a task not fully explained, to be deduced from the context. • Ability to make a decision and to choose from independent characteristics.</td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GIOCHI DI PENSIERO</strong></td>
<td>Riverdeep interactive learning</td>
<td></td>
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<tr>
<td><strong>Publisher</strong></td>
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</table>
### SHAPES AND CONSTRUCTIONS

<table>
<thead>
<tr>
<th>Exercise / Product</th>
<th>SUMMARY</th>
<th>COGNITIVE ABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Il gioco delle costruzioni</td>
<td>The student is presented with a shape which can be viewed as formed by simple pieces (square, triangular, semicircular, circular etc.); the task is to reproduce the shape exactly using the pieces or elements from a basic menu with unlimited pieces. At the lowest levels the shape is presented divided into pieces, while at the higher level the internal subdivisions are not visible.</td>
<td>• Recognizing and matching shapes, and evaluating their dimensions. • Accurate visual analysis • Ability to perform an explicit task. • Logical building of shapes based on an explicit model; setting a correspondence between available pieces and the shapes to be built.</td>
</tr>
<tr>
<td>Il percorso della tartaruga</td>
<td>The student has to build a suitable route to let a turtle reach 1 or 2 or 3 salad bunches, avoiding a number of obstacles; the route is built using pieces available from a menu; two pieces allow horizontal and vertical movements, and four curved pieces allow the four possible changes of direction. When more than one bunch must be reached it is necessary to understand in what order.</td>
<td>• Performing an explicit task • Logical ability to build a not univocal model based on the available information • Visual abilities for identifying shapes and cognitive abilities to understand their function in the exercise in order to build the route correctly.</td>
</tr>
<tr>
<td>Analisi visiva e strategie cognitive</td>
<td>A coloured square is given, built by overlapping several squared tiles of different colours with geometrical holes in them (the presence of the holes allows the colour of the squares underneath to be seen). The task consists in reconstructing the model by selecting the right pieces in the menu of 15 basic tiles.</td>
<td>• Recognizing and matching shapes. • Logical construction of shapes based on a model, which includes sequencing actions and therefore having a mental geometric model.</td>
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<tr>
<td>Tangram</td>
<td>The task is to build a number of different figures (starting with the extremely simple and ending with more complex ones) using pieces of different shapes. At the simplest level, the given pieces only need to be shifted; as the level increases, the exercise gets more difficult in that the given pieces may also need to be rotated or mirrored.</td>
<td>• Visual recognition and matching of shapes. • Creativity to find the position of a piece in a hole whose shape/size differs from the available pieces. • Ability to handle a mental model • Defining working strategies, following a non-explicit and not always univocal model • When the given shapes are complex, the task demands a strong imagination effort.</td>
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<tr>
<td>The factory</td>
<td>In a factory of square tiles decorated with differently oriented stripes and holes, a model to be reproduced is presented together with a basic plain piece. In order to perform the task three different kinds of machine can be used: the &quot;hole-maker&quot;, which makes holes, the &quot;turning machine&quot;, which rotates the piece, the &quot;stripner&quot;, which prints different lines. The machines must be used opportune in correct sequence.</td>
<td>• Visual ability of shape recognition and matching. • Logical ability to build shapes based on a model, including the task of sequencing actions and therefore working with a mental geometric model.</td>
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### VERBAL LOGIC

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<tr>
<th>Exercise / Product</th>
<th>SUMMARY</th>
<th>COGNITIVE ABILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>Understanding a task verbally</td>
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</tbody>
</table>
### RIORDINA LA STORIA
**Product**
A SCUOLA CON ADIBÙ (Preschool 4-5 y.o.)
**Publisher**
Coktel

The exercise presents four or five pictures visually representing a sequence of interconnected situations. The task of the student is to order the pictures in a sequential way, respecting the logical order of the events described in each of them.

- Understanding visually presented events.
- Accurate visual analysis.
- Understanding a sequence of events as a story.
- Linguistic abilities.

### Raccontami una storia
**Product**
A SCUOLA CON ADIBÙ (elementary school 6-7 y.o.)
**Publisher**
Coktel

The exercise presents a short sentence divided into chunks (one or more words); the pieces are presented on the screen in a scattered order and the task of the student is to rearrange them in a meaningful way.

- Understanding a task not completely described, to be gleaned from the context.
- Basic reading and writing abilities.
- Reordering a scattered sentence, logic of the “meaning”.

### Exercise
**a) Caccia all’intruso**
**b) Due parole insieme**
**Product**
ELSE
**Publisher**
DIDA-EL s.r.l.

The first exercise deals with the exclusion-inclusion of words in a semantic field, the second exercise asks the student to put together two words based on the possible logical connections between their meaning (they can be synonyms, antonyms, or related as cause-effect, instrument-function etc.).

- Understanding a task not fully described, to be gleaned from the context.
- Basic reading and writing.
- Performing logical connections between words on a semantic basis.

## 5 Conclusions
In this paper we examine the need for the construction of learning itineraries we encountered while working in the field of logic abilities at elementary school level. We explain how we built three learning itineraries using several different pieces of software all concurring to fulfil the same educational objective; we also point out that the structure of such itineraries can be more or less sequential, depending on the specific subject addressed.

In this framework we found once again that, in order to use the software in a useful and effective way, it is necessary to make a very detailed analysis of its content, highlighting, in particular, which cognitive abilities are required. Such an analysis is also essential in order to structure consistent and meaningful itineraries, considering the possible priorities (compulsory or simply useful) among the various exercises.

Organizing a group of lessons in the form of learning itinerary requires teachers to focus, to a much finer degree than they are used to, on the kind of abilities they want their pupils to learn/exercise, and to find tools supporting exactly those abilities. This implies having access to a variety of software tools, and learning how to perform a careful analysis of the cognitive abilities underlying each exercise. While this planning activity requires some effort, it offers the advantage of giving rise to more meaningful and consistent presentations and allows the educational path to be adapted in response to teaching styles and learning needs.

## References
2. SD2, Documentation service for didactical software, http://sd2.itd.ge.cnr.it/ (in Italian).
5. VV.AA., Dossier Svita, TD (Tecnologie Didattiche, ed. Menabò) n.21, 2000, pp. 4-25 (in Italian).