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Version Finale de l'article pour la conférence "The International Conference on the Learning Sciences", (formely the International Conference on AI and Education), Evanston, IL, August 1991.

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Abstract

Through the presentation of an initial version of a computer-aided system for the learning of reading, SIAAL, we show how new perspectives on this task are opened up by considering it collaboratively from the point of view of aspects of cognitive science, AI and new information technologies. For a number of reasons, the stage of learning chosen corresponds to the very early experiences in the classroom. SIAAL1 plays the role of a multi-expert coach who helps the student with the learning task by managing the multiple knowledge resources in a collaborative way. These knowledge resources are viewed as projections of those that could be used by the teacher. Representations of pedagogical situations are built from every interaction with the learner. They are used to update the learner model, and, with different psycho-pedagogic factors taken into account, for guiding the conduct of a session.

1. Introduction

1.1. The SIAAL project in context

The learning to read and reading mastering activities encompass multiple situations (elimination of illiteracy, functional illiteracy, early learning stages,...). These numerous situations and their socioeconomic incidences, such as problems of information accessibility, school failures, have made learning to read a fundamental problem in all societies.

In the context of computer-based systems developed for research on learning to read, the SIAAL project[1] which we present here comes within the current general perspective of Intelligent Computer-Assisted Learning Environments (Chambreuil, 1990). It attempts to create a new medium for the support of learning by combining aspects of the disciplines of cognitive science, artificial intelligence, new information processing technologies. The reading situation chosen by the SIAAL project is characterized by three aspects:

(1) *initial stages of learning to read*. In the first instance the SIAAL1 system focuses particularly on the very beginning of the learning process (first grade beginners/cours préparatoire (CP) in French primary schools).

We have chosen this very early stage of learning for several reasons:

- it is a key period for schooling,
- it is a period for which we had at our disposal solid practical experience in addition to theoretical studies,
- for the learner it is the period of systematized discovery of a new knowledge domain, and of mobilization of newly assimilated multiple cognitive resources,
- moreover, this stage of learning to read allows to approach the task without the necessity of facing the very complex problem of natural language processing.

(2) *learning in a mediating environment*. In this situation, the proposed system appears purely as an additional tool available to the teacher and not as a surrogate teacher. This choice allows - through an analysis of the learner's reading activity - to distinguish between problems relating to natural language understanding and those relating to the reading activity itself.

(3) *applicability for children in normal schooling*. This means, in particular, that we do not have to make hypotheses - linked to reported deficiencies - on access to information not related to reading.

In the rest of this paper, except where specifically mentioned, we refer to this particular situation.

1.2. Learning to read: a cognitive approach

In our approach to reading (and in the SIAAL project), we assume that the young child has a basic mastery of his/her native language. Without going into a precise description of current models of reading (Rumelhart and

[1] (Systeme Informatique d'Aide à l'Apprentissage de la Lecture: Computer-Assisted Learning to Read System)

McClelland, 1981; Perfetti and Rieben, 1989; Seidenberg and McClelland, 1989), we emphasize the following basic points:

- reading is a complex activity,
- reading can be seen as a dual process: building of meaning and/or of acoustic chains from a visual object (written material),
- this activity relies on the interaction between text-based data and reader-based resources,
- the resources called upon by the learner are numerous: perceptual, linguistic, metalinguistic, cognitive, metacognitive, affective. They are not brought into play at the same time, but are activated specifically with different priorities depending on the reading goal, the difficulty of the text and the reader's competence and aptitudes.

In his/her learning process, the child will have to organize the different knowledge spaces and master their interrelations. He will also have to control how the resources collaborate to achieve a task.

We now develop the main aspects of reading and learning to read processes, referring, on the one hand to a number of current studies (Ehri, 1989; Ferreiro and Gomez-Palacio, 1982; Sprenger-Charolles, 1988; Rieben and Saada-Robert, 1989), and on the other hand to our own observations made during the period since 1984 in CP. We illustrate these aspects by referring to one of the main problems of the initial stage, that of word recognition.

The written language has its own structures. The child has to understand the rules and working of the written system. Thus, he/she has to see the word as a specific graphic object, and not as a drawing, for example. He/she also has to see the word as a complex object, made up of letters varying in sort, number and position[2]. The word itself is an element of more complex structures (phrases, sentences, texts). The child will have to understand the position and function of a word in these structures.

The written system corresponds to the spoken one. The child has to establish this relationship and learn the correspondences between the two systems. He/she has to identify recurring regularities within words: auditory units (syllables), visual units (letter clusters specific to a given language). He/she can read a word using visual or phonetic clues, or both.

The written language is related to meaning. The child will have to establish the relation between a word and its meaning(s).

The written language is, in itself, an object of knowledge. Through the stages of learning to read, the child builds metalinguistic knowledge about

[2] A child may recognize some conventional letters in isolation but may not be able to relate them to the composition of a word.

writing. His/her aptitude to identify spaces between words is developed simultaneously with his/her mastery of word concept.

All these elements of knowledge interact simultaneously in the construction of the child's knowledge. There is a particular developmental order. Acquisition models (Frith, 1985; Seymour and McGregor, 1984; Ehri, 1985; Gough and Juel, 1989) refer to different stages: logographical, phonological, orthographical. However, we prefer to speak - as Rieben (1989) does - of "prevailing strategies": through our own observations of first grade beginners, we have noted important inter - and intra - individual variability in strategies, acquisition rhythms, as well as in the balance of the different components between them.

One remarks that the construction of knowledge does not follow a linear progression of visible performances. A child who is able to identify a word through the "whole word" recognition may have difficulty when reading this word at a later stage. This is not necessarily due to a regression but can be the result of the acquisition of knowledge about word analysis and its relations to the spoken word.

2. General conduct of the first working session

A working session with SIAAL1 (current first version of the system) is characterized by general pedagogical goals and by the types of activities offered to the learner.

2.1. The pedagogical goals

There are different types of pedagogical goals : for instance, goals giving rise to an evaluation at the very time of the session (immediate goals), goals giving rise to a familiarization session with evaluation being carried out in following sessions (postponed goals).

The first working session with SIAAL1 holds the following pedagogical goals as essential:

- matching written chains with phonic chains,
- identifying and recognizing some fifty words,
- mobilizing multiple strategies in this identification,
- doing a first analysis of the written chain and of the word, allowing us to put forward the regularities specific to the written language.

2.2. The types of activities of one session

In the first working session, all the activities are based on the reading of a story. Seven types of activities are offered to the learner. Each activity type is associated with an interface window that has specific functionalities and

types of objects which can be brought into play. In the following part, such a window will be called a "didactic workshop".

In the first didactic workshop (A1), the system provides the learner with a part of a story (a sequence defined by its discursive functionality). Each sentence of the sequence is simultaneously read to the student, displayed and illustrated by a drawing. By clicking on the displayed sentence, the learner can also get another reading of it. During the reading of a sentence, some phrases may be specifically marked (for instance, by highlighting).

The characteristics of this workshop interface are[3]:

- its constituents (sound, text, drawing),
- the spatial setting of those objects (in different parts of the window),
- the temporal setting of the objects (succession, simultaneity, overlapping),
- the structural relationships between the objects (highlighting during the reading, ...),
- the functionalities of action of the learner (clicking on a phrase or a sentence to get it read aloud, ...).

The second activity (A2) consists of checking the learner's comprehension of the story. Here again a specific window is used where one can manipulate sound, text, picture.

Activities (A3), (A4), (A5) and (A6) deal with the identification of (written) words or of regularities on words in different types of contexts :

- (A3) words to identify in the sentences of the story,
- (A4) isolated words in a "sound/text/illustration" association context ,
- (A5) isolated words in a "sound/text" association context ,
- (A6) words to replace inside a sentence.

The seventh type of activity (A7) offered to the learner is akin to a micro-world type activity. It consists in giving the learner access to the functionalities for using and updating a "didactic dictionary". The didactic dictionary associated to SIAAL1 is in itself a complex system. We will not tackle it further in the context of this paper.

3. SIAAL1 as a multi-expert coach

SIAAL1 has been conceived as a "multi-expert coach" for computer-assisted learning, organizing the multiple data resources in a cooperative

[3] All the other workshops have been developed according to the same specification principles.

way. These resources are seen as projections (or extensions linked to the specific possibilities of the computer) of the knowledge resources which could be used by a teacher.

In the following part, we simply indicate some directions for analysis and use on the base of the resources available within the SIAAL project.

3.1. Sound resources

Sound resources are characterized by the following aspects :

- specific characteristics, in the sense that the words or the sentences of the story match specific sound data, which can be analyzed as significant constituents in a reading activity (syllables or vowels in a word)

- the matching of items from other data resources (written text or illustrations). These associations may be made either from the sound resource or from items of other resources.

- functionalities for the computer system as a learning partner, in the sense that the sound resources are called up by the system for the reading of the texts, instructions are given for different activities and comments are made to the learner. But these resources may also be activated to answer the solicitations of the learner who, for instance, asks for a word or a sentence.

In other respects, the sound resources are also constituents of didactic workshops. They contribute to the characterization of pedagogical situations. In doing so, they tell us more about their own functionality. Thus the simultaneous presentation to a learner of a written word, its oral reading, a drawing associated to it, can facilitate the creation of correspondences. However that representation may also create a "cognitive overload" and in fact hinder the creation of the desired correspondences.

3.2. Knowledge about the story

The system must be able to select the items of the "world of the story" which are pertinent to the current working session.

Knowledge about the story generates problems to present to the learner. There are two aspects to this. It allows, on one hand, the definition of the relevant questions likely to be put to the learner within the scope of activities (A2), (A3), (A4) and (A5); and, on the other hand, the specification of various parameters of problem in the quest for an answer associated to a given question. For instance, when one word is to be identified among others, this knowledge will permit to select the group of words according to various structural criteria, one of which is their links with the sequences of the story already presented. In the same light, it will permit a definition of the texts for an activity (A6).

According to another view, this knowledge permits the analysis of the learner's answers with respect to their various relations of relevance to the expected answers and to the information conveyed by the text: answers explicitly shown in the text, answers that are deducible from the data contained in the text and answers corresponding to what the learner is expected to know about the world of the story. This knowledge acts as a filter of the learner's answers.

Without standing in the realms of general linguistic knowledge, the SIAAL1 system simply aims at dynamically building the only knowledge of the world linked to the story in order to use it in the ways mentioned above. For instance, the questions deal with particular relations between the characters of the story : these relations will be managed dynamically during the conduct of the story.

3.3. Pedagogical knowledge.

Other resources deal with knowledge, which we will describe as psycho-pedagogical. The development of a working session will be guided from these resources (and from the student model). They are of different types but somehow characterize an organized space that will be set up through the definition of an effective activity proposed to the learner.

Some of these resources will relate to general psycho-pedagogical knowledge, which structures the working session. For instance, it will organize the transitions between story reading, comprehension checking and different types of activities A3 to A6. This type of knowledge will also distinguish between activities relating to the application of "old" acquired knowledge, and activities leading to the building of new knowledge.

In a way, one can find some sort of very specific items of knowledge on the domain of learning to read at the other end of this knowledge space. They are used in establishing the elements actually introduced in a given activity. For instance, in the case of a word identification workshop, they will be the ones that stipulate whether the other words given as options are to be "close" words or "distant" words (here again with different proximity criteria).

Thus, we have a twofold organization of the knowledge space: a hierarchical organization in strata, and for each stratum of the hierarchy a specific organization (contrasting or complementary structures).

3.4. Student model

This resource aims at capturing four aspects of a student cognitive model (beyond an history of the successes and failures) (Clancey, 1986; Dillenbourg and Self, 1990; Self, 1988a, 1988b):

- the level of acquisitions for the target words in the session (in terms of "approached word", "recognized word", "assimilated word", "triggered word"),
- the influence of communication media in the didactic workshop (making it easier, disturbing),
- the way he/she builds his/her knowing-how-to-read (in terms of reading strategies),
- student's hypotheses on the domain (in terms used by Ferreiro (1982), for instance).

This information about the learner, resulting from an analysis of his/her activities, may also be compared to models of "learner types" or "evolution types", rather like stereotype models (Rich, 1989; Kobsa, 1990) corresponding to type (but dynamic) schemes constituted by a teacher through his experience.

This knowledge of the learner will influence the development of a session at the different organizational levels. It will not only contribute to the dynamic management of the types of activities offered but also, at the very time of an actual activity, offer a choice of elements of this activity: for instance the choice of words already known by the learner within a given didactic workshop.

3.5. Didactic situations

The dynamic management of the cooperation between the multiple resources is made possible by the foundation of "didactic situations". A didactic situation is a form of "instant snapshot" of an interaction between system and learner. It memorizes different factors likely to be relevant to the student modelling and to the control of the working session within the interaction. For instance, in an interaction related to a word identification activity including sound and graphic resources, the created didactic situation will memorize elements such as: the position of the word in the development of the session, the psycho-pedagogical factors affecting the situation, the type of didactic media used in the situation, the expected answer, the answer given by the student, structural elements about the written domain included in the situation (for instance, the other suggested words ...).

These didactic situations are stored and constitute an history of the working session. They are also regularly analysed (not necessarily at the time of their creation) by the mechanisms that are dynamically updating the student model, the psycho-pedagogic parameters which organise the working session, and the information on the story cited above.

Didactic situations may also be analyzed at different "depth levels" either when first building the student cognitive model (relating to stereotypical models) or in a revision of that building according to new convergence indices[4] (Wenger, 1987).

4. Working out the resources in a prototype system

A first prototype of a session with the SIAAL1 system has been developed in Lisp on Macintosh. One of the goals of the prototype was to provide the team with a research tool allowing the management of multiple data resources. Another goal was to begin the creation of various didactic workshop windows.

Because of time constraints on development, the system has been built around an inference engine which handles different rule-based representations of one aspect of the resources and their interactivity. These rules dynamically manage various bases of facts representing another aspect of the data resources. Finally a third aspect of some data resources (linked to their application in the didactic workshop, or to the expertise of the written language) is represented in terms of objects.

5. Conclusions: perspectives and difficulties

One of the immediate evolutions of the SIAAL project currently investigated - will deal with its architecture. Relying on an initial study made in 1988/89, we will develop a new system around an architecture that will use a control-blackboard (Gasser and Huhms, 1989; Engelmore and Morgan, 1988) which will be explicitly organized towards the management of multi-expert resources.

SIAAL1 was more concerned with items of interaction/cooperation of these resources, than with the investigation of one of them seen in isolation. Throughout that necessary investigation, we shall particularly concentrate on psycho-pedagogical factors as they play a central and organizing part in the dynamics of the system. The remaining difficulty is to point out those factors and their incidences, not at a highly general level but with the accuracy required by particular activity situations.

If one thinks that these investigations rely on analyzes coming from the cognitive sciences, one must not conclude that it is a one-way cooperation. Our own experience of working regularly with practising teachers, and of a pure theoretical reflexion shows us that the specification and realization of

[4] When a teacher can recall elements in a situation he did not take into consideration before and which at a given time become relevant.

such a prototype, even in the domain of reading, are particularly useful for bringing out a knowledge acquisition methodology.

Lastly, we will make a final remark more generally concerning the expertise of a domain and its use in a computer-assisted learning environment. In the system presented here, the expertise on reading and on learning of reading is not confined to one specific module (or to two if the teacher module is in charge of the learning expertise). The expertise appears rather as being distributed among the resources which are used. In the same way, the learner's acquisitions, the building of his/her knowledge about the reading sentences, also deal with distributed acquisitions whose gathering will constitute the desired mastery.

We will conclude by stating that we are left with many difficulties to overcome before we can use such systems in real pedagogical situations. However, the present state of each of the domains concerned and the opportunities for their improvement lead us to believe that in a near future, especially for a problem as important as learning to read, new tools to help learning will be integrated into the various educational structures (whether traditional or distance learning).

Acknowledgements

We would like to thank: Michael Pengelly for his criticisms on the paper; Delphine Renié for the English translation, and Rachel Panckhurst for the final corrections; the "Inspection Académique" of Clermont-Fd from the regional educational board for its support of our collaboration with the primary school of Manzat and the secondment of one of its teacher for the knowledge acquisition task.

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