# VIRTUAL LEARNING SPACES IN DISTANCE EDUCATION: TOOLS FOR THE EVA PROJECT

## 1. Introduction and previous work.

At the beginning, education was one-to-one. Thus, Aristotle was the teacher of Alexander the Great. This being expensive, groups of students were introduced, sharing a teacher, a library, a shop, a laboratory. This is the university model. Education in this model is in situ (students have to go to the classroom, to the library, etc.) and synchronous (they have to participate at the time the teacher is delivering his lecture).

It is quite expensive, especially in countries like Mexico, to build enough universities for everyone, scattered over the countre, with appropriate laboratories, libraries, etc. It is also quite expensive to go to live near the university, usually located in the capital of the state or of the country.[1] Thus, mail schools, distance learning, virtual universities and digital libraries were introduced. We elaborate on these models — artificial intelligence (AI) in education (Wenger, 1987), knowledge-based tutoring (Clancey, 1987) using computers agents (Genesereth and Ketchpel, 1994); natural language processing (Guzmán, 1998), common sense knowledge (Lenat and Guha, 1989; Guha and Lenat, 1994; Guzmán, 1994[a2])] and telecommunications.

### *1.1. The problem to solve.*

By using modern technology, the EVA (espacios virtuales de aprendizaje, or virtuallearning spaces) project aims to perfect the asynchronous and non-in situ (remote) educatinal model(s). At the same time, EVA seeks to meld hermoniously with classical methods.

### *1.2. Objectives of this research.*

- To develop a model, and the corresponding software, hardware and courseware (or teaching material), for high-level high-quality education which is essentially non-in situ (far away) and asynchronous, when condirering the ‘teacher’ and the ‘studente’.

- To use the former tools for personalized education, providing the students with most of the courserware (books, quizzes, etc.) they need. (This mitigates the need for each student to buy several copies of books, manuals, teaching material, etc).

- To help the students to help each other, whenever possible.

[1] For instance, there is a tendency in the Institutos Technológicos to request from their faculty to have at least an M.Sc. degree. Once a professor has academic duties, it is quite difficult for him or for his institute to let him leave for a couple of years to go to some capital to get his degree, and then return.

*1.1.2. Our setting.*

We assume that there are enough students, in remote places, who cannot travel to attend in situ universities, and lack adequate access to books, simulators, and other teaching material. They have access to a PC which is (occacionally or continuously) connected to a network. The students are willing to take a computer-administered quiz, to ascertain their initial state of knowledge. The students know what they want to study (know their final state). They study at their own pace through EVA, but can also learn through the usual ways: buying a book, attending a lecture, studying with classmates, asking and advisor, practicing on the computer.

The Knowledge Space or Learning Space is all those concepts and information that could be transmitted to a student of a given discipline (Computer Science, say) — it is the union of all books in the discipline. For the experiment, the Knowledge Space of EVA is computer science at the Master of Science (M.Sc.) level. The ANIEI (1997) has already defined and discretized the Knowledge Space of Undergraduate computer science.

*1.2.2. Main features of EVA and our main Contributions.*

- The discrtizing of the Knowledge Space. By the assumption of Section 1.2.1, EVA needs to supply the student the right teaching material. Thus, EVA requires access to adequate book chapters (modules), which of course somebody has to write. In order to make the amount of writing finite, we descretize the Knowledge Space, so that two modules either overlap completely or not at all. (The space is partitioned into modules). This allows a computer program to select appropriate modules for a given student, if the current state of their knowledge and the desired final point in the Learning Space are Known.

- Polybooks: automatic formation of study plans (learning trajectories) and asynchronous delivery of the teaching material to each student (in the form of personalized books, called polybooks).

- Computer management of student advances. Each time the student finishes reading a module, she takes a quiz (every module ends with a quiz), thus moving the student to a new current state of knowledge.

- Automated search of additional teaching material, not yet located in the Knowledge Space, through natural language searching tools (Clasitex; Guzmán, 1998).

- Automatic placement of hyperlinks in ‘normal’ text to other ‘normal’ texts (medina, 1998[a]), thus enriching the learning habitat of the student.

- Automatic finding of possible classmates and advisors.

*1.3. Previous work.*

EVA has many precursors, and builds on many of them:

1. Traditonal methods: teaching in the presence of the teacher ('in situ' teaching); paper books, paper libraries; synchronous question-and-answer sessiones.

2. Open education. Which is essentially asynchronous and non-in situ: correspondence shcools, where printed chapters are sent to the student, and grading is also done via mail. Home study. Home practice.

3. Education via satellite, teleconferences. A live or recorded lecture is delivered through television. Questions and answers and discussion forums may be synchronous or asynchronous; by electronic mail, for instance. Virtual university.

4. Extending the delivery media. Electronic libraries. Distribution through CDs.

5. Competence-based education. What one learns is defined by ability, knowledge and training defined by 'posts' or positions in the workplace.

6. Life-long learning: recognizes that learning is a longterm commitment, especially in fast-changing disciplines (such as computer science).

7. It is fascinating to discover that EVA can blend with 1-3, use the techniques of 4, and co-exists with 5 and 6.

*1.4. Previous work by us.*

Some additional information about EVA can be found in Núñez (1997); Núñez et al. (1998).

*1.4.1. Gathering of information via agents.*

ANASIN (Guzmán, 1994b) is a commercial product that gathers information in different sites, dispersed over a large region of time and space, in order to obtain strategic data, useful for decision making, from operational data sitting in files and tables located in computers located in the work centers, The agents used in Anasin share a single ontology or data dictionary.

The INJECTOR OF AGENTS (Martínez, 1998) places demons in remote places, using the available network. It works under a variety of network types, communication types, protocols, and it assumes a hostile or disordered environment in the host, therefore needing to send several agents to become familiar with a host's environment, so that the last agent reaching it is the agent one wished to inject.

*1.4.2. Handling of texts written in natural languages, concept trees.*

CLASITEX (Guzmán, 1998) is a program that finds the main topics in an article written in Spanish. It does not work on key words, but on concepts, It uses a concept tree. For this reason, it is capable of finding an article talking about shoes, even if the article does not contain such a word, but contains instead the words boot, moccasin, sandals etc.,

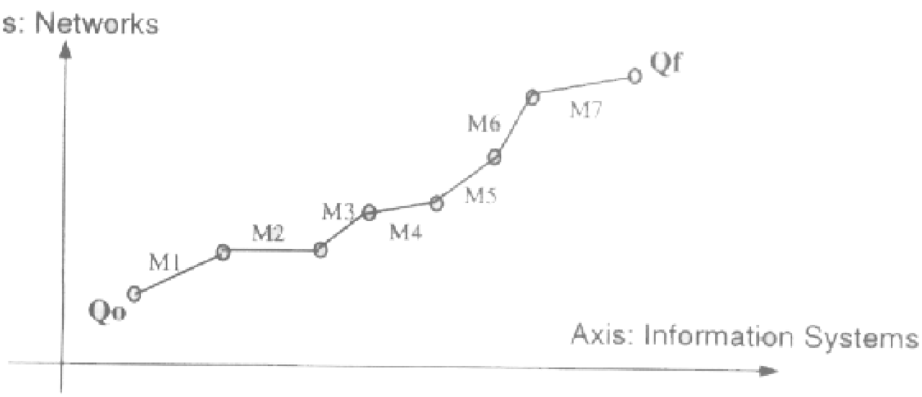


Fig. 1. Learning trajectory, from the initial knowledge state Qo to the final state Qf. The spaces has eight dimensions, only two are shown in this figure.

Even if these words may refer to other contests or concepts, e.g. moccasin is also a tribe of American Indians.

CLASITEX++ (Beltrán et al., 1998) is a variant of Clasitex that also having a tree of concepts in English, can analyze texts in Spanish and in English. Its trees are larger. It is written in C (Clasitex is written in Unix shell, with sed, awk, yacc, and other utilities).

## 2. Parts of EVA, and how it works.

The EVA software delivers personalized learning material (polybooks) to each student. For this to be possible, EVA has access to a large collection of modules (book chapters) written in several formats: in Word, in Power Point, etc. Knowing the current knowledge state, and the desired final state, EVA arms the personalized polybooks. EVA then monitors the student advance, through appropriate quizzes located at the end of each module. If the students provide their work schedule, EVA can program them with synchronous activities: e.g. attend this teleconference on Thursday at 18:00 on TV channel 22; watch the educational video on channel 2 of Edusat, July 23 at 6:00 am; join a synchronous question-and-anser session.

*2.1. Learning trajectories.*

EVA applies to each student, initially, an examination to measure their computer science knowledge (Qo in Fig. 1). This examination has been routinely applied at the Centro de Investigación en Computación (CIC) for the last three years, for student selection.

*2.1.1. Discretizing the learning space.*

Measuring students, arming books out of chapters, and classifying questions requieres some orderin the Knowledge Space. For this, the Graduate Computer Science[2] knowledge is divided into modules (unit learning modules, or ULMs; Núñez et al., 1998). Informally, a module is a chapter of a book, a book is the written material needed to cover a graduate course that lasts a semester, normally 80 hours of lectures in the classrooms. Naturally, this is a guide, and not a strict definition. Each of the axes of the Knowledge Space is divided into ULMs — the division looks like the index of a book, a collection of subjects. Of course, the hard part is to instantiate the modules (that is, to write them).

In each axis of the Learning Space, there is a precedence relation: a < b means concept a has to be learned before concept b. Between axes, there is a no-precedence relation: the learning of a concept in axis i (information Systems) is not affected by the Knowledge of the student in axis j (computer architecture), where $i \neq j$. This independence assumption normally holds. Where it does not, EVA uses tables containing precedence relations between concepts located in different axes, to capture these precedences.

*2.1.2. Initial state.*

EVA applies to each student, initially, an examination to measure the Computer Science knowledge in each of the eight axes that ANIEI (1991) has defined: Social Environment; Mathematics; Computer Architecture; Networks; Basic Software; Programming and Software Engineering; Information systems; Man-machine Interaction. Thus, each student is reduced to a vector with eight components.

*2.1.3. Final state.*

Each of the students states the area in which they want to do their M.Cs. work. There are only six possible final states, corresponding to the six areas (specialties) at CIC. But the EVA experiment only covers one of these areas: now, there is only one final state (Qf in Fig. 1) for all EVA students. (This is not strictly true, due to the presence of optional subjects).

[2] EVA's first experiment is to teach the subjects of an area of the Master of Science Program at C.I.C. EVA can be applied to other areas of knowledge, as well as to other levels (undergraduate level, say).

*2.2. Polybooks.*

Polybooks are like normal books, except that: (1) each module covers a ULM of the Discretized Learning Space (Section 2.1.1); (2) each module can be built up in a different media: video, Power Point, Word, audio, etc.; (3) each module ends with a quiz; (4) a polybook is armed (by concatenating suitable modules) for each student; (5) the material is not sent by paper, but by electronic deliverty through the network.

This individualization is possible since we know the initial and final states of the student.

The manufacture of the learning trajectory for a given student proceeds as follows: for each axis, find their initial and final concepts CI*i* and Cf*i*, for *i* = 1,...,8. Find suitable unit learning modules (ULMs) to go from each CI*i* to Cf*i* (*i* = 1,...,8). If the independence assumption hold (Section 2.1.1), EVA will arm eight polybooks, one for each of the axis, each covering the missing knowledge to go from the initial concept CI*i* to the final Concept Cf*i*. The learning trajectory of the student will consist of eight disjoint learning trajectories, which can be studied (travelled) in any order — in parallel, for instance — as shown in Fig. 2. Only four of the eight axes are shown; axes are shown parallel, although they are orthogonal.

Each axis shows only the initial and final concepts; many other intermediate concepts exist, but are not shown in Fig. 2 (compare with Fig. 1).

When the *independence assumption* fails, that is, a < b for a in one axis and b in aanother, EVA inserts in the learning trajectory of the student the corresponding prerequisite, shown as a dotted arrow in Fig. 2 (only one prerequisite link is shown). Once this is done, the learning trajectory is finished, and it is relatively easy to arm the corresponding polybook(s).

*2.2.1. Knowing what the student has learned.*

When the student has finished a module, the computer administers the quiz found at its end. Thus, EVA watches student progress, and it knows at every moment what the student already knows, To do this, EVA keeps track of the initial, current and final states of each student, as well as other statistics pertaining to their learning behavior. This is done by a bookkeeping or administrative software, an earlier version of which (C. Guzmán, 1998) session of questions and answers.

*2.3. Integrating synchronous activities.*

EVA asks the students for their calendar of events. Then, EVA arms their learning trajectory containing synchronous and synchronous activities: among the latter, to attend a conference or a teleconference; to watch a relvant TV program; to participate in a (live) session of questions and answers.

*2.4. Finding classmates and advisors within the students.*

A *classmate* of a student is antoher student having a similar learning trajectory, and a close current state. By comparing learning trajectories of students, EVA suggests possible classmates for study, homework, writing computer programs, etc.

An **advisor** can be another student (or an alumnae) with a similar learning path, but closer to their goal, Using a similar algorithm, EVA suggests possible advisors.

*2.5. Finding new learning material suitable to each student.*

CLASITEX is a concept-processing program that finds the main themes or topics in a Spanish article or text. An English version also exists (Beltrán et al., 1998). Given the learning trajectory of the students, and the languages they read, with the help of CLASITEX, EVA finds suitable material in the web, or in a data base, and sends it to the students when they are about to need it. Medina (1998b) is working on this feature, wihch will then be added to EVA. This is possible because the current state of the student is known; hence, EVA can deduct at least eight concepts that they are currently learning (one for each axis of the Learning Space); giving these concepts to the agent that uses CLASITEX, the appropriate articles (that cover some of these eight concepts) can be retrieved.

*2.6. Questions and ansers in EVA.*

EVA uses synchronous and asynchronous question-and-aswer sessions. But EVA does more. What is a question? A question and its answer is a (small) path in the Knowledge Space. Thus, it can be located in such space. Therefore, EVA indexes the questions (it know where), for later use by new students. 'Before asking, please read all thee 63 answers.' This is a generalization of the file of commonly asked questions that one finds in manuals of mature software. Notice that the question-answer pairs (perhaps in multimedia format) can be indexed by CLASITEX too, but with fuzzier results.

*2.7. Automatic placement of hypertext links.*

EVA can add hypertext links (automatically) to: (a) material found in the web or data base; (b) new polybooks; (c) old text books; (d) material written by the studente; (e) questions (see Section 2.6). For instance, if a text found in material (a) through (e) mentions 'boots', EVA (through CLASITEX) can place hypertext links to texts where the main topic is shoes, or boots, or garments, since CLASITEX knows the ontology or knowledge tree of the subject area (it knows that shoes are divided into sandals, boots, moccasins, etc., and that shoes are 'brothers' of shirts pants, socks, etc.). Thus, EVA can enormously enrich the learning environment of the student.

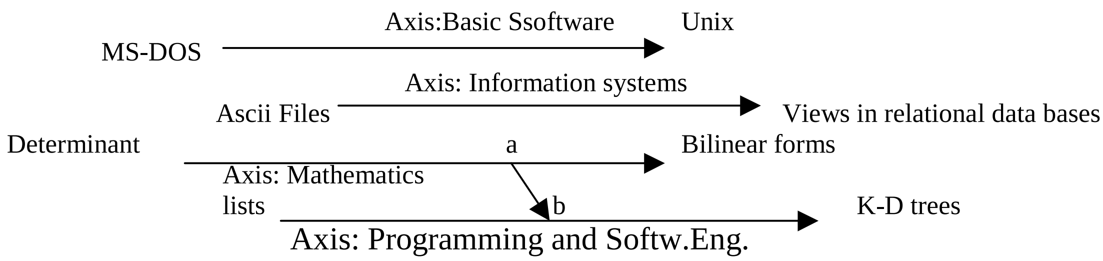


Fig. 2.

These links can reference a dictionary; thesaurus; an explanation text; other books or polybooks where superior concepts (generalizations) or detailed concepts (specializations) appear; questions stored in the data base; drawings (if they have key words). Moreover, the indexing can be normalized (lins only point to concepts in the discretized Learning Space) or, more frequently, un-normalized (links point to concepts).

Links can be placed to relevant articles (since CLASITEX knows which are the main subjects of an article). Links can be placed from Spanish to English articles, and viceversa. Color or appearance of link shows its type: definition, explanation, link to a main article about the theme, generalization (sandal points to shoe), specialization (Medina, 1998a), other links: ‘grows in’, ‘produced in’, ‘part of’, ‘cited by’, etc. (Lenat and Guha, 1989).

Links can also be placed that are *semantically meaningful*. A link from the word ‘star’ to an explanation about the solar system is not meaningful if the source document talks about movie stars. But CLASITEX will not fall into this confusion; most likely, it will have detected whether the amin topic of the source document was about famous people or about sidereal bodies.

*2.8. The transmission of polybooks.*

A polybook, once armed, is transmitted from the EVA server to the student’s computer (or to a nearby local polybook server, if it exists), in a store-and-forward fashion (i.e. not in real time); it can be done overnight, or by using electronic mail. The existence of local polybook servers allows many students to share ULMs.

*2.9. The learning environment.*

We have been experimenting with different types of student computers. We have:

(A) PCs, that are linked to a polybook server, which also handles discussion forums, chats, etc. This can be seen as *the current technology*.

(B) Network computers, which are like (A) but need an additional software server. This can be seen (perhaps) as the *future technology*.

(C) Video-receiving devices: currently, PCs, which could perhaps later be enhanced by special cards for faster video handling. The goal of these devices is to experiment how to send video through ordinary telephone lines, using powerful compression algorithms. If successful (not yet), we could send by a telephone line our live teleconferences, and by another line full duplex audio, enabling student questions to reach the speaker in real time. This can be seen as *the poor man's technology.*

(D) An even cheaper solution than © for teleconferencing i to transmit (off-line) the slides or the Powwer Point presentation of the speaker, and then to transmit in real time full duplex audio only — this needs only one telephone line — on which we overlap short beeps to indicate left arrow, right arrow, next page or slide, and so on. In the reciving PC, these commands move the cursor to the correct place in the presentation. In this manner the speaker points to parts of his slides, but his moving face is never seen.

Currently, we have ta CIC a mixture of (A), (B) and (C) in a single room — due to lack of space — which we hate to call the EVA classroom, since EVA supposedly does not need classrooms.

**3. R & D activities, current status.**

Thinking and theorectical work began in 1997. Funding for the project (see Acknowledgements) started early in 1998, thus construction lags behind.

*3.1. Status of the EVA project (July 1998).*

*3.1.1 Theory, models.*

ANIEI has already discretized the Learning Space for undergraduate Computer Science. EVA will do this discretizing (Section 2.1.1) for one of the six M.Sc. areas. Work has just begun. No area has yet been selected.

*3.1.2. Software.*

The generator (Section 2.2) of individual learning trajectories is being built by Argelio de la Cruz. The integrator of synchoronous activities (Section 2.3.) has not been designed. Thes classifier of interests (Section 2.4), to find classmates and advisors, is being built. The Information Retriever (Section 2.5) is being built by Norberto Medina. The manager of personal academic advances (accounting of academic scores, courses, etc.) is being built by Maria Alonso. The question's classifier (Section 2.6) does not exist. Although it could be a variant of the classifier of interests of Section 2.4. The placer of hypertest links (Section 2.7) is under construction by Norberto Medina. The transmitter of polybooks (Section 2.8) has not been designed, although perhaps a simple approach will work: send modules as computer files, that is what they are.

*3.1.3. Hardware.*

PCs, Network computers and a couple of servers are up and running. A video compressor [Section 2.9( C )] was built, but abandoned (it transmitted about six frames a second); no furhter work is in progress. The device of Section 2.9 (D) is commercially available as computer software.

*3.1.4. Generation of polybooks.*

EVA needs about 20 polybooks (Section 2.2) for the experiment with one area of computer science. Six books are scheduled for 1998. The other books are scheduled for 1999. There is a polybook on languages, automata and complexity being written, while an existing book on agents will be converted into a polybook, in order to comply with the discretizing of the Learning Space.

*3.1.5. Evaluation.*

It is important, at the end of the experiment, to compare learning through EVA against traditional learning. What subjects are better suited? Which media (see Section 2.2) best conveys which kind of knowledge? It is too early to start theoretical or practical work in this.

*3.2. Conclusions.*

Most of the interesting conclusions of the EVA experiment will have to wait until more work has been done. Right now, we can say:

EVA experiments at the same time with three levels of technologies:

- INEXPENSIVE: (a) deferred (store-and-forward) transmission of educational material by network; (b) electronic mail; (c) real-time transmission of video (lectures) and sound by two telephone lines.

- CURRENT: PCs with multimedia, ftp, Internet.

- FUTURE (some are currently expensive for massive use): NC computers, ATM.

EVA appears to be a new and self-sufficient and complementary educational method, which can be applied at several educational levels. It introduces a new teaching material, polybooks: free (for the moment), personalized, tailorable, self-configuring, self-actualizing and (some of them, perhaps) interactive.

EVA lives in harmony and can be mixed with traditional education, satellite and TV education, virtual university and teleconferences, competence-based education, life-long learning.

EVA may be of economic and social impact; if successful, it will lower the cost of good education.

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