3. Exploitation and technology transfer

3.1 Target groups

- **Developers and Researchers in the field of Artificial Intelligence &Education** for the toolkit and the design methodology: the AI & Education community is in big need for available toolkits. Our tools will be usable by any programmer with some knowledge of Lisp. Most existing systems have been used for research purposes only, few have been completed, and even less have been distributed. Therefore we are sure to fill in a need.
- **Students at the University level** for applications**.** Intelligent Learning Environments run for the moment on hardware which is only available at the University level. Also, the kind of learning and teaching sponsored by ILE's is more dominant at this level. It involves integration of various kinds of knowledge, teaching is less focused on clearly identified goals, but frequently students are supposed to learn by doing individual research. Artificial Labs such as MEMOLAB have a good potential for becoming essential to such teaching. Furthermore, TECFA is interested in teaching of complex, non pre-structured knowledge.

3.2 Means to reach target groups

- Our toolkit will be made available by FTP (free of charge) to Developers and researchers in non-profit organizations. The availability will be announced on selected News groups and in specialized printed Newsletters. Other means of distribution will be evaluated.
- The Intelligent Learning Environments developed at TECFA, i.e. MEMOLAB and a second application, will be available on the same medium for testing purposes to persons working in the same field.
- Starting 1992, TECFA will offer a postgraduate diploma in educational technologies. Some of our diploma students will have to work on the evaluation of MEMOLAB with undergraduates of the "Faculté de Psychologie et des Sciences de l'Education". As soon as a stable version of the system will be available, we will try to find external testing sites.

3.3 TECFA's possibilities

- For electronic distribution, TECFA has its own FTP server.
- Starting october 1992, we will have the necessary manpower with students of our diploma to conduct more extensive testing.

3.4 Cost and Schedule of valorization

- The toolbox and a good Beta version of MEMOLAB will be released already by the end of 1992. We will try to coordinate our work with other people in the field right from the start. This operation will involve no additional costs.
- On the other hand, diffusion of MEMOLAB to potentially interested university teachers may involve substantial travel costs. MEMOLAB (and the second application we will produce) will not be a commercial system, and some background in computer science will be required to install it. Furthermore, teachers will probably need some training to profitably use an Intelligent Learning Environment in their courses.

with more traditional ones and other emerging techniques from fields such as data visualization. It is not always efficient to program every module in an intelligent system with AI techniques. Research such as ours can help to point out, where we need AI and where we better use other techniques.

- **Interdisciplinarity**
  The research team involved in this research is composed by persons with very different backgrounds. Each person can bring into this project research interests which concern also those different fields. For example, the design of the laboratory in Memolab was guided by principles of neo-Piagetian research on human memory capacities and evolution. On the other hand MEMOLAB will be a testbed to check whether this psychological theory is operational and can be used for teaching. Another person on the team is interested in tools for knowledge manipulation, i.e. helping persons to organize, store, visualize, modify and create complex information, a research domain which is sometimes called "New AI". Since, in a rich ILE we create some sort of artificial lab with several tools and help systems, we will also contribute to this new field of research. The same remarks can be made of course for AI. Some problems we are tackling address real hard AI issues (case-based reasoning, dynamic planning and scheduling).
- **Application domain**
  Usually research in AI & Education focuses on very technical domains. The need for learning environments in "soft" domains is just as high. Our ILE work is geared towards the human sciences and produces results which normally can't be expected from research on teaching more formal knowledge.
- **Formalization of ILE design**
  Research in AI & Education has been dominated by "scruffies". This is the usual phenomenon observed when people attack a new field of research. It is time now to produce clear theoretical frameworks for producing ILE's. Our work together with John Self (University of Lancaster) may allow to help bringing research in AI & Education up to a more mature stage.

(b) Practical Implications

- **Promotion of Swiss AI & Education research by supporting an existing center**
  The initial grant from NFP23 helped us to create a center of research in AI & Education which has gained international recognition. We now have six persons working full or part-time on AI & Education issues. If we can keep this level, or increase it, Switzerland would maintain such a center in this promising field of research. Innovative software design and development is hard and it needs manpower.
  Since the beginning of the project we have established contact with the following researchers interested in AI and Educational Computing in Switzerland: Prof. K. Reusser and H.Kaiser (Universität Bern), R.Devi and T.Rätz (Universität Basel), E.Forte and P.Ysewijn (EPFL), Prof. P. Bonzon (Université de Lausanne), Prof. Courbon and Prof. Levrat (Université de Genève), M.Rosner and R.Johnson (IDSIA), Prof. R.Pfeifer (Universität Zürich).
- **Impulses to the Computer Based Training Industry**
  Intelligent Learning Environments and other kinds of AI & Education software are still in an early stage. It is not expected that the CBT Industry will make direct use of all our research now. However, important impulses can be given to industry and the school system and some have been taken already. For instance, modified expert systems are now being used for task training in industry.We have developed good contacts with several companies: Le Concept Moderne SA (Geneva), Hewlett Packard Europe, Brodman Software Systems (Zürich), Cap Gemini (Paris), plus several companies involved in the JITOL Delta project.
- **Sponsoring of research-oriented teaching, and learning by doing**
  Intelligent Learning Environments are profitably used in areas which need learning by doing. An example is experimental methods. When students get their licence diploma, they normally are not operational for research since they have never done any. They need on the job training which may take up to two years. The use of systems like Memolab should help to shorten significantly this period. Increasingly, we need people in research and industry who can solve problems in an independant way making use of various tools and problem solving strategies.

4.2. **Intelligent navigation and information manipulation tools for the hypertext**

Coordination: P. Mendelsohn
Main Implementor: Research Assistant
Priority: low
Research Status: experimental
Manpower (man/month): 3
Content: Navigation in hypertext is a hard cognitive issue. Graphic and knowledge based tools are need to help the user to orient himself in the graph, to find information and to manage extracted information.

4.3. **Knowledge visualization and manipulation**

Coordination: D. Schneider
Main Implementor: D. Schneider and research assistant
Priority: low
Research Status: experimental
Content: Knowledge visualization and manipulation is a new line of research sometimes called “New AI”. Its existence is due to the increasing need felt by people using a computer to be able to “see” what information is available and to present and to adapt it according to the current needs. Such facilities are also important in ILEs. Indeed, if exploratory learning is to be taken seriously, knowledge visualization and manipulation is an important issue in AI & Education.

4.4. **Experimenter Interface to study learning processes**

Coordination: P. Mendelsohn
Main Implementor: B. Borcic
Priority: low
Research Status: experimental
Content: In principle, ILEs could be used to study learning processes since the behavior of the student is recorded. Moreover, many features of a system can be parameterized. These two possibilities can be combined to create an experimenter interface which will allow to design learning experiments under various conditions.

4.5. **Computational mathetics**

Coordination: P. Dillenbourg
Main Implementor: P. Dillenbourg
Priority: medium
Research Status: experimental
Content: The implementation and ILE (and hence of our toolbox) would be improved by defining a domain independant semi-formal language. This language will describe the coach reasoning and the interactions between the user and the system.

Summary of the means requested from the FNRS

The design and implementation of the ILE project requires that we continue with the current manpower, i.e. two researchers paid by the NPR23 funds, during two years. Given that the main part of the design stage is already done, the people appointed on the continuation will have in priority a computational background.

The first position will be a senior research assistant (maître-assistant) with substantial experience in AI, probably Dr. Mélanie Hilario who works on AI issues in the current project. This collaborator will contribute to the workpackages 2.2, 2.3, 2.8, 3 and 4.1.

The second position will be a research assistant with good interface programming abilities and a good knowledge of AI programming in Lisp. His main contribution will be in the new field of knowledge visualization and manipulation which is associated to AI research and highly important to the user’s acceptance of AI systems. He will be mainly involved in the workpackages 2.1, 2.4, 2.6, 2.8, 3, 4.2 and 4.3.

As we can see, the main contribution of the collaborators paid by the FNRS will concern line 2, i.e. the improvement of the toolbox. The total manpower needed of the project has been assessed to 83 man/months, among which 48 are requested from the FNRS and 35 will be provided by TECFA. The contribution of collaborators paid by FNRS on each workpackage will be proportional to the importance of this workpackage within the global project.

The implementation of the new ILE will start in 1993. The expansion and improvement of MEMOLAB and the toolbox will run over the two years, as well as line 4.

2.4 Theoretical and Practical Implications

(a) Implications for research

- **Completeness and scale**
  Usually research in AI (as well as in the field of AI & Education) leads to rapid prototyping in order to test or to generate new ideas. The challenge to build a complete system is not just a question of refining the prototype. Once a system has to account for all possible user actions, complexity becomes very high. This difficulty often can’t be resolved by simple refinement, but may need a redesign of certain components. Also, the need for new components may emerge. For instance, large hypertexts need sophisticated navigation tools, whereas small ones do not. This is the reason why we want to continue working on the Memolab System. Since this scale problem is not frequently tackled in AI, we hope to produce solutions for this important issue.
- **Richness of Learning Processes**
  In the same spirit, computer-based training systems generally focus on a specific teaching method, ignoring that learning is a complex process involving various kinds of learning activities (such as exploration, imitation, mutual regulation and problem solving). For example, in MEMOLAB, learning experimental methods involves manipulation of objects in a microworld, use of various tools and methodologies (documentation, statistics), analogical reasoning with example prototypes and use of help and tutoring systems. Only the combination of those elements and the interchange of information between them can guarantee efficient learning.
- **Combination of various AI and non-AI techniques in software engineering**
  Also related to the previous points, there is the interesting and necessary problem of integrating AI techniques

2.5. **Integration of modules, objects and knowledge in a large ILE.**

Coordination: D. Schneider
Main Implementor: D. Schneider
Priority: medium
Research Status: semi-experimental
Manpower (man/month): 6
Content: Currently, the organization of the modules and the objects manipulated is specific to each system. We will work on a more general way of implementing the integration of the various components in a large ILE. This issue is linked to the workpackages 2.2, 2.3 (OOPS-engine) and 2.6 (interface routines).

2.6. **Interface routines**

Coordination: D. Schneider
Main Implementor: Research Assistant
Priority: high
Research Status: applied
Manpower (man/month): 6
Content: An ILE toolbox must include a certain number of high-level widgets, as well as object display and manipulation procedures which are not standard in the available tools. Especially microworlds provide the user with means to build objects. Some of the needed procedures may be generalized.

2.7. **Pedagogical knowledge**

Coordination: P. Dillenbourg
Main Implementor: P. Dillenbourg and Senior Research Assistant (M.Hilario)
Priority: medium
Research Status: semi-experimental
Manpower (man/month): 3
Content: For Memolab we developed a set of domain-independent coaching rules. The set rules will be tested with another ILE and since it will be public hopefully by other researchers. The presence of pedagogical knowledge in the toolbox will constitute an original feature with respect to existing toolbox.

2.8. **Documentation of the toolbox**

Coordination: D.Schneider
Main Implementor: All
Priority: high
Research Status: applied
Manpower (man/month): 3
Convtent: Every module in the toolbox will have a reference manual and a short user guide illustrated with a few examples.

2.9. **Report on ILE methodology and programming**

Coordination: P.Dillenbourg
Contributors: P.Dillenbourg, P.Mendelsohn, D.Schneider
Priority: low
Research Status: applied
Manpower (man/month): 6
Content: Provided that the other workpackages leave sufficient resources, we would like to transmit our knowledge about ILE design to potential users of our toolbox and other ILE programmers.

Line 3. Implementation of a new ILE (12 man/months)

As explained above the implemented of a new ILE will assess the generality and the usability of our toolbox.

Coordination: P. Dillenbourg, P. Mendelsohn, D. Schneider
Main Implementor: All
Priority: high
Research Status: applied (experimental for some components)
Manpower (man/month): 12
Content: The choice of the application domain will be constrained by several factors: the possibilities offered by the toolbox, the relevance of direct object manipulation, the expertise of the research assistant to be hired, etc.

Line 4. Advanced research issues (minimum 9 man/months)

The research line defined in the workpackages below reflect our longer termresearch interests. The MEMOLAB system, the toolbox and the new ILE will allow permanent members of TECFA and members of other research centers to pursue more basic research. With the exception of the workpackages 4.1and 4.2, we will invest our own resources and we cannot predict their precise duration. However, since those workpackages are tightly connected to the submitted ILE project we also include them.

4.1. **Dynamic Instructional planning and adaptation of the system to the user**

Coordination: Senior Research Assistant (M. Hilario)
Main Implementor: Senior Research Assistant (M. Hilario)
Priority: high
Research Status: experimental
Manpower (man/month): 6
Content: The goal of this workpackage is to adapt the techniques of opportunistic planning developed in AI to manage the difficult ILE issue of allowing the user to escape from the established tutoring plans. This will probably require to modify the current implementation of the OOPS engine, for instance to handle the tutor's unanswered requests.

Line 1. Refinement of Memolab System (17 man/months)

1.1. **Experimentation with students and teachers**

Coordination: P.Mendelsohn
Main Participants: Graduate Students and own assistants
Priority: high
Research Status: applied
Manpower (man/month) 6 (TECFA)
Content: Memolab will be tested inside the Faculté de Psychologie et des Sciences de l'Education by the research team. We plan to have two complete test/modification cycles. In addition, we hope to find external testers. The main goal of the experimentation is to answer questions as those listed above in line 1.

1.2. **Refinement of Memolab**

Coordination: P.Dillenbourg
Main Implementors: All
Priority: high
Research Status: applied
Manpower (man/month): 6
Content: The experimentation and the refinement of Memolab together strongly interact. The results of the experimentation will may require major changes to some components. We will pay particular attention to the design of the lab, to the hypertext functionalities and the pedagogical rule bases.

1.3. **Knowledge acquisition tools for the simulation**

Coordination: B.Borcic
Implementation: B.Borcic
Priority: low
Research Status: experimental
Manpower (man/month): 3
Content: Add a knowledge acquisition tool for the case-based simulation engine which automatically generates the case knowledge base.

1.4. **Improve the documentation for MEMOLAB**

Coordination: P.Dillenbourg
Priority: high
Manpower (man/month): 2
Content: The user guide for Memolab will be available on-line and on paper. It includes technical and pedagogical information necessary to use Memolab. It will be especially important to distribute Memolab to foreign test sites.

Line 2. Toolbox for ILE design (45 man/months)

2.1. **Expand the data analysis and the statistics tool**

Coordination: D.Schneider
Main Implementor: Research Assistant
Priority: high
Research Status: applied (experimental for data-visualization)
Manpower (man/month): 6
Content: Research will focus on various ways of visualizing and manipulating data and statistical results, in order to help the student to learn about data structures and statistical laws. Such tools must include direct "point and click" manipulation aids. Moreover the interface to the tutoring agents should be improved.

2.2. **Add an interface to the OOPS engine**

Coordination: Senior Research Assistant (M.Hilario)
Main Implementor: Senior Research Assistant (M.Hilario)
Priority: high
Research Status: applied
Manpower (man/month): 6
Content: At the end of 1992, we will have a minimal, but operational interface. A full interface should allow the author to follow step by step the execution of the rule-bases, inspect the state of the rule bases, analyze the structure of the rules, etc.

2.3. **Improve the OOPS engine**

Coordination: Senior Research Assistant (M.Hilario)
Main Implementor: Senior Research Assistant (M.Hilario)
Priority: medium
Research Status: semi-experimental
Manpower (man/month): 3
Content: In order to support multiple agents, the OOPS engine may require further changes to accommodate multi-agent reasoning. Furthermore, with the growth of the system performance issues may become crucial and a RETE mechanism may have to be implemented.

2.4. **Integration of hypertext**

Coordination: D. Schneider
Main Implementor: Research Assistant
Priority: medium
Research Status: applied
Manpower (man/month): 6
Content: Currently in our system, hypertext may be displayed on any window and hypertext buttons may activate any system function. However those functionalities have not been systematically explored and we wish to explore further the integration of hypertext reading with other activities of the student and the interaction of those with tutors.

- What hypertext functionalities are used by the learners?
- What are the experiments that the system has not been able to simulate?
- In which conditions do the learners take control of their own learning activities?

Other such questions will doubtless arise. Any complex software needs to be adapted *to* and *with* the users. Such a process needs time. Refinement of Memolab towards a system that is *useful* and *used* in a real teaching context is expected to last at least two years (starting with a good Beta version in november 1992). Experience taught us that the condition for a system being used in the classroom includes more that being simply bug-free or user-friendly.

Line 2: Improve the TOOLBOX

Our concern for domain-independent tools has so far influenced our program design. In the Memolab system we can distinguish between general components (the toolbox), domain specific components, and components which have intermediate status. Already in our initial project of November 1989 we made the distinction between those three levels of generality (page 4). In Memolab, components relating to experimentation (e.g. the data analysis tools, statistics tutoring, and to a lesser extent the simulation) relate to the domain of teaching experimental design, whereas the OOPS engine and the Hypertext modules are domain independent. Please read the *full* intermediate report of November 1991 for details (page 4-6).

The toolbox will improve and expand the set of tools that have been created so far for MEMOLAB. These tools (OOPS-engine, hypertext, graphical routines,...) will be fully documented with an on-line hypertext based user manual, that can be printed as well with TEX macros. The tools allow to fill the libraries that constitute the system. These libraries will not be empty at the beginning, but include programs (knowledge bases) developed for MEMOLAB or the other ILE (see Line 3). This includes for instance the domain-independent coaching rules created for MEMOLAB.

The toolbox will be a research tool. It will have several features that do not exist in the currently available tools.

- It is not intended to be used by an ordinary teacher. The author must know some Lisp programming.
- It is open: the advanced user will be able to inspect and modify not only the objects libraries but the tools themselves.
- It is transparent: it will include tools for allowing the authors to monitor interactively the pedagogical decision processes (which are hidden in usual authoring tools).
- It is opportunistic: most authoring tools generate a rather rigid mode of interaction, while a major difficulty in ILE implementation is to support a mixed-initiative dialogue, i.e. the tutor must update its pedagogical plan when the learner escapes from the plan established.

General user guidance will be added to the toolbox to facilitate its use by newcomers with a minimal AI background.

Line 3: Implementation of a new ILE

We want to test and to guarantee the tools generality by designing another ILE with the toolbox. By comparing the systems, we will induce the common features that should be generalized and identify the functionalities that are efficient or that should be added to the toolbox. This inductive approach is both our method towards generality and the 'proof' that the tools are domain-independent. This approach continues the bottom-up method we followed since the beginning of MEMOLAB.

At this stage, we have not yet defined a topic. Our efforts in recent months have been concentrated on the benchmarks of our current NFP23 project and we need a few months to agree upon an interesting new topic. The new domain should allow us to enlarge the application domain for the toolbox. If necessary, we will present a short research plan for this new ILE in november 1992.

Line 4: Advanced research issues

MEMOLAB, the toolbox and the new ILE to be implemented will allow us to investigate a set of research issues, some of which are hard AI issues. The results of those investigations will enrich our knowledge of ILE design and will lead us eventually to redesign parts of the system and the toolbox. This set of issues includes dynamic planning, advanced interface design, adaptive systems and formalization. Please refer to the description of the workpackages for further details.

We view the design of an authoring tool as a contribution towards the elaboration of 'computational mathetics'. 'Artificial Intelligence and Education' research has so far produced a collection of sophisticated systems. However, these are generally ad hoc systems, highly constrained by the domain taught. Design choices are rarely explicit. By 'computational mathetics', Self refers to a formal theory of ILE design. The theory does not describe the learners' cognitive processes (i.e. it is not a psychological theory). It describes how the system reasons and interacts with the learner. The toolbox will be based on a high-level language for describing learning and teaching interactions.This formal language will be a first step towards the long term goal of computational mathetics.

Estimation of workpackages

General remarks:

- TECFA will input almost 3 man/years from its own resources: (40% of Daniel Schneider, 40% of Pierre Dillenbourg, 20% of Patrick Mendelsohn, 20% of Boris Borcic, 20% new assistant of TECFA) during the two years. We expect to continue this research beyond 1994 by our own means.
- Each workpackage will have at least one person in charge of execution. Overall coordination of the project is a result of frequent meetings. P. Dillenbourg will continue writing most of the design specifications, D. Schneider will overview the general computational integration, and P. Mendelsohn will conduct work of interest to psychology.
- Each workpackage has a priority and a research status. Work packages with high priority will be implemented, those with low priority may or may not be implemented according to our resources, shifting research interests and difficulties encountered. Research status can be applied or experimental. 'Applied' means that we are fairly sure to be able to deliver. 'Experimental' means the opposite, since one can't predict in advance the difficulties that may be encountered with more basic research problems in AI.

Cacao

TECFA is participating in the Cacao project within the COGNISCIENCE program (funded by the CNRS, France, with the 'Laboratoire de Genie Informatique' (Grenoble) and IRPEACS (Lyon). TECFA's contribution will be the creation of a language for describing the information that an interactive system may acquire through the interface. This work goes in the same direction as the formal language we want to develop in the submitted intelligent learning environments project. Funding for the preliminary stage has been obtained.

Chaos

Chaos is a microworld for the exploration of musical composition. It is implemented by Pierre Dunand (chargé d'enseignement at TECFA) and R. Boesch with Object Logo 2.5 on a Macintosh with a MIDI interface.

PH.D's

TECFA, in 1990 and 1991 obtained three Ph.D's in the fields of AI (Melanie Hilario), AI and Education (Pierre Dillenbourg) and Computer assisted learning (Philip Swann). Both thesis of P.Dillenbourg and M.Hilario were already in an advanced state when hired by TECFA and they have been completed during spare time.

- Pierre Dillenbourg: *Human Computer Collaborative Learning*. A doctoral thesis in artificial intelligence, submitted to the University of Lancaster, Department of Computing, in December 1991.
- Mélanie Hilario: *L'apprentissage d'heuristiques de contrôle pour la planification: un approche abductive*. A doctoral thesis in artificial intelligence, submitted to the University of Paris VI, in December 1991.
- Philip Swann: *Theory and Practice of Computer Assisted Language Learning*. A thesis submitted to the Open University for the Degree of Philosophy in Computer Assisted Learning in August 1990.

Publications related to Intelligent Learning Environments and/or AI:

Dillenbourg P. (1989) Designing a self-improving tutor: PROTO-TEG. *Instructional Science*, 18, 193-216.

Dillenbourg P. (in press) "The Language Shift: a mechanism for triggering metacognitive activities". To appear in P. Winne and M. Jones (Eds). *Foundations and frontiers in Educational Computing Systems*. Berlin: Springer-Verlag.

Dillenbourg P (to appear) "The Computer as a Constructorium: tools for observing one's own learning". In M. Elsom-Cook and R. Moyse (Eds). *Knowledge Negotiation*. London: Paul Chapman

Dillenbourg P., Hilario M., Mendelsohn P. and Schneider D (1990). "Training Transfer: A Bridge Between the theory-oriented and product-oriented approaches of ITS design". *Actes du Second Congrès Européen "Multi-Media, Intelligence Artificielle et Formation* (APPLICA-90).

Dillenbourg P. and Mendelsohn P. (in press). "The genetic Structure of the Interaction Space". To appear in E. Costa (Ed). *New Directions for Intelligent Tutoring Systems*. Berlin: Springer-Verlag.

Dillenbourg P. and Self J. A. (in press) "Designing human-computer collaborative learning". in C. E. O'Malley (Ed), *Computer-Supported Collaborative Learning*. Wiley & Sons.

Dillenbourg P. and Self J.A. (in press) "A Framework for Learner Modelling". *The Journal of Interactive Learning Environments* (Editor: E. Soloway).

Dunand P. (1990) Notes sur l'utilisation de l'ordinateur dans la création graphique et/ou musicale. CNAC, *Actes du Colloque "Dessine-moi un Pixel"*, Centre Pompidou, Paris, avril 1990.

Dunand P. (1990) Interfacer la pensée musicale. Notes sur l'ordinateur et la pensée musicale. *Actes du Colloque "LOGO et Apprentissage"*, Université de Fribourg, octobre 1990.

Hilario M. (1990) "L'apprentissage d'heuristiques de contrôle en vue de la génération de plans". Convention IA 90, *Actes de la convention Intelligence Artificielle,* Palais des congrès. Paris: Editions Hermès.

Hilario M. (1990) "Learning Control Heuristics to Guide Planning". *Actes de Cognitiva 9*0, Madrid, novembre 90.

Mendelsohn P.(1990) *"Les Environnements Intelligents d'Apprentissage". Onzième cours avancé "Psychologie génétique et Sciences Cognitives" de la fondation Archives Jean Piaget*. Genève, 10-14 septembre (10p.).

Mendelsohn P. (1990) *"LOGO: Qu'est ce qui se développe ?", Actes du colloque "LOGO et apprentissage"*. Université de Fribourg, octobre 1990 (10p.).

Mendelsohn P. (1991) "Les modèles cognitifs dans les environnements d'apprentissage: implémentation ou contemplation?", *Actes des 13èmes Journeées Francophones sur l'Informatique* (53-60. Université de Genève.

Mendelsohn,P. and Dillenbourg,P. (in press) "Le developpment de l'enseignement intelligemment assité par ordinateur", in Symposium Intelligence Naturelle et Intelligence Artificielle, Pari, PUF.

Schneider, D. (1989) "Les systèmes explorateurs intelligents, *Enseignement supérieur en Europe* (also in *Higher education in Europe*), Vol. XIV, No 2

Swann P. (1990) *Theory and Practice of Computer assisted Language Learning.* Thesis for the Doctor of Philosophy in Computer Assisted Learning, Open University, UK.

2.3 Detailed Research Plan

We would like to go further in the research methodology we followed so far, i.e. to continue this research along its four work lines.

Line 1: Refine MEMOLAB

In the AI & Education community, research teams have often concentrated their work on a particular system component, generally the student model or the expert model. Hence, not many completed and experimented systems exist. At the end of '92, MEMOLAB will be close to such a system, but it will suffer from a lack of experimentation. We believe it is worth devoting some effort to turn it into a convincing example of what a completed ILE may be.

From '93, the evolution of MEMOLAB will be driven by experimental results. The first experiments are scheduled for '92. However, if the MEMOLAB project ends in '92, we won't have the opportunity to modify MEMOLAB according to experimental results. We believe that a system may only become 'convincing' after several design-and-test cycles.

Our plan is to run such successive design-and-experiment cycles. We plan to make MEMOLAB available on our FTP-server in order to encourage experimentation by other groups than TECFA (both in Switzerland and abroad). We know from experience that testing a system always reveals unexpected problems. Here is a sample of questions for which the experimentation should bring answers:

- Does the 'restructure experiment' function help learners to acquire a higher level representation of the problem?
- How quickly do the learners adapt themselves to the new interface after a language shift?
- Does the lab interface allow learners to concentrate on the methodology of experimentation?

The current "Intelligent Learning Environments" (NFP 23) project.

Our current project and this request for continuing it beyond 1992 intend to create a methodology and the necessary tools for the development of Intelligent Learning Environments (ILE's). Our initial ambition was to develop an authoring library for designing and implementing ILE's for teaching experimental methods in the human sciences. During the first year of research (1990), we had to shift the strategy to reach this ambitious goal. Although generality remained our research goal, we started by designing a particular system.We briefly explain why.

Many research teams with a similar goal and a very much larger manpower have failed to create powerful authoring tools because they started with the wrong question. If one asks what functionalities are shared by any educational software, the generality constraints are so high that one inevitably comes out with a set of neutral interface tools and with procedures for specifying the sequence of activities. The pedagogical features of the authoring process are almost lost. The same remarks can be made for the contents of a microworld.

To avoid this trap, we opted to go from a particular case to general principles. We started this research with the design and the implementation of MEMOLAB. Both the conceptual and the computational work achieved so far have been possible because we tackled a concrete problem, rather than a set of abstract functionalities.

However, design and implementation of MEMOLAB have been carried out with a permanent concern for the generality of the solutions proposed. We first produced a design framework. It decomposes learning into a sequence of hierarchically integrated sub-systems. The integration results from using the representation language of a subsystem as a command language in the next sub-system. This domain independent architecture plays a very important role that most authoring tools ignore: it translates a theory of development (namely, R. Case's neo-piagetian approach) into system specifications (representation and command languages).

As it exists now, MEMOLAB is a collection of components. Most components are partly or totally domain-independent.The hypertext class for instance enables the author to create his own example of hypertext in any new domain with a very simple syntax.The simulation can only be generalised to experimentation in human sciences. Some components, e.g. the 'Encyclopaedia of Memory', are specific to MEMOLAB.

The agent's reasoning is supported by the Object-Oriented Production System (OOPS-Engine) we have implemented. An OOPS component may interact with any component written in CLOS (Common Lisp Object System).

The pedagogical roles have been distributed among several agents. The coach is a domain-independent learning manager. It uses a high level description of the domain knowledge and learner activities (examples, theory, exercises) that fits with most subject matters. The coach's recommendations are turned into domain-specific concrete interventions by tutors. A tutor is responsible for local tutoring. One tutor, Master-of-Design, has been implemented. This distribution of roles among a coach and several tutors allows us to incorporate explicit pedagogical knowledge in the tool-box.

We aim to continue this dual development process, working on the particular level towards general results. As announced in the intermediate report (November 91), until November 92 we will:

- modify the simulation to broaden the range of pedagogical strategies;
- add a small expert system in experimental design that will allow the tutor to diagnose the learner's mistakes and generate appropriate feed-back and problems;
- refine MEMOLAB coaching and tutoring rule bases;
- rewrite the pedagogical rules in a more general language;
- focus on the issue of dynamic planning (the learner escapes from the tutor's plans);
- add the data processing components (data-tools, stat-tools, data-king and stat-girl);
- separate more clearly the libraries that are specific to MEMOLAB from those that are domain-independent;
- improve and document the tools (hypertext, OOPS engine, interface tools);
- start to experiment MEMOLAB with real users.
- make available MEMOLAB and toolkit to peer researchers.

Jitol

JITOL ("Just in time open learning") is a large scale European Delta Project, whose Swiss partners are hosted in TECFA. TECFA itself has been given six man/years in this project. The central objective of JITOL is to undertake and evaluate large scale pilot implementations of an information technology based open learning environment for the professional development of individuals in a number of different domains. The project will in particular address the issue of "just in time" access to appropriate knowledge through the use of electronic communication networks giving access to tutors, experts, other learners, counselors, and multimedia resources.

Smile

John Self, one of the best known world-wide researchers in AI and Education (Computing Department, University of Lancaster, UK) and Rodger Hartley (Computer Based Learning Unit, University of Leeds, UK) have obtained a research grant to collaborate with TECFA. Since it is funded by the British ERSC and SERC agencies, the SWISS part is supposed to get its own funding. This project is entitled 'student modelling in intelligent learning environments' (SMILE) and investigates the role of cognitive diagnosis in non-directive learning environments. The research methodology will try to integrate computational and empirical approaches. It is especially oriented towards formal approaches. This project starts in January '92 and lasts 3 years.

Calliope

Philip Swann ("maître-assistant" at TECFA) has started a project on "Object oriented design for computer supported language learning". This involves the implementation of task templates in the Smalltalk environment for the rapid prototyping of structured language learning tasks, in a form suitable for use in psycholinguistic experiments and second language instruction. We intend to investigate if the task modules developed using Calliope could be run concurrently with other learning environments such as Memolab under X. This would allow students to design and simulate psycholinguistic experiments using the combined resources.

2. Research Plan

2.1 Artificial Intelligence & Education: The state of the art

The field of AI and Education exists since about two decades. Today a small, but well established research community exists. Traditionally, the field has been split into Intelligent Tutoring Systems and Microworlds. More recently, those two approaches have been merged into the field of "Intelligent Learning Environments".

Research in "AI and Education" is based on the computational study of learning and teaching processes. The design of intelligent learning environments (ILE) raises several challenges for AI researchers, both at the technical and epistemological levels. The reciprocity of the relationship between AI and ILEs has been illustrated by the work of W. Clancey (1983). His attempts to use the well-known expert system Mycin as a training tool showed the limitations of early production system architectures. He demonstrated the necessity of explicitly representing problem solving strategies and thereby prefigured the second generation of expert systems (Steels, 1990).

Nowadays, several AI techniques are tested or developed through the implementation of ILEs. Recent developments on belief systems are explored in order to bypass the difficult problem of student modelling (inferring the student's misconceptions from her behavior on the interface) (Self, 1991). Dynamic planning methods, especially blackboard systems, are used to allow the tutor component to adapt its didactic plans to the student behavior (Murray, 1989). Among other techniques, we point out the use of classifier systems (Hron, 1990), case-based reasoning techniques (Bloch and Farrell, 1988), explanation-based learning (Costa and Urbano, in press) and inductive learning methods (Dillenbourg, 1989), neural networks (Mengel and Lively, 1991) and distributed problem solving (Brazdil, in press). Some of these techniques are used in MEMOLAB, the system that we are developing.

However, the scope of artificial intelligence goes far beyond an inventory of techniques. AI is concerned with epistemological issues as well. Those issues are critical when designing an ILE (Wenger, 1987). The 'symbol grounding' crisis (Harnad, 1990), that has shaken the symbolic paradigm, has also affected our discipline. Focus has moved away from internal and mental representation towards external representations and social interactions. The recognition of the social grounds of individual knowledge recently led to the design of apprenticeship systems (Newman, 1989) and collaborative learning systems (Dillenbourg and Self, in press). The importance of environmental resources has been advocated by researchers within the 'situated' stream (Brown, 1990). The cognitive architecture of MEMOLAB gives a central role to patterns of interaction between the learner and the learning environment (Dillenbourg and Mendelsohn, in press). The impact of AI and cognitive science on the development of ILEs goes beyond implementation techniques. It concerns the whole design process, including the cognitive features of the interface.

This project also belongs to the field of authoring tools, i.e. tools that support the design of educational software. There currently exist four main categories of authoring software: (1) Traditional CAI authoring languages and authoring systems (e.g. Authorware, TenCORE, Pilot,...). (2) Educational Simulation Software (e.g. Stella,...), (3) Toolkits for interactive software (e.g. Hypercard, KnowledgePro, Guide,...) and (4) Expert System Shells (KEE, Art, ...). In addition, some people have started to develop more specific tools for ILEs, but those systems are generally close to expert systems shells and hardly available to the public. Two current challenges in this domain are to integrate functionalities found in these various categories of authoring tools and to express pedagogical knowledge.

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2.2 Related Research in TECFA

The main research project on Intelligent Learning Environments is the current NFP23 project initially called "Les systèmes explorateurs intelligents" and now called "Intelligent Learning Environments" (ILE). Two new projects in international cooperation are directly related to our main project (Smile and Cacao). Other members of TECFA are involved in other AI & Education projects (Calliope with Ph.Swann and Chaos with P.Dunand). Under the supervision of D. Peraya and P. Mendelsohn, TECFA is the host of a large Swiss contribution to a European Delta consortium on Open Learning (JITOL). Other projects in Computer Based Learning exist, essentially as Ph.D work.

Intelligent Learning Environments

NFP23 Program; Project No. 4023-27013;
"Les systèmes explorateurs intelligents"; Prof. P Mendelsohn and D.K.Schneider.

Renewal Proposal

1993-94

This document is a part of the proposal submitted in november 19991 to the NFP 23 program of the Swiss National Fond .

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Abstract: Intelligent Learning Environments

We suggest to develop further the Intelligent Learning Environment (MEMOLAB) and the authoring toolbox that we have developed so far within the NPR23 program. The prolongation will follow four main lines:

- **Line 1: Refine MEMOLAB**
  There are not many Intelligent Learning Environments available in the world. Most research teams have produced partial systems. MEMOLAB will be one of the rare complete, experimented and available systems.The results of our experimentation will guide the improvements to be made. The goal is to turn MEMOLAB into a convincing example of ILE.
- **Line 2: Improve the TOOLBOX**
  The MEMOLAB system includes several (partly) domain-independent components that will be integrated within a toolbox for ILE design by the end of 1992. This toolbox includes libraries of programs and tools to execute this programs. We plan to improve the tools and to add programs to the libraries.
- **Line 3: Develop a new ILE with the toolbox**
  The best way to improve the toolbox is to develop an ILE in another domain with the toolbox (as available in November '92). The multiplicity of teaching domains will be both the method for inducing general facilities and the demonstration of the TOOLBOX generality.
- **Line 4: Advanced research issues**
  MEMOLAB, the new ILE to be developed and the toolbox will provide us with objects that support various investigations. We suggest several research issues that could be explored with this material: dynamic planning, intelligent hypertext navigation, knowledge visualization and manipulation, computational mathetics and experimental interfaces.

The estimated total manpower is 83 man/months, of which 48 man/months (i.e. 4 man/years) are requested from the FNRS and 35 will be provided by TECFA's own staff.

The project will lead to three deliverables, corresponding to research lines 1, 2 and 3.