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Evaluation of the effectiveness and use of an autonomous or integrated hypertext in an activity learning environment

Daniel Scherly[1], Laurent Roux[2] and Pierre Dillenbourg[3]

[1] Corresponding author:
University of Geneva
Centre Médical Universitaire
1, rue Michel-Servet
CH-1211 Geneva 4,
Switzerlan
tel. (41-22) 70 25 937
fax. (41-22) 70 25 122
Daniel.Scherly@medecine.unige.ch

[2] University of Geneva
Centre Médical Universitaire
Laurent.Roux@medecine.unige.ch

[3] University of Geneva
TECFA, FPSE
Pierre.Dillenbourg@tecfa.unige.ch

Abstract

This paper presents a study which evaluates the use and efficiency of two computer learning tools for basic virology. The first, VIROLAB, is a simulation of a biology laboratory. The learner uses the virtual lab facilities to help defective viruses to multiply. Some knowledge of the field has been formally deposited in an integrated hypertext. The learning occurs through resolution of problems and, possibly, through reading the hypertext. The second tool is the hypertext which has been extracted from VIROLAB and which is now considered as an independent learning environment. A series of multiple choice and open questions has been integrated in the hypertext in order to help structure its reading. In this case, the learning occurs only through reading.

This study addressed two specific questions: 1) which of the two tools is the most efficient for knowledge acquisition, and 2) are there some differences in the use of the two hypertexts? Comparison of pre- and post-test scores showed that neither of the two learning tools is better than the other. However, VIROLAB facilitates the acquisition of a certain type of knowledge. To our surprise, analysis of the navigation paths showed that VIROLAB users dissociate the reading of the integrated hypertext from the problem resolution activities. The implications of this finding for the design of the learning environment are discussed.

Keywords :

hypertext, navigation, learning environment, microworlds, medical education, virology

Introduction

Given today’s facilities to produce and publish hypertexts, training institutions tend to transform their paper based and ex-cathedra courses in hypertext formats. One can easily see the advantages of this distribution mode, but maintained at this level, computers would only be used as information vehicules whereas they can offer much more. They have the power to provide rich learning envrironments, helping learners to actively build their knowledge.

Research on hypertexts has shown the importance of the subject expertise (Rouet, 1992, McDonald and Stevenson, 1998), of the cognitive loads (Schroeder et Grabowski, 1995), of the epistemic beliefs (Jacobson, 1995), of the interface features (Rouet, 1992) and of the task requirements (Zeller et Dillenbourg, 1998). In spite of the renewed interest for the hypertexts, the latter are less and less considered as pure training tools (Schneider et al., 1993; Forte et al., 1993). This point of view is based on the development of the theories in cognitive science, especialy those in the field of situated learning. The later considers that the training should offer meaningful, authentic activities so that the learner can more easily build his or her knowledge stuctures. It is from this point of view that VIROLAB has been designed.

VIROLAB simulates a biology laboratory in which the learner must help defective viruses to multiply. For that, the learner must obtain information about the structure of the chosen virus and find the right cell strain to infect. We call this activity an *inquiry*. In order to stimulate thinking and reflexion, the viral cycle is interrupted many times by questions or actions to which the learner must respond to allow the multiplication process to continue. VIROLAB is hence different from genuine microworlds in which learners do not encounter such questions. Once the infection cycle is accomplished, the student can choose another virus to study. To accomplish the task, the student has access to many rooms equipped with analytical instruments, an automatic personal lab journal, and library books containing the relevant domain knowledge.This library is structured as an hypertext, which again makes VIROLAB richers than genuine microworlds.

The second training tool, the Hypertext, is a version of the hypertext included in VIROLAB. However, for this stand-alone hypertext, reading is structured by twelve questions which are integrated into the software. These questions are an explicit formulation of some of the problems that the VIROLAB users encounter and can be answered by the study of the hypertext.

Two questions guided this study :

1) Effectiveness: In terms of knowledge acquisition, which of the two learning tools is the most efficient? This question led us to examine if some virology concepts were learned more efficiently through one or the other learning environment.

2) Reading behavior: According to the questions and problems encountered, how do the VIROLAB or Hypertext users consult the available documentation ?

Materials and methods

The two learning environments

VIROLAB

According to the "market place" metaphor, this virtual laboratory consists of several rooms: a hall giving onto a corridor which leads to four side rooms (figure 1).

********* insert Figure 1 here *************

Those rooms are:

1. The *laboratory* which is equipped with several instruments to investigate the structure and composition of the virus. In order to create a situation of problems, each virus is defective: it misses one or more of the components necessary for its multiplication. The student will have to open the freezer of this room to choose one or more enzymes that (s)he will add to the virus at the appropriate time.
2. The *culture room* is used for testing the virus functionality. In this room, the student choose the appropriate cell type to be infected. If the choice is correct, the infection process is engaged.
3. The *office* which contains the lab journal. Each time the student gains one piece of information about the chosen virus, it is automaticaly recorded in the lab journal. When a multiplication step is successfully achieved, a summary of this step is also recorded in the lab journal. This lab journal should reduce the user cognitive load.
4. A *library* which is made of hypertexts (figure 2). These documents are available any time and the information can be retrieved through a search engine. The hypertext structure is described in more detail in the next section which deals with the second learning environment.

************** insert Figure 2 here ****************

Finally, two additional features equip VIROLAB :

- a glossary explaining most of the scientific terms used

- a help menu listing the pedagogical goals and explaining the software features

The Hypertext

This second learning environment is made from the VIROLAB library but which has been transformed into an autonomous learning tool. In order to compensate for the activity offered in VIROLAB and to give a goal to the hypertext reading, twelve questions have been integrated in this software. These questions are a reformulation of the problems with which the user of VIROLAB is confronted and their sequence follows that of VIROLAB. They are of two types. The first type has answer buttons which, when clicked, give an immediate feedback. The second type consists of open-ended questions which can be answered only by reading the hypertext. The user can navigate freely between the questions and the hypertext. They receive an immediate feedback for multiple-choice questions (but not for open questions).

The hypertext structure is of the tree type. It looks like a book table of contents and hence induces a reading behavior which is quite linear. The first level displays the four available documents which are iconified by four booklets (see figure 2). One click on a booklet commands the display of the tree structure of this document. One click on a branch brings the corresponding document section. A navigation bar at the bottom of the window permits the navigation within or between the documents. The *left* and *right* arrows display the preceding and following pages, respectively. To jump to another part of the document, the *index* button displays the tree structure of the document. To go to another document, a click on the *library* button displays the top level hierarchy as shown in figure 2. The *recent* button brings the last visited node (which is different from using the *left* button which displays only the previous pages within the same document). Finaly the button *search* allows information retrieval based on keywords. Obviously, this hypertext contains words which are *hyperlinks*. Beside the four documents, a glossary defining most scientific terms is available by pressing the *glossary* button.

Experimental design

Twenty eight medical students from the third study year and one qualified nurse took part in the experiment. They were divided into two balanced groups (gender), one group working with VIROLAB and the other with the Hypertext. The experiment took place in two meetings, each one being made up of the four following phases:

1) 30 min for the pre-test

2) 10 min of software demonstration

3) 1h45 - 2h00 to work with either VIROLAB or the Hypertext

4) 30 min for the post-test

For the phase three (training), the students received a sheet containing the work specifications. The hypertext group was asked to write down the answers to the 12 questions integrated in the Hypertext.

To answer the first study question, that of effectiveness, we compared the score obtained by the students during the pre- and post-tests. These two identical tests comprise a series of 15 open-ended questions. To try to avoid bias for one or the other group, we conceived 3 types of questions:

- VIROLAB type (Viro): 6 questions to which the VIROLAB group should be the best capable one to answer. These questions concern the understanding of a process and they resemble problem resolution questions.
- Hypertext type (Htxt): 6 questions to which the Hypertext group should be the best capable one to answer. They are purely factual questions.
- Indifferent type (V-H): 3 questions of which the probability to give a correct answer should be equal for each of the two groups.

Examples of these questions are given in the Discussion.

In order to be able to analyse the student's reading behavior, and therefore to anwer the second study question, the two software programs were equiped with a tracking system which automatically recorded the individual's navigational paths. This recording system was totally transparent to the user and it produced a log file (also referred to as a dribble file) which was then imported and analysed with a spread sheet.

The following data were collected:

variable 1: name of the node visited

variable 2: time spent in the node

variable 3: button used to exit the node (left, right, hyperlink, recent, search, index, library) variable 4 : number of screens displayed (i.e. for VIROLAB, the sum of the hypertext nodes visited and the screens displayed during work in the laboratory)

Those four variables allowed us to derive 18 additional variables which are not described here.

Statistical analysis

Each response to the pre- and post-tests was scored 2, 1 or 0 for a correct, a partially correct, and a wrong response, respectively. Hesitating to process the data as numeric or rank values, we compared the probability threshold obtained with the Student T test and an analysis of variance for data considered as metric value, or the Wilcoxon W test (matched values) or the Mann-Whitney (unmatched values) for data considered as rank values. In fact, these two methods gave the same significance threshold. Therefore, only the results obtained with the Student T test are presented here. The threshold considered is 0.05. The data were analysed with the SPSS software.

Results

Effectiveness of VIROLAB compared to the Hypertext

Global analysis

The pre- and post-tests comprise 15 questions, therefore giving maximal scores of 30 points. After 2 working hours with one or the other program, the members of each of the two groups pass from an average score of 11.6 in the pre-test to an average score of 19.6 in the post-test. The average gain is 8.14 for the VIROLAB group and 7.93 for the Hypertext group. Although VIROLAB seems slightly more effective than the

Hypertext, the difference is not significant. Therefore, in these experimental conditions, one cannot conclude that one learning environment is more effective than the other.

Analysis by categories

In this section, we investigated whether certain types of concepts are better acquired by one or the other tool. In other words, is there a significant difference between the two groups for their average gains to the VIRO or Htxt questions?

The results are summarised in Table 1.

************ insert Table 1 here ***************

The above data show that there are no differences between the two groups regarding the Hypertext type questions. On the other hand, the VIROLAB group answers significantly better the VIROLAB type questions ($t = 2.07$, $p = 0.049$) than the hypertext group.

The interaction effect between the question type and the learning tool used, visually perceptible in the figure 3, is not confirmed by the variance analysis ($F = 2.87$, $p = 0.102$, mixed space - independent on the dimension « group », apparited on the dimension « type of question »)

Hypertext reading behavior

The analysis of the navigational path data shows that the average reading time for the VIROLAB group is 49 minutes whereas the one for the Hypertext group is 96 minutes (Table 2). In other words, the VIROLAB group reads two times less than the Hypertext group, but nevertheless obtains similar scores at the post-test. Given the fact that the VIROLAB group answers significantly better the VIROLAB type questions and that the information related to those are acquired through an inquiry activity, one can conclude that an exploratory activity like VIROLAB advantageously replaces simple reading.

********** insert Table 2 here **********

The difference between the two groups for the time spent reading the hypertexts was expected since the Hypertext group had no other choice than to read. However, the difference in the reading behavior surprised us. Table 2 shows that the VIROLAB group does not read the documents during the problem resolution, but outside the inquiry process, i.e. either before starting to study a specific virus or afterwards, perhaps as a revision of the case.

Both hypertexts are short (92 pages) and their structure is of the hierarchical or tree type. This architecture and the small number of word-hyperlinks condition its reading as linear and passive. However, one can consider that the frequency of the usage of the index, of the word-hyperlinks, of the glossary and of the serch engine is an indicator of a more active reading. Those data have been extracted from the navigation pathes and are summarized in Table 2 above.

It is notable that both groups consult an index every 2 minutes on average. The features grouped under the name *active search* (word-hyperlinks, glossary, search engine) are not used very often, although they are used twice as often by the VIROLAB group. The latter observation is not, however, statistically significant. One might imagine that the VIROLAB group uses the active search tools more often because its members are concentrated on inquiry activity and they want to rapidly get information without losing time browsing the hypertext. This interpretation is probably incorrect because the hypertexts are consulted mainly outside of the inquiries, However, it is not impossible that subjects may read them in a more goal-oriented way because of their problem-solving experience. Another interpretation is that it is the interactive activity in VIROLAB itself which induces this behavior, through removing the inhibitions of the users and permitting them to try all the features of the software.

Discussion

Although the analysis of the collected data leads to some significant results, one must treat them with some caution. First, the sample was small (n = 29) and quite heterogeneous regarding its results to the post-test. Second, the time spent to work with the learning environments was short (2 hours). It is highly probable that the data would have been different after a prolonged use of the tools. Unfortunately we were not able to juge the long term effect of each tool: some differences could have emerged. With these precautions in mind, we will now discuss the results.

Effectiveness

Globally, in term of training effectiveness, one cannot say that one learning environment is better than the other. Therefore the effort spent in the development of a program like VIROLAB is questionnable. To evaluate this issue, several elements must be taken into account. The strongest element against such development is its cost. It is usually admitted that one hour of self-learning requires about 300 hours of development. In its favour, however, there is substantial evidence from research in the fields of cognitive and constructivist psychology of the value of active participation of learners in the learning process. These studies have clearly shown that students who participate in productive activities (rather than rote learning, as is too often the case) have a deeper understanting (versus surface understanding) of the field and retain better what has been learned / taught. The design of VIROLAB has been inspired by these pedagogical concepts. First, the student is in a problem based situation: he must help a defective virus to reproduce itself and infect other cells. Second, the task is marked out by explicit questions and problems which should help the learner to think and reflect on the how and why of the viral cycle. Third, the system partially analyses the users reactions and responds with an appropriate feedback. Finally, although VIROLAB is only a rough simulation of a biology laboratory, its features are close to what could be expected for a situated environment (Goldman et al. 1996, Rieber 1992).

The importance of productive learning activity is corroborated by the fact that the questions of the VIROLAB type are better answered by the VIROLAB group. The VIROLAB type of questions usually require, in VIROLAB, an interactivity between the user and the system (decision, moving objects, feedback on a user choice). Below, we reproduce two such questions to illustrate what we mean.

Question 7 :

The viral attachment to a cell receptor is a very important step. In the HIV and Influenza cases, what are these receptors and what distinguishes them?

Question 8 :

HIV adsorbs to the cell surface through its interaction between gp120 and the cell receptor CD4. However this interaction is not sufficient to permit the entry into the cell ? What is missing ? Add it and indiquate what is the next step.

These two questions deal with the interaction mechanisms between the cell receptors and the viral anti-receptors. The VIROLAB users had to actively match the viruses and the cells (visual recognition, decision, validation of the choice by drag and drop) in order to initiate the viral cycle. The Hypertext group could answer only by reading the hypertext.

Navigation

One way to gauge the utility and efficiency of learner controlled multimedia environments is by analysing navigational paths (Lawless and Brown, 1997). The present analysis revealed an astonishing fact: VIROLAB users rarely consult the hypertext during the inquiry process; they consult it either before or after having studied a virus. There is thus a dissociation between problem solving and hypertext reading activities. One possible explanation for this dissociation is that the problems are already sufficiently structured so that the student can find the solution without consulting the hypertexts of the library. We believe a more likely explanation is that users are intrigued by the course of their investigation, being concentrated on the task to do (help the virus) rather than « losing » time reading. Do they dislike performing two concurrent tasks (maintaining two different contexts - the microworld problems and the hypertext search - might lead to cognitive overload)? It is worth mentioning that this behavior is the one found in real laboratories. The scientist does not interrupt his work at the bench to go to the library to read an article; he does so either beforehand to help prepare his experiment, or after the experient is finished.

The dissociation of problem solving and reading activities has some implications for software design. Is it necessary to incorporate more declarative knowledge around the task (in the feedbacks, « balloon » within the action window) and not outside the task (as is now done with the hypertext)? How to do it without making the activity heavier? Is it necessary to create direct and mandatory links with the hypertext documents or only to mention them, leaving the user free to activate those links? One way to link the activities in the lab and the hypertext would be by co-ordinate the navigation actions in both parts of the software, e.g. one movement in the lab moves a pointer or a bookmark in the hypertext, and vice versa. The use of a pedagogical hypertext with an oriented path like the one developped by the Forte team (Forte et al, 1993) would be worthwhile to explore.

Reviewing many articles dealing with the analysis of navigational paths in hypertexts, Lawless and colleagues (Lawless et Brown ,1997; Lawless et Kulikowich, 1996) concluded that there are three common navigational profiles: the knowledge seekers, the feature explorers, and the apathetic users. In our study, we did not find these three profiles. The very conditions of the experiment (voluntary subjects, a reading stimulated by searching activities) ensured that all subjects belonged to the knowledge seekers profile. At the most we found two extreme subjects: one person being a novice with computers (subject A) and the other being very interested by informatic tools (subject B). Their navigational behavior corroborates their feelings towards computers. Subject A reads the full documents using only the forward and back buttons, reads much more than is necessary to answer the questions or makes inefficient use pf the information. Subject B, being computer literate, uses all of the features offered by the navigation bar (especially the search engine): he is not afraid to leave text linearity to jump within the hypertext. The effect of familiarity with informatic tools has been observed many times, notably in the study by Zeller and Dillenbourg (1998).

Conclusion

This study has highlighted four elements:

1) Neither of the two learning environments seems superior to the other in terms of global training effectiveness.

2) However, VIROLAB helps to understand more complex information.

3) The problem resolution activity in VIROLAB advantageously replaces reading activity, since this group reads two times less but is as knowledgeable as the hypertext group.

4) The VIROLAB users dissociate the problem resolution activity from the reading activity.

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Tables

Table 1. Comparison of the average gain between the two groups according to the type of questions.

	VIROLAB type questions	Hypertext type questions
VIROLAB gr.	average gain = 0.71	average gain = 0.43
Hypertext gr.	average gain = 0.49	average gain = 0.50
	t of Tstudent = 2.07	t of Tstudent = -0.53
	significance = 0.049	significance = 0.60

Table 2. comparison of the variables extracted from the navigational paths

	VIROLAB	Hypertext
total reading time	49 min.	96 min
reading during the inquiry	17%	61%
reading outside the inquiry	83%	39%
index calls	0.57/min. reading	0.55/min. reading
active search	0.11/min. reading	0.06/min. reading

Figures

Figure 1.

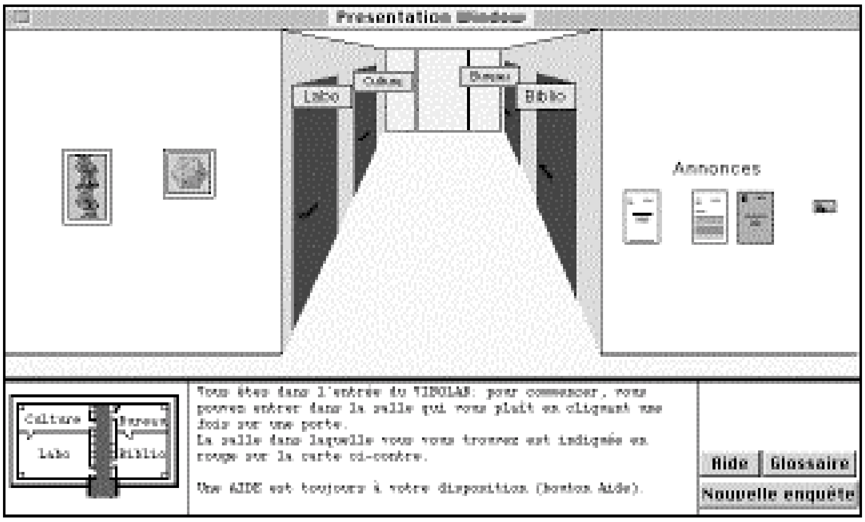


Figure 2

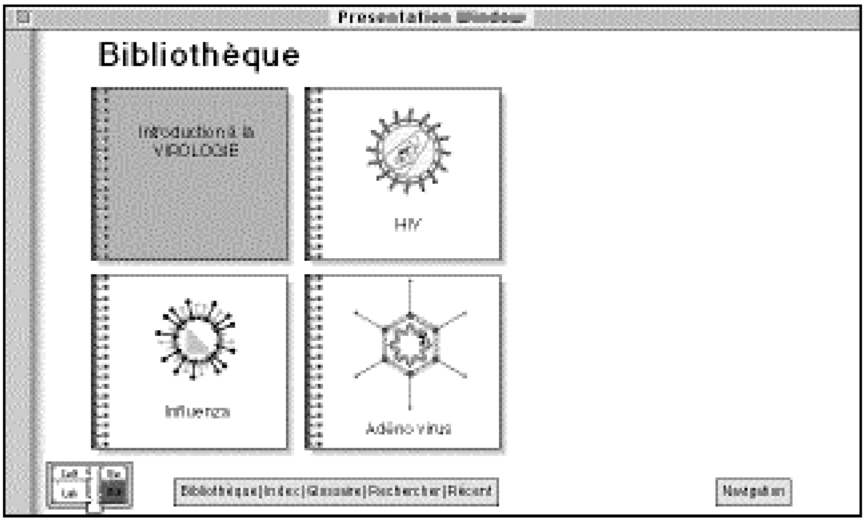
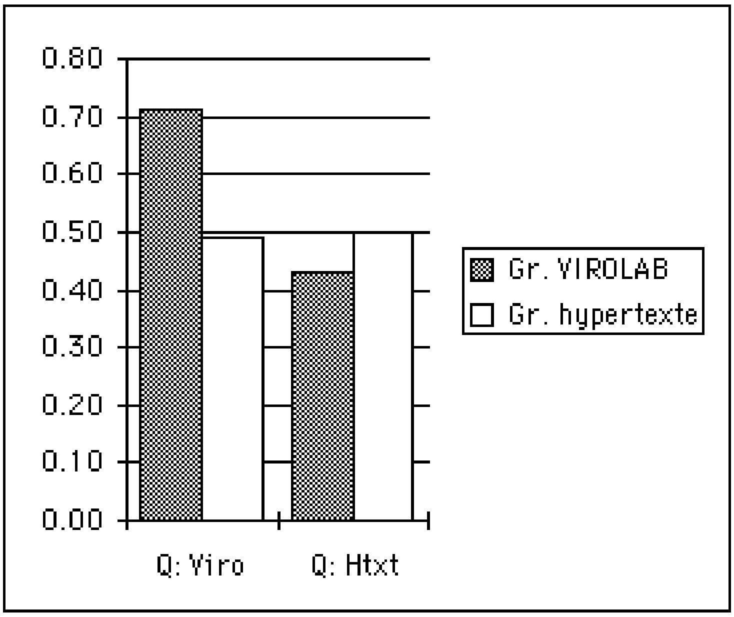


Figure 3


0.80
0.70
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0.50
0.40
0.30
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0.10
0.00
Q: Viro
Q: Htxt
Gr. VIROLAB
Gr. hypertexte

Legends

Table 1:

For each question, the gain is the score at the post-test minus the score at the pre-test. From those values, an average gain as been calculated.

Figure 1 : screen snapshot showing the entrance of VIROLAB.

The screen is divided in two panels. The upper one contains all the graphics and texts displayed according to the actions of the user. The lower one is divided in three sections: the left one displays a sensitive map for the navigation in the laboratory, the middle one displays all the feedbacks and instructions, and the right one contains general navigational buttons.

Figure 2 : screen snapshot showing the four hypertexts available in the library.

The library contains reference hypertexts on the viruses which are studied in VIROLAB. Texts and graphics are displayed in the space above the navigational bar located at the bottom of the window.

Figure 3 : Diagram of the average gains of the two groups according to the type of question.

The x-coordinate represents the type of question and the y-coordinate the average gain for the two groups. The VIROLAB group is represented by the grey columns and the Hypertext group by the white columns.