DOCUMENT RESUME

ED 466 151 IR 021 221

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TITLE	Combining Instructionist and Constructionist Learning in a Virtual Biotech Lab.
PUB DATE	2001-06-00
NOTE	6p.; In: ED-MEDIA 2001 World Conference on Educational Multimedia, Hypermedia & Telecommunications. Proceedings (13th, Tampere, Finland, June 25-30, 2001); see IR 021 194. Contains small print.
PUB TYPE	Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Biotechnology; Computer Software Development; Computer Uses in Education; *Constructivism (Learning); *Cooperative Learning; Educational Research; Foreign Countries; *Laboratories; Virtual Classrooms
IDENTIFIERS	Germany

ABSTRACT

The background of this paper is an internal research project at the German National Research Center for Information Technology, Integrated Publication and Information Systems Institute, (GMD-IPSI) dealing with software engineering, computer-supported cooperative learning (CSCL) and practical biotech knowledge. The project goal is to develop a software framework in order to simplify the implementation of such virtual laboratories. The framework is called CoopLab because an important aspect of the framework is to enable cooperative learning in the virtual laboratory environment. (However, this functionality is still under development in the current state of the project.) The paper describes a constructionist approach as an enhancement of "instructionism" in virtual laboratory environments. It discusses learning in virtual laboratories from an "instructionist" and a constructionist viewpoint and relates them to virtual biotech laboratories developed as an application of the CoopLab framework. Virtual labs based on the CoopLab framework have the capabilities to meet the requirements of constructionist learning environments. A comparison to related work unveiled the specific potential of CoopLab applications to support constructionist learning. (Contains 15 references.) (AEF)

Combining Instructionist and Constructionist Learning in a Virtual Biotech Lab

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Abstract: The functional and didactical design of a virtual learning environment depends on the underlying learning theory. We discuss a virtual biotech lab as a special kind of virtual learning environment from an instructionist and a constructionist viewpoint. The virtual biotech lab introduced in this paper is an application of CoopLab, an object-oriented framework for the development of cooperative virtual labs. The virtual lab supports instructionist as well as constructionist learning and allows a combination of both approaches.

1. Introduction

Laboratory education in natural sciences is time consuming and expensive. Equipment and educational staff of a laboratory is limited and in a lot of cases not sufficient for the number of students that demand a lab course. Unexperienced students have to repeat parts of an experiment. Each mistake and a new trial produces more costs and often toxical waste. The costs for lab courses in natural sciences represent a great expense factor for universities and research institutes.

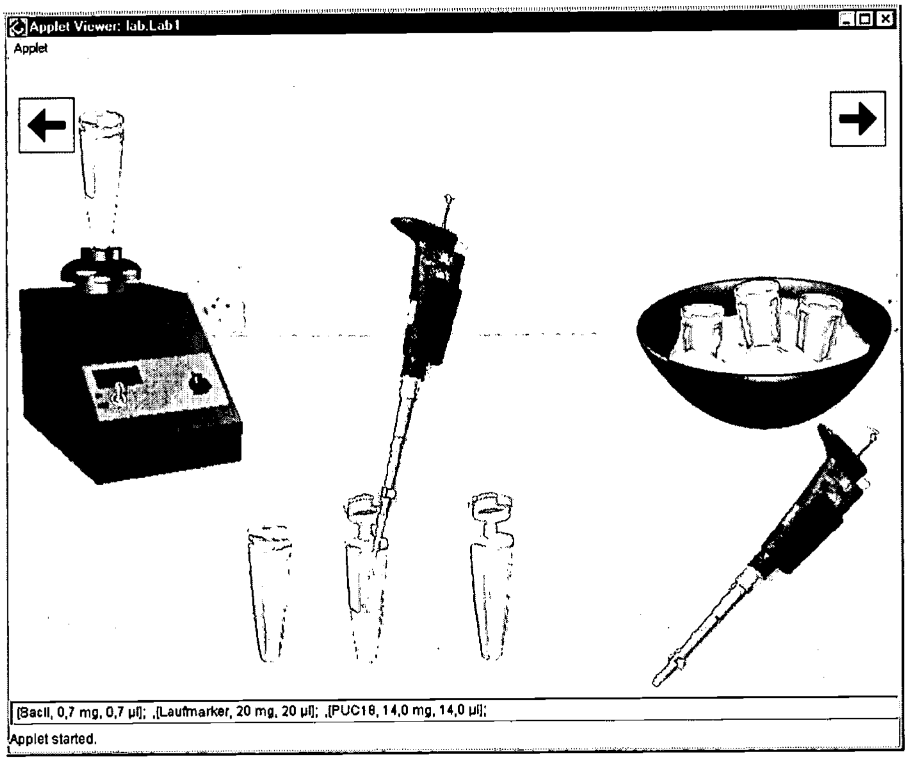
Not only material restrictions obstruct the offering of real world labs but also restrictions in the number of available tutors who have to assist the students in doing the practical experiments. Some of the students need more assistance than others, but individual assistance is nearly impossible during a practical lab course with a number of students of ten or more.

With virtual laboratories some of these restrictions can be addressed: A virtual laboratory is a graphic environment that gives the user the impression of a workbench, which is similar to a real one. Applets enable the user to perform typical biotech experiments in an analog way to a real world lab.

The background of this paper is an internal research project at GMD-IPSI dealing with software engineering, computer-supported cooperative learning (CSCL) and practical biotech knowledge. The project goal is to develop a software framework in order to simplify the implementation of such virtual laboratories. The framework is called CoopLab because an important aspect of the framework is to enable cooperative learning in the virtual laboratory environment. However, this functionality is still under development in the current state of the project.

The target group of the biotech applications built on the framework (i.e. the virtual labs) are students in molecular biology and trainees in genetic engineering, who want to prepare themselves for the practical work in real world labs. We want to stress that the virtual labs, which can be created using the framework do *not* intend to replace real world labs. A virtual lab created by using the CoopLab framework represents an additional workbench with the aim to improve the practical and theoretical preparation of the users and to reduce some of the restrictions of real world lab courses, which are mentioned above.

CoopLab is implemented in Java (based on JDK 1.1), but we are currently moving to Java 2. Java is becoming a prominent programming environment for the design and implementation of nearly all kinds of frameworks.



[BacII, 0,7 mg, 0,7 µl]; ,[Laufmarker, 20 mg, 20 µl]; ,[PUC18, 14,0 mg, 14,0 µl];

Applet started.

Figure 1: Screenshot of a virtual lab workbench

2. Application Domains

CoopLab applications are supposed to simulate real world lab experiences. So far the application domain has proven its power for the development of biotech labs, although it could also be used for other domains. The work in such a biotech lab is comparable to the work in a common chemical laboratory. To simplify it, you can say that the student in a real world biotech lab handles chemical fluids and organic material (like living cells, bacteria or plant cells) to fulfill a number of proposed tasks like DNA analysis, cloning or production of proteins etcetera.

A common practical experiment is the restriction analysis of bacteria DNA: Doing this, the user must prepare the DNA for an analysis by applying various chemicals in combination with special enzymes to the cell DNA, which has to be analyzed (see next paragraph).

Normally you cannot recognize any results with your own eyes, but instead you must use detection tools and machines, wich are applied to the DNA or the containing tubes.

2.1. A Sample Biotech Experiment

As a prototypical application the biotech experiment *Plasmid Restriction Analysis* is chosen. A step-by-step overview of the experiment *Plasmid Restriction Analysis* is given here with an emphasis on common elements, which are found in many biotech experiments. For more information about genetic engineering see (Watson et al. 1992).

During this sample experiment the DNA of bacterial plasmids is treated with special enzymes (called restriction enzymes). This treatment leads to a splitting of the plasmid-DNA into different fragments. With the so-called gel electrophoresis the fragments are compared with an already known standard DNA-fingerprint (mostly the so-called λ-standard). That makes it possible to find out the length of the newly generated plasmid fragments.

The following tasks are summarized in order to provide a clue of the typical working steps in a biotech experiment:

1. Pipet plasmid-DNA into the micro tube with the enzymes and the puffer and shake it shortly with a vortexer.
2. Spread the mixtures of enzymes and DNA together with the λ-standard on a prepared agarose gel.
3. Put the gel into the electrophoresis chamber and start the electrophoresis by switching on the voltage generator.
4. When the electrophoresis is finished, switch it off and put the gel onto an UV-light screen.
5. Take a photo of the observable DNA bands and interpret the results.

The user of the CoopLab application, which is built for doing this experiment, can execute the five steps in a customized way: With the help of mouse events like clicking or dragging, the user can touch, move and combine tools, devices and tubes on the screen, which are similar in appearance, behaviour and usage to the corresponding elements of a real world lab.

The tasks that the user has to fulfill, can be presented in form of a step-by-step protocol list. This protocol can be integrated into the software e.g., as a checkbox-list or alternatively appended as a printed handbook. A typical task would be "Pippet 0.7 µl of the enzyme SacII into the micro tube with the plasmid-DNA." or "Put the gel onto the UV-light.". Each single operation can be performed with help of the computer mouse and, in cases of alphanumerical inputs, the keyboard. After a successful experiment the user gets an adequate feedback: This can be a text output like "The experiment Plasmid Restriction Analysis is finished." in combination with a visual illustration of the experiment goal.

3. Instructionism and Constructionism in a Virtual Lab

In theories on the use of computers in education two main approaches can be differentiated: The 'instructivist' and the 'constructivist' approach (Greeno 1991, p.3).

A focus of instructionism is to increase the efficiency of learning. All actions of the computer aim at transmitting knowledge to the student. By applying this approach the learner is regarded as "the passive recipient of instruction" (Reeves 1993).

In contrast, constructionism regards learning as a process in which the learner actively constructs his or her knowledge by interacting with the subject-matter. The role of the computer is to support such kind of active learning by providing an appropriate learning environment.

What do these approaches mean for the design of virtual labs? From an instructionist viewpoint virtual labs have to support the execution of a linear sequence of steps, which lead to the learning goal. Students are prompted to press the right button, to perform the right interactions or to enter the correct value in order to proceed to the next step. A virtual lab based on this approach would control the student's actions and gives feedback on their correctness. There is little space for the student to deviate from the correct way.

An implementation of the constructionist approach can be found in situated learning (Brown et al. 1989), (Lave & Wengler 1991). According to (Herrington & Standen 2000) an environment for situated learning should fulfill the following criteria:

- authentic context: The context in which the knowledge is learned should resemble the context in which it is normally used.
- authentic activities: The activities performed in the learning environment should resemble real-life activities with respect to the complexity and structure.
- access to expert performances: The student should be able to learn from expert solutions.
- multiple roles and perspectives: The environment should enable students to look at a problem from different viewpoints in order to get a more realistic model of the subject-matter.
- reflection: Reflection on the learning should be supported by providing authentic contexts and non-linear navigation through the whole virtual environment.
- collaborative construction of knowledge: The environment should support collaboration between students.
- articulation: The students should be supported in learning to speak the special language of the discipline.
- coaching and scaffolding: The teacher should be able to provide support for the students, e.g., provide hints and structure the learning activities.
- authentic assessment: The assessment should be seamlessly integrated with the activity.

Remember that in our didactic approach virtual biotech labs serve the purpose of helping students to prepare for real world labs. In the virtual biotech lab students learn about:

- the functionality and behaviour each tool in the real world lab provides,

- the experimental setup for the real world lab, and
- the procedures they will need to follow the tutor's instructions in the real world lab

In order to meet the criteria for situated learning environments our virtual lab environment provides graphical representations of the tools and objects used in a real world lab. These representations can directly be manipulated by the student using mouse and keyboard devices. By arranging these representations the user is allowed to construct arbitrary experimental setups. A workbench is provided in the virtual lab, which serves as a common frame for a set of tools. All objects can interact with each other on such a workbench, while each object has a certain state and can change its state according to user input resp. interactions with other objects. Thus procedures consisting of multiple steps can be performed in the virtual lab. With these features a virtual lab can provide the authentic context, authentic activities, and articulation. Furthermore reflection on the learning process is stimulated through the authentic context as well as the free navigation through the lab environment.

As stated in the introduction the cooperative learning support will become a central aspect of the CoopLab framework, so that collaborative construction of knowledge and reflection, coaching and scaffolding can be supported in the virtual lab. These criteria fall into the category of the so-called *distributed contructionism*, which extends constructionism by focusing specifically on situations in which more than one person is involved (see Resnick 1996).

The provision of multiple roles and perspectives on the subject-matter as well as expert performances can be achieved through external material and data or - in the collaborative usage - by co-learners and tutors. Due to its solely preparative nature the assessment is of less importance in our virtual biotech lab.

4. Related Work

There are several web-based software systems for the training of natural science lab courses available as described in (Hampel et al. 1998) or in available web courses like in (Physics 2000 lab). But both systems miss the power of offering complete virtual environments that are functionally equivalent to real world experiences. Moreover, they provide only a restricted degree of freedom with respect to the user interactions.

Two ongoing projects are more comparable to CoopLab: *GenLab* (Boles et al. 1998), a project conducted by the OFFIS research institute in Oldenburg and *ViSel* (Giegerich & Lorenz 1998), a project conducted by the University of Bielefeld. They also use multimedia technologies to build up a virtual learning environment, but do not aim at integrating any CSCL-features. ViSel is implemented as a Toolbook application, whereas GenLab is implemented with Macromedia Director.

Similar virtual labs are also developed as part of the *Biology Labs On-Line* (Bell 2000) project, which is conducted by the California State University in Chico (USA). These virtual labs provide simulations covering the subjects of evolution, genetics, protein translation, demography and some more topics. They provide Java-based applets, which help to understand and learn the different topics more easily. But in contrast to CoopLab applications, they do *not* offer a virtual lab environment, which gives the user the impression of workbenches analog to a real world lab. They provide a fixed experimental setup whereas in our virtual labs the experimental setup can be constructed and/or modified by the user.

5. Conclusions and Future Work

In this paper we described a constructionist approach as an enhancement of instructionism in virtual laboratory environments. We discussed learning in virtual laboratories from an instructionist and a constructionist viewpoint and related them to virtual biotech laboratories developed as an application of the CoopLab framework. Virtual labs based on the CoopLab framework have the capabilities to meet the requirements of constructionist learning environments. A comparison to related work unveiled the specific potential of CoopLab applications to support constructionist learning.

As already mentioned above, it is a future goal to support collaborative learning in a virtual lab. This could be realized by combining the CoopLab framework with DyCE, a Java framework for the development of modular groupware (Tietze & Steinmetz 2000). In a collaborative virtual lab its state can be made persistent on a server. Different users can log into a collaborative virtual lab and share the same data ("lab-sharing"). If they log into a lab at the same time, they can additionally communicate, work and learn simultaneously. The virtual lab provides awareness of the other students' presence and activities in the lab.

Using this technology, a tutor can enter the virtual lab and provide support, e.g., by answering questions, explaining tools, demonstrating experimental setups, or performing lab procedures. Similar to this, many more CSCL scenarios are possible. Such scenarios are even closer to the experience of a real world lab than a single user application.

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DyCE framework:
http://ipsi.gmd.de/concert/projects/dyce

Physics 2000 lab:
http://www.colorado.edu/physics/2000/index.pl