DISTANCE LEARNING AS A NEW METHOD FOR STUDYING THE EARTH SCIENCES IN HIGH SCHOOL

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ABSTRACT

The aim of this research was to develop a computerized distance-learning unit that will fit the needs of the Israeli high-school earth-science syllabus. the ability of students to conduct lab-activities as a part of a distance-learning unit was the main focus of this study. As part of this work, a web-site was developed for this course. It includes a home-page for the students, a message page, information about the course, links to related sites and web-based activities. The activities section contains hands-on lab-activities, scientific papers, a web-search page and a database for performing analyses. The program was implemented in six grade-12 classes containing 70 students in total. Implementation was followed by a formative-evaluation study that focused on three students and utilized qualitative research-tools. The research-tools included interviews and observations that were made on the students as they performed the web-based lab-~~oratory~~ activities. These tools enabled us to analyze students' performance during the web-based hands0-on lab (Web-HOL) activities. The main findings of this study are:

- It is possible to conduct successful, hands-on lab-based distance learning.
- A majority of the students improved their independent learning-skills after using the materials found in the distance-learning activities.
- Based on our experience and findings we suggest that the difficulties described above are not unique to student performance during Web-HOL activities specifically but rather to hands-on lab-activities in general

KEYWORDS

Distance-learning, Web-based hands-on lab-activities, earth-science education.

INTRODUCTION

The Earth and Environmental Sciences (EES) have been gradually introduced into the Israeli educational system over the past decade. During the last years there are difficulties in increasing the number of schools participating in this program. The main constraints are a shortage of available earth-sciences teachers and the reluctance of principals to open new programs of study due to economic limitations and inter-staff politics. A possible solution to these problems is allowing a few students from several schools to participate in a new program as distance-learners. The aim of this research was to develop a web-based distance-learning unit that will fit the needs of the Israeli high-school EES syllabus. This program allows small groups of students from different schools to participate in the program with a minimal investment from the school. It is important to note that such a program should support all of the needs of a standard EES program. In order to achieve this goal it is important to define both the characteristics of the EES syllabus, as well as delineate the use of the WWW in education in general, and in the science curriculum, specifically.

The use of WWW in education

Since the early 1990's many researches have attempted to characterize the wide variety of Web-based learning-environments (Barron, 1998; Berge and Collins; 1995, Harasim, Hiltz, Teles and Turoff, 1995; Harris, 1998; Bonk Cummings, Hara, Fischler and Lee, 1999). Mioduser and Nachmias (2002) classified four main functions of the WWW in teaching and learning:

- **Content-delivery:** This is the most obvious feature: using on-line sources of information for educational purposes.
- **Instructional delivery:** using the Web as a learning environment, e.g., distance-learning courses and even degrees, collaborative learning projects, virtual-environments for complementary and informal education.
- **Communication support:** Using the web for new forms of interaction, collaborative work and learning among the partners in the educational processes (e.g., students, teachers, experts, parents).
- **Computer-Mediated and creation support:** using the web as a creation environment (for creating presentations, web pages etc.) using computer-based tools.

This classification of WWW learning was based on a survey of existing educational web-sites. Based on this survey it was possible to define the function of the planned web-based course. Since the aim of this work is to allow students to participate in the course, the learning environment should support instructional delivery and tools for communication between the students and the remote teacher.

The characteristics of the Israeli EES syllabus

The Israeli EES syllabus focuses on a wide variety of topics from different earth-science fields. A major characteristic of the program is the importance of concrete hands-on lab-activities and field-trips. The distant-learning environment would need to substitute other activities for these vital components of the program.

Since the Web-based environment can not replace the field environment, this research will focus on the possibility of conducting Web-based Hands-On Lab-activities (Web-HOL) within the framework of a distance-learning course.

Harasim et. al., (1995), claimed that the laboratory is a necessary learning-environment for illustrating basic concepts in science. The writers define four types of laboratory-activities that can be combined in the framework of a distance-learning program. Three types are specifically oriented towards distance learning activities: computer-based simulations, videos and home-kits. The fourth activity is based on conducting laboratory-activities in a traditional lab-environment. Only the third type of activity, using home-kits, permits students to conduct hands-on activities as distance-learning activities. Franklin and Peat (2003) compared hands-on versus virtual biology experiments and concluded “real experiences are valued for their hands-on, 3D nature but also for their ‘reality’. If we wish to excite students about biology we consider that it is essential that they experience as much real material as possible within the constrain of time and budget”.

The advantages of hands-on lab-activities in science programs in general , and the frequent use of lab-activities EES programs specifically, obliged us to conduct such activities as distant-learning activities. Moreover, as designed, all of the Web-HOL activities should permit the students to conduct all of the activities in their distance-learning location.

A major problem that needs special attention is student mistakes during the laboratory-activities. It is quite common with hands-on lab-activities that even minor mistakes can cause the whole activity to fail. In the “traditional lab” the teacher can prevent such failures. Covington (1998) claims that such failure can influence the student’s future success. For some individuals, failure can also distort their memories of past successes. In order to prevent student failure, it is necessary that the instructions provided in a distance learning environment will allow the students to conduct the laboratory-activity with minimal mistakes. Thus it is critical to define the basic principles for designing Web-HOL activities that will prevent mistakes during the activity.

Distance-learning lab-activities have been described in previous works (for example Alhalabi, Hamza, Marcovitz and Petrie, 2000; Forinash and Wisman, 2001; Boone, 1996). However none of these studies examined a model that is specifically based on Web-HOL activities.

This paper describes an innovative attempt to conduct distance-learning hands-on lab-activities in the framework of the Israeli EES high-school program.

OBJECTIVE

The objective of this study was to develop a model for teaching hands-on lab-activities as an integral part of a web-based distance-learning course.

THE RESEARCH SCHEME

In order to develop the model it was necessary to create a learning-environment that would allow the researcher to both test and implement the Web-HOL.
The research scheme included three stages:

- Curriculum adaptation and development.
- Implementation.
- Evaluation study.

The Curriculum Adaptation and Development Stage

The Israeli high-school earth-science unit "Earth-systems, the greenhouse-effect and the global-Carbon-Cycle" was adapted and modified for this distance-learning program. The original program was developed about five years ago as a textbook and laboratory manual format. The described program was taught in a traditional class without computers and guided by the classroom teacher. Adapting the unit for the web included transferring the texts and the activities to digital-format and adding adequate instructions so that students could conduct the activities without the physical presence of a teacher.
In order to implement the program, a web-site was developed to support instructional delivery, as well as to provide tools for communication between the students and their remote teacher. The site included the following sections:

- Information: information about course content as well as a short description of students' assignments.
- Messages: messages concerning the new tasks and a list of the assignments that were submitted by each student. This section was updated on a weekly basis.
- Links: links to related websites. Some of them were added and reviewed by the students as part of their assignments.
- Participants: This section included personal details and E-Mail addresses of the students and teacher who were participating in the course.
- Assignments: This section includes assignments completed by the students during the program.

The twelve learning activities on the website included the following: an acquaintanceship activity; three critical reading activities; five web-based data collecting and analyzing activities, and three hands-on lab-activities.

Special attention was focused on adapting the Web-HOL activities so that the students could conduct the experiments by themselves. As part of this process, we used, in addition to the textual explanations, photos and video clips in the lab-activities. The activity files were in Microsoft-Word format so that the students could download the files and work on any computer. In addition, the students could send and receive these files by email. The lab-activity files included three parts:

- Background: Explanations about the activity objectives and the connection of one activity to another. This part includes computer-based explanations about the materials as well as questions for the students.

- Instructions for executing the laboratory experiment: This part includes textual explanations followed by photos and video clips. To complete this material, students needed access to both computer as well as lab equipment.
- Summarizing activity: In this part the students make conclusions about the activities they had just completed, as well as answer introductory questions about the next activity.

The Implementation Stage

The program was implemented in five 12th grade classes (N=70) who majored in the EES program as part of their high school matriculation program. Each class participated in the program for about 16 weeks, with four hours of class each week.

The school's EES teacher was responsible for preparing the lab activities in school. The teacher and the researcher met on a weekly basis to discuss previous activities and prepare for the next activity.

At the beginning of each activity the students had to download the MS Word formatted activity file to their computers. During the activities the students could contact the tutor using a Chat program (MSN messenger).

In order to conduct Web-HOL it is necessary that both the (web connected) computer as well as experimental materials be located in the same classroom. This special requirement constrained us towards using the computer classroom for the needs of this program.

The first 2-4 hours of the course were dedicated to an "acquaintance" activity: The students opened an E-Mail account and sent E-mail containing their personal details to the tutor. Those details were added to the web site. In the next set of meetings the students completed their assignments at their own pace. Some of the students preferred to complete the assignments from their home computers, while others conducted all of their activities from school. The students' assignments were sent to the tutor (the researcher) to be checked. The tutor sent the assignments back to the students with remarks no more than two days after receiving them. Each week the students had to check their messages and find out how they were progressing.

At the same time, students could not work at their own pace when they were doing the lab activities. Instead they received a fixed schedule for conducting each experiment. Thus the lab activities acted as a "dead line" for submitting all of the other activities that were necessary in order to complete the lab-work.

THE EVALUATION STUDY

Methods

Research tools

This study used the following qualitative research tools:

Interviews: In order to build a detailed picture of the students' difficulties while learning this program, the interviews took place before, during and after the implementation. During the pre-program interviews the students were asked about their previous computer experience, their attitudes towards using the computer and Internet in school, and general expectations about the proposed course. Additionally the students were asked to discuss the Web-HOL activities they had conducted.

Videotape recording: During the lab activities the sample group was videotaped. The videotape was used to identify and critique the ways the students conducted the activities, as well to monitor their difficulties.

Sample

The research sample included a group of three female students. The class teacher was asked to choose three students that usually worked together as a team during class activities. In this paper the students will be designated as student1, student2 and student3.

Research design

The data collection was done in three stages. Each stage was pursued as a case study and was built around a lab activity that was videotaped.

The data analysis of each case study was used to determine how students function during the activity as well as to improve the activity design based on the results. The improved activity design was used as a template to design the next activity.

Interviews were conducted two weeks prior to the first activity, right after the second activity and a week after the end of the implementation. The attitude of the three students towards the program in general and toward each of the activities specifically was analyzed using the interview material. The videotape data was used to analyze how the students performed while completing the activities. The integration of such sources of data permitted us to build a detailed picture of the Web-HOL was implementation.

RESULTS

The results described here include a description of the three case studies.

Case Study 1

General Description

The purpose of this activity was to demonstrate the effect of photosynthesis and respiration on atmospheric CO_2 concentration. During this activity the students had to prepare three containers with different parts of vegetation and to observe the difference in the color of a pH indicator that was located in the containers. Preparation of the containers included cutting the leaves and the flowers according to the instructions and covering different parts of the plants with aluminum foil.

The activity file included a list of questions and instructions concerning the lab activity. The instructions were presented as a list of "actions". Next to each instruction a camera icon was presented. The icons linked to a picture or to a short video clip demonstrating the "action". The total number of photos in this activity was 10.

Class activities were focused around two areas: the computers that were located along the class walls, and the tables with the experimental materials that were located in the center of the room. The distance between the computers and the tables was about two meters and it was impossible for the students to see both the computers and the experimental set up simultaneously.

Analysis of the videotape:

The video analysis focused on the lab activity, which ran for approximately 22 minutes. It is important to note that before the students started the activity they decided to print the instructions from the computer, since the computer was located too far from the experimental set up. However they only printed the written instructions without the photos, which presented detailed visual explanations of the instructions. Additionally, they could not watch the video clips from the computers while they were conducting the experiment.

During the first ten minutes the students worked according to the written instructions and did not exhibit any need for assistance. During this time they prepared the control container that contained no vegetation whatsoever, and put four flowers into the first experimental container. While preparing the first two containers the students talked about several topics not related to the activity. They then prepared the second experimental container with 4 flowers and a specific amount of green leaves. However, they could not figure out from the written instructions the exact number and shape of leaves that they should put into the container. At this point student3 moved to the computer table and examined the pictures. After about 2 minutes she found out that the photos were not identical to the vegetation that was on the table. Since she was still not sure about the leaves she contacted the tutor using MSN Messenger asking how they should put the boughs in the container. Student2 got upset with the misunderstanding and started arguing with the other group members claiming that it was necessary to contact the teacher. At that point she went out of the class to get assistance from the teacher. When student2 came back all three students sat together and completed this task.

Analyzing the location of each of the three team's members along the time interval of the activity indicates the following: Student1 spent all of her time near the experiment setting; moreover, the videotape also indicated that she took a leading role in preparing and performing the experiment. Student2 spent more than 90% of the time around the experimental setting. The videotape indicated that she left the experiment setting only once in order to look for help from the teacher. Student3 spent about 70% of the time around the experimental setup. During the remaining time she went to the computer to look for visual instructions for the experiment and to contact the tutor.

- Thus, the videotape analysis indicated four important findings: Although no teacher was in the class, the students spent all of their time in on-task activity. At the same time, while preparing the experiment they discussed off task topics.
- The distance between the laboratory set up and the computers, did not allow the students to work simultaneously with the two different learning environments.
- The misunderstanding the students experienced while preparing the third container indicates that the pictures in the computer should match both the equipment and the materials used in the classroom.
- Although no instructions were given about how to divide the work between the students, each of the students took a specific role in the team. Student1 prepared and ran the experiment while staying with the experimental set up during the whole activity. Student3 was in charge of checking information on the computer, and she was the first one to move to the computer setting whenever it was necessary to do so. Student2 took the role of connecting with "external sources" of help - the teacher.

In order to better understand the findings presented above, each student was interviewed (about 2 weeks later) about the difficulties that they had experienced in conducting the first lab activity. Analyzing their answers indicates that each one of the students held a different attitude concerning the importance of the online textual instructions versus visual demonstrations (photos and video-clips):

Student 1: *"I think that the textual instructions are more helpful than photos"*.
Student 2: noted that she did not open the photo files.
Student 3: *"The photos illustrate the experiment in a very clear way".*

These answers indicate that only student3, who was "in charge" of the computer, and was the only one who actually saw the photos, found the photos helpful.

The data that was collected during Case Study 1 indicated the following:
- According to this experience, it appears that students can conduct lab activities without the physical presence of a teacher in the class.
- Since some students prefer to use the textual explanations it is necessary to include a clear and detailed explanation as well as photos that will match the equipment the students will actually use.
- Since the instructions appear on the computer's screen it is recommended that the computer and the lab settings be located next to each other.

Case-Study 2

A general description:

The purpose of this activity was to demonstrate the phenomenon of gas-exchange between air and water and the effect of partial atmospheric gas pressure on this process. During this activity, the students had to fill two test-tubes with water; they then added pH-indicator and attached two balloons to the tubes, with the first balloon being filled with air and the second one with CO_2. The preparation for this lab-activity required that the students be more focused than in the first Case-study, since it was very important to keep the balloons filled during this experiment.

The activity file included links to nine photos that presented the visual-setting of the experiment. However, based on the conclusions of the first case-study, special attention was given to providing the students with detailed textual as-well-as visual explanations that were identical to the lab-equipment found in the classroom. Additionally, based on the findings of the first case-study, during this activity the experimental set-up and the computer were both located on the same table.

Analysis of the videotaped activity:

The video analysis focused on the lab-activity, which lasted approximately 22 minutes. The analysis indicated that the students did not leave their seats during the whole activity. They spent about 20% of the time (about five minutes) in off-task social conversations between themselves, and with other students in the class.

During this activity the students opened only the first two of the nine photos. When they had to attach the CO_2 balloon to the test-tube they did not do it correctly and the gas escaped. At that point Student2 went out of the class and asked the teacher for another balloon.

After they finished setting up the experiment student2 asked students from other groups: *"How long do we have to wait until the indicator's color will change?"* As no one could answer them, student3 asked the tutor using MSN-messenger and received an answer.

During the activity student1 was in charge of the experimental set up, student3 was in charge of the computer and student2, who was sitting next to the experimental set up, was responsible for interfacing with the teacher and other groups each time they had a question.

Interviews with the students about this activity took place on the same day that it was performed. The students said that the location of the computer and the experiment was more useful for their work. With regards to the mistake that they had made during the activity student1 said: "*I thought that the textual instructions were clear enough*". Student2 said, *"I think that when the instructions are not clear it is best to ask the teacher"* student3 said, *"I did not see any reason to open all photos because the written instructions were clear enough"*.
Student1 added, *"It is necessary to add to the instructions the exact time that each step takes"*.

The following findings emerged from both the videotape-analysis and the interviews:

- At least one of the reasons why the students made mistakes in performing the experiment was due to the fact that they did not consult the photos. Changing the activity's instructions so that the students must consult the photos may solve this problem.
- In contrast to the first activity, during this activity the students spent some time in off-task activity. Since the preparation for this activity obliged the students to be more focused than in the previous activity they could not discuss off-topic subjects and prepare the experiment simultaneously.

Case-Study 3

A general description:

The purpose of this activity was to illustrate to the students' the scale of different carbon reservoirs in earth. The lab-experiment demonstrates the amount of CO_2 that is released when dissolving five grams of $CaCO_3$. During this activity the students are required to pour five grams of $CaCO_3$ into 50 grams of HCl; the resulting CO_2 is directed into a graduate cylinder filled with water. The gas pushes the water out and the volume of the gas emitted as a result of the reaction can be measured. This activity is more complex than the previous two activities and in some of its stages at least two students have to be involved (so that the water is not lost from the graduate cylinder).

Based on the analysis of the previous activities it was obvious to the designer that he should build the activity file in such a way that the students would not ignore the photos. In order to achieve this goal the activity file (MS-Word format) did not include any instructions. While conducting the activity the students had to open a link to the activity's instructions. The instructions appeared as a series of 10 html pages, with each page containing a short and focused instruction including a photo or a video-clip demonstrating it.

Since part of this activity involved using a large container full of water, it was necessary to conduct it on a separate table from the computer. Thus the class-setting during this activity was similar to the class setting during the first activity.

Analysis of the videotape:

The video analysis focused on the lab-activity, which ran for approximately 25 minutes. It indicated that the students followed the instructions very carefully. They watched all the photos and video-clips and conducted all the activity stages according to the instructions they read and watched.
Even though the experiment was rather complex, no technical difficulties were observed. The students followed all of the instructions and knew what to do during the entire process.

The fact that all of the instructions appeared on the computers forced the students to move back and forth between the computer-table and the experimental-setup. During much of the activity the students rotated between the computer and the experimental-setup. In some cases the students also moved amongst the other groups in the classroom. To fully describe the location of the students during the activity, the videotape was divided into 16 episodes according to the students' location. The end of an episode was defined when one of the students moved between the three different locations (computer, experiment and other groups). Table 2 illustrates the location of the three students during each of the 16 episodes, as well as the number of times (including total time) each student spent in off-task activity.

Table 2. Location of students during activity three

	Student 1 (No of episodes)	Student 2 (No of episodes)	Student 3 (No of episodes)
Computer table	2	4	6
Experiment table	11	8	9
Other groups	3	4	1
Personal "off-task" No. (total time)	2 (2 min.)	4 (3.5 min.)	0

Based on this table, it is clear that student1 was the most active in executing the experiment, whereas student3 was most active at the computer table. The number of times student2 moved between the different locations was the greatest; moreover she also spent the most time on off-task activity.

In the interviews that took place two weeks after the activity, the students expressed the following attitudes towards the instructional format of the third experiment:
Student1: *"you had no option; you had to see the photos so that you would not make any mistakes".*
Student2: *"it is much more clear this way, but some photos were unnecessary because the textual explanation was clear enough".*
Student3: *"this format is much clearer; it is better also because you could easily move back and forth with the instructions".*

The data collected during case study three indicated the following:

- The instructional format reduced dramatically the number of mistakes that the students made during the preparation and execution of the experiment. The students had no reason to guess what they needed to do because they were "forced" to look at the visual explanations (photos).
- During this activity it was clear that two of the group members preferred to be more active with a specific part of the activity such as the experiment (student1) or the computer (student3).

Analyzing the results of the three case studies indicates that although the activity design was improved during the implementation, this change had a different effect on each one of the three students. In order to get a detailed picture of the students' attitudes toward web-based distance-learning as well as their performance during the lab-activities, the data collected about each student was analyzed.

Student1:
During the three activities student1 was very active with the experimental-setup and tried to decrease the time she spent at the computer table. During the first interview she described herself as *"an old fashion learner".* She defined the Internet as a *"nice source of information and meaningful technology"* on one hand, but *"very harmful to social relations"* on the other hand.

During the interview this student said that she preferred to read instructions from paper rather than from the computer monitor. She noted that books are permanent, hence more valid, claiming, *"Book-based knowledge will last longer".*

With regards to adding computers to the school science syllabus, she said that she knew that this was the future trend, but she preferred that it would not happen.

In the second interview student1 said that she realized that *"it is not as bad as I thought"* but she still believed that writing with paper and pen is a more meaningful way to learn: *"when I type my answers into the computer I always try to do it as short as possible"*. When she was asked specifically about distance-learning with lab-activities, she said that detailed and clear verbal explanations were more important than visual explanations (such pictures and video-clips).

At the third interview student1 defined this type of learning as "nice" but she still expressed the idea that it adversely affects social relations between people: *"I do not think that our school should be so proud about the intense use of computers and distance learning. It might be a good solution to remote areas but it does not have any advantage over the traditional way of learning".*

Concerning lab-based experiments she said: *"the photos are very helpful but it can not replace a good verbal explanation. I would always prefer to conduct the lab-activities while the teacher is present in the classroom".*

Student2:
Student2 can be described as the most "mobile" student. She divided her time between the experimental setup and the computer table; however, at the same time she was the first to lose patience, and stop using the computer-based communication tools and to look for assistance from other students or from the teacher.

During the first interview student2 said that she used the Internet as a source of information for a wide variety of topics. At the same time, she noted that she had never used it for any kind of computer-based communication. She defined herself as "*being curious to learn with this method*" but she did not know what to expect.

During the second interview she said, "*I think that working with computers causes delays. Additionally, I'm used to writing answers using pen and paper and I still find it more convenient. I have to get used* *to the keyboard*". She claimed that the only advantage of the computer was the ability to use photos and video-clips during lab-activities. With regards to the teacher in the classroom she said: "*sometimes, when I do not understand something and there is no teacher to ask, I become very upset*".

At the last interview the student said that it was possible to conduct all types of activities without the presence of the teacher in the classroom. The most significant advantage of this method is *"the ability to use photos and clips during the lab-activities*".

Student3:
Observation of all three activities indicates that student3 was always "in-charge" of the computer. She was the one who watched the photos, used MSN-messenger and typed the experimental results. Her answers during the first interview fits these observations She made it clear that she preferred using computers: "*I communicate very well using the computer and I spend several hours a day working and playing with my computer, doing graphics, surfing the web and chatting*". She noted that when she works with other students she is (always) in charge of the computer.

In the second interview she said that she enjoys this kind of learning and thinks that she learns better in this way: "I pay more attention to my answers when I type them but I do not like to read from the computer's monitor".

Concerning the lab-activities she said:
"I liked the web-based experiments, as the photos were very helpful; however in some cases not all of them were necessary. It is very convenient to type experimental results during and not after the end of an activity".

Concerning the presence of the teacher in the class she said:
"I think it is important that the teacher will be in the classroom, at least some of the time. Sometimes you need to ask a question and computer communication is not enough".

During the last interview the student said that the whole course was a positive experience for her but *"since I have used computers for years it did not change the way I use computers, but it was an interesting learning opportunity and I'm sorry that it did not start in our school a few years earlier".*

Discussion and Conclusion

The following discussion will focus on two aspects of the results:

- Improving the design of the Web-HOL
- The differences between the three students as witnessed by their performances during the distance-learning lab-activities.

Improving the Design of the Web-HOL
The outcomes of this study enabled the researchers to define the following basic principles for designing Web-HOL activities:

- Since some students prefer to read the instructions and other prefer to work according to pictures and video-clips, full and detailed instructions should be presented both textually as well as visually.
- The textual instructions should include short and focused sentences that will be easy to understand and remember, and will prevent students from reading just a part of the instructions.
- In spite of the fact that the students said that some of the pictures were unnecessary, we recommend using visual instructions (photos or video-clips) to demonstrate each stage of the activity. This recommendation is based on the observations that sometimes when the students worked only according to the textual instructions they made more mistakes.

- Since in some cases the students avoided following the instructions and instead completed the activity based on their own best guess, it is recommended that the textual and visual instructions will appear together. In this way the students will not have the option to choose whether they want to view each of the steps or not.
- In order to prevent misunderstandings during the activity, it is recommended that the experimental equipment and materials be identical to the photos.
- The class should be arranged so that the experimental-setup and the computers are next to each other.

The observations and interviews indicate that throughout the implementation there was general improvement in how the students' functioned from one activity to the next. The success of the third case study indicates that it is possible to conduct hands-on lab-activities without the physical presence of a teacher in the lab. In part, this can be explained by the improvements that were made to the designs of the activities.

While examining all three activities it is clear that this specific group of students tried to perform all of the tasks during the course. The interviews and the videotapes indicate that the need for teacher assistance during the first two activities was mainly a result of ambiguous instructions. The current evaluation study enabled us to identify the ambiguity and to modify the instructions accordingly. The performance of the students in the third lab-activity with the modified instructions seems to indicate that it is possible to conduct hands-on lab-activities within the framework of a distance-learning course. However, since this conclusion is based on a very small sample it is important to check the principles that were developed in this study with a larger group, and with other types of hands-on lab-activities.

In addition to the improvement in the instructions, one might suggest that the improvement of the students' performance is due to a reduction of the novelty of this type of learning environment and its setting. In this study it is impossible to differentiate and define the relative influence of both factors: the improvement of the activity design and the improvement of the students' learning skills. The basic principles for designing Web-HOL activities listed in the beginning of this discussion enable future research to focus on this question.

The preliminary results indicate that it is possible to decrease the need for a teacher during lab-activities.

Students' difficulties during the activities result mostly from the following reasons: (a) the design of the instruction file; (b) the students' tendency to avoid reading textual instructions when they think it is not necessary and (c) students difficulty in focusing simultaneously on two domains during the activity.

Based on our experience as science teachers in high school we have experienced similar difficulties during (regular) hands-on lab-activities in the class. Hence, we suggest that the difficulties described above are not unique to student performance during Web-HOL activities specifically but rather to hands-on lab-activities in general. However, the similarity between Web-HOL activities and hand-on lab activities indicates that future research should focus on pedagogical aspects of students understanding rather than technical aspects of performing the activity.

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