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Vireal Lab – From Instruction to Construction§

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Abstract: Living in a century in which the turnover of new insights in biomedical sciences is accelerating rapidly, educational institutions have to face the problem of the sustainability of its teaching strategies. There is no doubt that the task of every university is to keep the quality of its education on a high standard. This goal can only be achieved if the increasing information of high complexity can be adequately integrated into teaching scenarios and constantly be available with reasonable accessibility. Conventional types of teaching media are no longer qualified for this purpose. New teaching technologies, carefully integrated into the curriculum are believed to be an essential media to guarantee the constant high standard of education. In addition, nearly all modern research in life sciences nowadays has switched to teamwork to be able to create real breakthroughs in basic and medicinal sciences, *e.g.* the Human Genome Project. This fact demands appropriate team teaching and working concepts as well as a well-equipped environment to support collaboration. In this article a completely new scientific environment for teamwork in education and research in life sciences is presented: *Vireal Lab*, a physical learning environment, equipped with interactive tables and white boards with built-in electronic devices and touch-sensitive surfaces. It supports all modes of face-to face or virtual collaborative learning and working. Since collaborative learning is believed to be one of the most successful learning methods it is, for the first time, supported by appropriate new technologies. *Vireal Lab* is an innovative approach to meet the high demands of today's teaching and research in life sciences

Keywords: Collaborative learning environment · e-Learning · Teaching · Teaching sciences · *Vireal Lab*

Introduction: Changes in Teaching of Medicinal Chemistry

During the past 100 years, learning systems have undergone a demonstrable shift. For decades learners were thought to be 'receivers of knowledge' and teachers were thought to be 'instructors of knowledge'. The roles and the hierarchy between learners and teachers were strictly defined. Only teachers were allowed to handle the precious molecular models and to demonstrate them in front of the class. Whereas learners passively assumed the role of 'consumers' by watching and listening to the teachers but were not allowed to handle the models themselves. While teachers were expected to transfer knowledge, learners were viewed as 'blank boards ready to be filled with knowledge'. Consequently, learners had only to write down what their teachers told them. At the same time, students had often limited opportunities to understand or make sense of topics because many curricula emphasized memory rather than understanding [1]. Accordingly, learning goals mainly consisted in recapitulating what teachers taught rather than what learners actually understood.

This so-called instructivist learning system was reasonable at the time since the scientific content to be taught was not as complex as it is nowadays. To be precise, scientific content was of the same complexity at that time but the lack of sophisticated analytical technologies meant that the real complexity of scientific data could not yet be detected. Knowledge of certain molecular structures or molecular interactions was so poor at that time that words and simple drawings were sufficient to explain them appropriately. Such 'simple' knowledge, of course, did not require any elaborated teaching systems, learning goals and technologies than the classic lecture mode, the ability to remember, and the blackboard (Fig. 1).

Teaching and learning systems have, over the past 20 years, undergone a demonstrable shift [2]. Recent studies and recommendations of the new science of learning put emphasis on constructivist concepts rather than on instructivist theory and approaches. The main reason behind con-

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§Supplementary material to this article can be downloaded under *www.vireal.ethz.ch*

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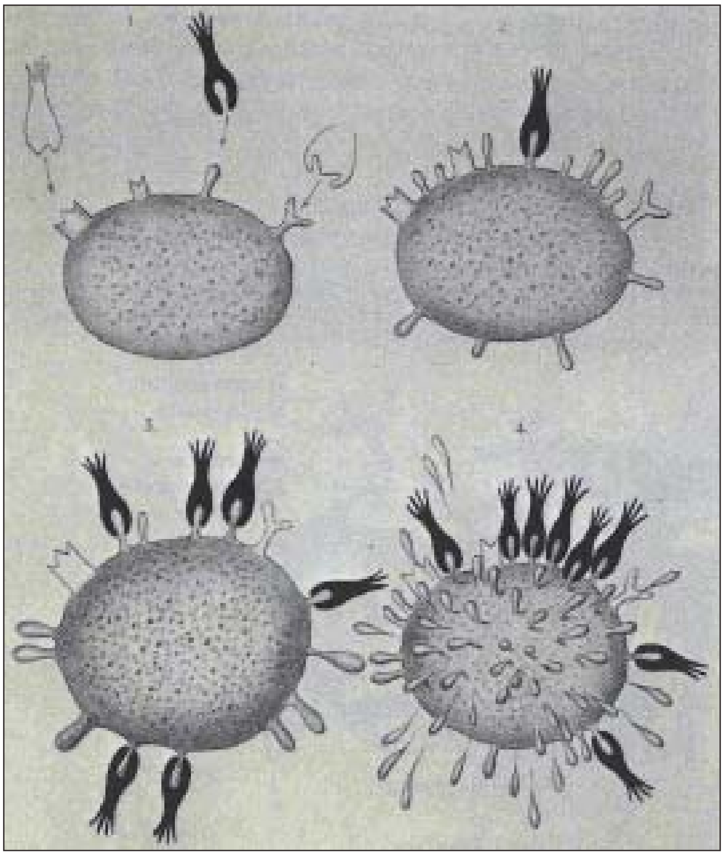

Fig. 1. Hand drawing of antigens and antibodies, presented in the CROONIAN LECTURE entitled 'On Immunity with Special Reference to Cell Life' by Prof. Dr. Paul Ehrlich, Director of the Royal Prussian Institute of Experimental Therapeutics, Frankfort-on-the-Maine. (*Proceedings of the Royal Society* (London) March **1900**, *66*, 424–448)

structivist concepts are that knowledge actively constructed by learners will last longer than knowledge passively received by them through listening to a lecture.

A constructivist perspective considers learners as actively engaged in constructing knowledge and teachers as becoming the guide and facilitator of learning rather than the director of instruction. Now learners are active constructors of knowledge and assume the role of the producer rather than the consumer of information.

Consequently, the hierarchy between learners and teachers breaks down to a common learning community in which both learners as well as teachers are involved. Learners are no longer 'blank boards ready to be filled with knowledge', they bring their own needs and experiences to the learning situation. Constructivist learning emphasizes learning as a social and collaborative endeavor as well as problem-solving of realistic and authentic tasks [3]. This approach looks for what students can apply, analyze, interpret, and generate based on what they already know and understand, rather than on what facts they can remember. From a constructivist view, students must be provided with a rich learning environment [3], where skills and knowledge are best acquired within realistic contexts.

Thus, learning goals have also undergone major changes. Everyone expects much more from today's schools than was expected 100 years ago [1]. While learning goals in the past were mainly aligned with reproducing the content of a textbook, constructivist learning goals ask for ability to explain, to apply, to interpret, and to generate realistic and authentic tasks. Additionally, according to new social needs, learning goals such as communication skills, technological competency, organization capability, and team problem solving have to be taken into account as well.

A fundamental tenet of modern learning theory is that different kinds of learning goals require different approaches to instruction. New goals for education require changes in opportunities to learn [1]. Aside changes in teaching approaches and learning goals, the type of knowledge and contents of teaching have also undergone progressive changes. In the past research in biomedical sciences was not so highly developed, so that conventional types of teaching media such as text, overhead and blackboard were sufficient to represent the scientific data.

Nowadays, research in biomedical sciences has undergone very progressive development resulting in tremendously accelerated generation of information. Sophisticated scientific technologies enable accurate investigation of complex data at a molecular level and thus increase immensely the knowledge in biomedical sciences. For a deeper understanding of such complex data, conventional types of teaching media are no longer ideal. Today's teachers are obliged to give learners an idea of how complex scientific data are in reality, according to the results of research. Although today's students in pharmaceutical chemistry are still expected to be able to explain the effect of a drug, they are now required to describe it in an atomic representation. This progress demands new teaching technology in order to properly represent the complex data.

For example, since Kekulé und Couper in 1857 defined the three dimensions of molecules, one of the major learning difficulties for students involves the mental transformation between two-dimensional (2-D) and three-dimensional (3-D) representations of molecules. Many students are not able to form 3-D mental images by viewing 2-D chemical structures and to mentally rotate 3-D images [4] (Fig. 2). Real-time 3-D representations of a receptor and its ligand are however crucial in understanding their molecular interactions and thus the mechanism of drug effect.

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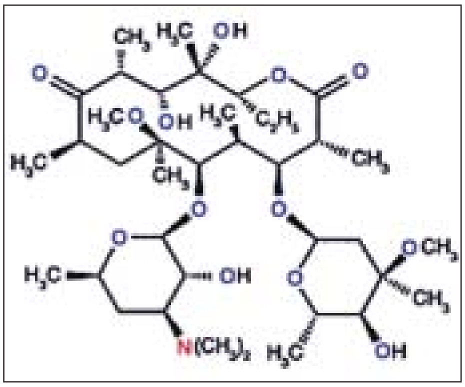

Fig. 2. A two-dimensional (2-D) representation of the Macrolide Clarithromycin illustrates the complex conformation of the residues. For a better conformational understanding of the molecule, a spatial three-dimensional (3-D) representation is definitely more helpful. But unfortunately, this could not be performed on this two-dimensional medium. For three-dimensional (3-D) representations, virtual space however is obviously a more promising medium. To view the 3-D structure of Clarithromycin follow the URL: *http://www.vireal.ethz.ch/DEVELOP/Clarithromycin3D.mol* (Chime-Plugin-Download: *http://www.mdl.com/chime/index.html*)

New teaching technology with proper simulation software applications can be sophisticated learning aids, helping students visualize complicated three-dimensional concepts such as potential energy surfaces or molecular docking [5]. Viewing dynamic and three-dimensional animations created by technological tools could help students learn to use microscopic and symbolic representations to describe and explain a chemical process [4].

In addition, students should have the option to observe and manipulate these objects at a molecular level by themselves. This is important since students understand a subject better if they construct it themselves step by step, rather than being told what it is and simply asked to remember it [6]. Consequently, such computerized molecular models should not be kept for the teacher's use only but must be accessible for learners as well. Indeed, computer teaching aids for more complicated molecules and chemical systems are the wave of the future [5].

Multimedia technology is permeating the educational arena and changing the way teachers teach and students learn. By incorporating technology, especially multimedia technology, into the classroom, the teacher can adopt new instructional strategies to create a stimulating teaching and learning environment. It will enable teachers to pursue traditional goals with new fervor and success.

'Our students must be versatile to these challenges in technology, and our teachers must be proactive to the new requirements. [There is a need to]… devise curriculum so that the culture of 'learning how to learn' and lifelong learning can be rapidly inculcated into the students' [3].

But also, they have to be flexible and open to the changes. Several writers, however, have questioned the value of such 'media-centered debate' and suggest approaching the question not in terms of whether media affect learning but rather by asking: In what ways can we use the capabilities of media to influence learning for particular students, tasks, and situations? [7]. Which approach is best suited for technology integration? There is no right or wrong answer, yet there is one more question to bear in mind: Who is going to decide this? The software package producer, the computer, or the educator? Firstly to believe that acquiring the hardware and the software packages will resolve the problem is denying the importance of the human mind and capacity to choose. Second, the computer can be used as a tool to facilitate teaching and learning. However, the machine cannot make the choice of pedagogical approach. Whether to use one approach or the other is up to the teacher, who knows the lesson objectives, the expected results, and the students [8].

Concept of *Vireal Lab*

Different theoretical precursors emphasize collaboration as a successful and powerful activity for learning and problem solving [9]. During collaboration students discover, construct, and become aware of their own cognitive structures by representing and explaining their concepts and ideas.

Although constructivism and collaborative learning dominate the field of learning they are not properly supported by accurate technologies. So far, face-to-face collaborative learning and working mode has not been supported by proper computer tools. Computer technologies are however important to provide students with the newest results of research and to prepare each student for 'tomorrow's challenge'. All common PCs and notebooks are designed for individual work but not for a collaboratively working group. It is absolutely a false approach to support collaborative working with a personal computer: the name tells it all, it's a personal computer, absolutely not made for teamwork. What is definitely needed is a kind of 'team computer'.

Being aware of the necessity of new teaching technology in order to provide students with a properly equipped environment for teamwork, a constructivist-learning environment, the so-called *Vireal Lab* (*vi*rtual-*real*-Lab), has been set up in the library at the Institute of Pharmaceutical Sciences at the ETH Zürich (Fig. 3). One definition (of such a constructivist learning environment) is: 'a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem-solving activities' [3]. Teamwork is and will remain very important – all modern research in life sciences has switched to teamwork. Only big teams, linked together worldwide, are able to create real breakthroughs in basic and medicinal sciences. Therefore, proper high-tech communication tools are crucial for high-level teaching and research. To prepare students for this working situation, *Vireal Lab* is established as a completely new scientific environment which combines virtual worlds with the real world of a library.

Vireal Lab is an innovative physical working environment, where high-tech roomware enables all modes of *vi*rtual and *real* collaborative works and learning. High-tech communication roomware are interactive tables and white boards with built-in electronic devices and touch-sensitive surfaces. The latter allow you to spontaneously control any computer applications and make any annotations on the surfaces by using your fingers or a pen. The roomware represents a kind of 'team computer'. Each of them provides easy access to the Internet, databases and local computer network. A large shared, working surface allows everyone to see the object displayed, thus enabling everyone to participate in the problem solving and discussion and to operate spontaneously by means of a pen or a finger (for technical details see next chapter). This approach creates a completely new type of synchronous and asynchronous interactive collaboration in different scenarios:

- *Vireal Lab* can be used by research teams to present and discuss their results using the large display to comment

Fig 3. a) CommBoards®, interactive digital wall surfaces; b) InteracTable®, an interactive table, designed by Wilkhahn (*www.wilkhahn.de*)

their data. This is possible for local teams as well as for remote teams using a special software and video-conferencing technology.

- *Vireal Lab* is a suitable environment for new constructional teaching strategies to create stimulating teaching and learning approaches
- *Vireal Lab* is also adapted for self-study and information searches using books and virtual sources.

Vireal Lab is a working environment for all purposes, especially for any kind of collaborative work. Not only for research or educational purposes in life sciences but also for collaborative work in engineering, architecture or business.

Such a multifunctional environment is additionally supported by wireless LAN technology, mobile tables and chairs enabling a mobile and flexible working style.

Vireal Lab plays a major role in implementing the new teaching concept in pharmaceutical chemistry at the Institute of Pharmaceutical Sciences at the ETH Zürich. It forms the basis of a constructivist collaborative and problem-based learning concept. The new concept entails that learners construct their own knowledge together with others in small groups based on realistic problems. Thus, knowledge will be applicable to realistic situations and will not be restricted to abstract and 'inactive' knowledge. Further, knowledge will be constructed through exchanging individual knowledge, mutual explanations and discussions. In this aspect learners are given at the same time the chance to learn about social soft skills as well. In such a constructivist concept the role of the teacher has changed from being the instructor at a higher hierarchy to becoming a facilitator of the learning process in the same learning community as the students. In the move from a teacher-centered to a learner-centered learning situation students have a greater opportunity to actively construct knowledge and establish and exercise teamwork and leadership skills [2]. Consequently, learning becomes accessible for everyone, informal and self-determining. As Trondsen said: "We'll be looking increasingly at informal learning. How do you use it to support, interact and communicate?" [10].

Since personal contacts and communication are still basic human needs, learning environments have to meet these needs as well. It has to foster human contact and enhance an informal but collaborative working mode. *Vireal Lab* is ideally suited to support such face-to-face concepts of collaborative learning.

The *Vireal Lab* environment enhances the lesson in a way that would not be possible without it.

Technology

Hardware

A large-sized interactive monitor consists of in each case: a Pioneer plasma display (PDP 502 MXE), an attached interactive SMART Board foil for the PDP (PP250) as well as a personal computer (PC) with operating system (OS) Windows 2000 or alternatively a workstation SGI with OS IRIX, appropriate driver software for the SMART Board foil, and a graphic card (Matrox Millennium G550 DualHead 32 MB DDRRAM AGP Bulk), which supports the larger display format 1280×768 pixels.

The characteristic of this interactive monitor lies in the integrated SMART Board function, which enables navigation with the finger over the whole surface and thus replaces the mouse.

The SMART Board interactive whiteboard is a great tool for presenting information to others, allowing you to control any applications by simply touching the display and writing across various open applications to highlight important facts.

If necessary a wireless keyboard with wireless mouse supplements the operating functions.

A further peculiarity is the relatively large distance between the computers and the screen units: the connection was realized with a 22 m long cable (patch cable: RJ 45, cat 6 & serial cable) and special signal transmission arrangements (keyboard/video/mouse (KVM) switch technology). Based on this solution, the installation PCs can be placed anywhere within this area.

A further technical aspect is the network load. Analyses of measurements yielded no extraordinary network loads. The characteristically used bandwidth can be designated in comparison with the theoretically possible bandwidth by 100 Mbit/s as modest.

Application Specifications

The components of SMART Board Tools are briefly described below:

1. Floating Tools

The Floating Tools are a versatile palette of buttons that float over any open application on a SMART Board and offer a wide variety of functionality. In addition to providing software counterparts to the Pen Tray tools (a virtual stylus, highlighter and eraser), the Floating Tools also offer access to tools that change a left- to right-mouse click (Windows only), create geometric shapes, provide a large pointer for presentation purposes and restore cleared annotations.

2. SMART Notebook

SMART Notebook software may be used to create, organize, save and print notes from a PC equipped with a SMART Board interactive foil.

Notebook software includes many object-creation tools for creating a variety of annotations within Notebook files, and graphics, text and clip art from any other application can also be imported into Notebook software.

Before a meeting or a presentation, the tools available in SMART Notebook software can be used to create a multi-page Notebook file. The file can then be opened on the SMART Board interactive area during the meeting. While meeting participants provide comments and make suggestions, their input can be captured by using the many tools available. Navigation between each page in one's Notebook file can be accomplished by simply touching the interactive screen.

But Notebook software is much more than just an electronic flip chart for displaying presentations or capturing notes from a brainstorming session. It also serves as a receptacle for anything you write on the SMART Board interactive whiteboard over any application.

As soon as you write over a Windows operating system application with a Pen Tray stylus, a toolbar appears that lets you save a bitmap image of both your annotation and the underlying application. When an image is captured, the image is automatically placed on a new page of the current Notebook file. The captured annotations may be saved as a Notebook file, a PDF file, a series of image files or an HTML file (Windows only).

3. SMART Keyboard

However, many occasions arise when a keyboard is a necessary tool: For example, one may want to rename a file and type a new name into the 'Save As…' dialog box. The SMART Keyboard is a quick and easy way to fill in the dialog box right at the board surface, without having to move to an attached or wireless keyboard. The on-screen keyboard also offers a very easy way to log on without resorting to an actual keyboard. For a Windows operating system user who prefers not to type, one can press the 'Write Button' on the keyboard, and then write in the Handwriting Recognition window with one's finger or a stylus. It is not necessary to alter one's handwriting to be recognized by the software or to perform any handwriting-training procedures. The SMART Keyboard will recognize and convert one's handwriting into typewritten text that can be further edited before inserting the text directly into an active application or dialog box.

4. SMART Board Control Panel

The SMART Board Control Panel is a tabbed interface for configuring the SMART Board interactive whiteboard functions and accessing the advanced features.

In the Board's tab you can:

- connect or disconnect the SMART Board interactive whiteboard to/from the serial ports on your computer,
- perform the SMART Board interactive whiteboard orientation procedure,
- configure the SMART Board interactive whiteboard for projected or non-projected mode,
- run a status log for diagnostic purposes and for Windows operating system users, access the SMART Board software Diagnostics program to test any connected SMART Board interactive whiteboards,
- access advanced settings,
- configure and perform an orientation for multiple SMART Board interactive whiteboard operation (for Windows operating system only).

In the Pen Tray tab you can:

- customize the Pen Tray tools to accommodate individual user preferences or revert to default values,
- create and save individual user profiles (for Windows operating system only).

In the Floating Tools tab (for Windows operating system only) you can:

- customize the Floating Tools to accommodate individual user preferences.

NOTE: Windows operating system users can also enlarge the Floating Tools with additional buttons, create, and save unique Floating Tools profiles for individual users.

The Main Applications of *Vireal Lab*

Teaching

Humans are motivated to develop competence and to solve problems; they have, as White [1] put it, 'competence motivation'.

Social opportunities also affect motivation. Feeling that one is contributing something to others appears to be especially motivating [1].

Learners of all ages are more motivated when they can see the usefulness of what they are learning and when they can use that information to do something that has an impact on others – especially their local community [1].

One way to help students learn about conditions of applicability is to assign world problems that require students to use appropriate concepts and formulas. If well designed, these problems can help students learn when, where, and why to use the knowledge they are learning [1].

Savery and Duffy [2] set out the following 'instructional principles' derived from constructivism:

- Anchor all learning activities to a larger task or problem.
- Support the learner in developing ownership for the overall problem or task.
- Design an authentic task.
- Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning.
- Give the learner ownership of the process used to develop a solution.
- Design the learning environment to support and challenge the learner's thinking.
- Encourage testing ideas against alternative views and alternative contexts.
- Provide opportunity for and support reflection on both the content learned and the learning process.

Wilson [5] pointed out that in learning concepts where collaboration is the key, one has to include tasks that encourage discussion. Students need to analyze data or do a synthesis for which they have to compare data and draw conclusions, or do evaluations in which they look at data and use it to answer questions or solve a problem. The questions must be challenging enough that students need to talk about them with each other to solve them [5].

The learning contents must foster the skill to seek information, think critically, use the information and communicate effectively and work in a team [3].

Based on those suggestions a new concept of collaborative learning has been designed for the lessons of medicinal chemistry.

The learning scenario chosen for our own set up is based on the method of the learner-centered collaborative learning of Sharan & Hertz-Lazarowitz [11]. Due to the time limit of one semester the accomplishment of the method was slightly modified and shows the following procedure:

- Students are asked to form groups with five to seven persons per group.
- The teacher gives an authentic problem and defines a time schedule. The realistic problem to be solved was that students were asked to assume a research team and to develop a drug with certain predetermined criteria.
  The given task is a very realistic world problem and corresponds to recent research. Students had all the means one needs in a real research team to solve the problem as well. Fundamentally, there was a real chance to solve the problem.
- Each group works on the problem and self-organizes their duties.
- The teacher's role is to facilitate and to assist the learning process to ensure that they maintain the right focus.
- At half time and at the end of the time each group has to present their results in front of all other groups and the teacher.

- After that, all results are discussed in detail and rated by the teacher and students.

To help students get an idea of collaborative learning the puzzle-method was additionally applied to the process:

- The teacher chose three topics which could help students to solve their problem and which were linked together.
- Five or six questions were prepared for each topic in written form.
- Each group was asked to assign members to all three topics.
- All students from different groups who were assigned to the same topic form the 'expert group', and tried to learn about this topic and answer the questions.
- After that, all members of the 'expert group' returned to their own group and told their members about what they had learned about their topic. So did the other members. A collaborative knowledge exchange, followed by a discussion represented a typical form of collaborative learning.

One of the main challenging aspects of collaborative learning is to find an efficient way to elicit individual knowledge in collaborating groups and to communicate it [9]. One possibility to overcome this challenge is to design a competition between groups. This could motivate each individual to give the best in order to help his/her own group to win.

For this purpose a competition was planned and attended the whole process. All groups got the opportunity to collect scores through their achievements as a group. The winner group was then rewarded with a prize.

Research

We are planning the development of a novel communication system based on the *Vireal Lab* technology.

Since there is a lack of sophisticated scientific technologies in most developing countries, accurate research is generally difficult. To guarantee a sustainable cooperation between ETH Zürich and research institutions of developing countries, the *Vireal Lab* technology will be set-up in one of the corresponding developing countries. This concept enables researchers of those countries to have permanent, direct, and rapid access to the automated labs and the collected data in Zürich. Thus, they will be able to use the *Vireal Lab* not only as a communication platform but also as a means to access sophisticated instruments. Moreover, they may participate in the screening process from their own country without being permanent residents in Europe. The outlined collaboration concept gives them the opportunity to share the high standards of the technology and the know-how of Swiss Research Institutions. Whereas they (partner developing countries) provide us with samples (out of sea, Flora, Fauna) and local research staff, who will be remotely advised using *Vireal Lab* technology. This is a benefit for us since due to international agreements, it is forbidden to bring samples into industrial countries and to investigate those samples on usability (*e.g.* as drugs), unless permission is sought. The administrative and scientific work of the distributed partners/co-workers will then be supported by a document management software tool with interfaces to chemistry specific software and hardware. The use of this software is based on a mutual agreement, which allows us to use the software for free as long as the functions of this particular management software will be advanced in our project.

Feedback

Student Feedback

To evaluate the impact of *Vireal Lab* especially on teaching, a collaborative project between the Institute of Pharmaceutical Sciences and the Institute of Work Psychology of the ETH Zürich was launched. The main focus of this project was to analyze the application and the impact of *Vireal Lab* on the learning process and learning effect of students in medicinal chemistry of the Institute of Pharmaceutical Sciences. The experiment took place during two semesters and was mainly based on the learning scenario described above. All lessons were audio- and videotaped in order to analyze interaction and learning processes. Also learning effects concerning professional competence and social competence were analyzed. Such investigation unveils the substantial value and possible difficulties of implementing further new media technology.

Final results of this project have not yet been thoroughly elaborated and will be published at a later date. But so far, enough student feedback has been collected to give some representative statements:

Students are enthusiastic about the well-equipped environment, allowing a collaborative learning scenario. They particularly appreciate the social form of the teaching strategy, enabling them to collaborate with colleagues and especially with teacher and assistants. However, each working group should not have more than six members to avoid hindering the close collaboration within the group.

Yet, it remains to be said, that collaborative learning requires much more time to finish an item compared to conventional lectures. But it is realized that the knowledge one gains in a collaborative learning scenario is deeper and more versatile than knowledge acquired from a lecture.

The technical support, especially the 3D-visualization of molecules, is of great benefit to understand and discuss molecular problems. The reason is that students can see and explore the molecule three dimensionally by touching and moving it. This eliminates the student's major learning difficulty of mental transformation between two-dimensional (2-D) and three-dimensional (3-D) representations of molecules. Many students are not able to form 3-D mental images by viewing 2-D chemical structures and to mentally rotate 3-D images [4].

Thus, the roomware helps students to understand a molecular problem much more easier.

Further more, the large display seems to stimulate participation, interaction, and discussion within a team. That is because the large shared working surface of the roomware allows everyone to participate and to operate spontaneously by means of a pen or a finger. On the contrary, team-members of the reference group, who are only allowed to work with their personal notebooks, declare that personal notebooks clearly hinder communication between team-members and thus are counterproductive for collaborative learning. This is exactly the benefit of *Vireal Lab* as an appropriate environment supporting teamwork with adapted new teaching technology.

Moreover, due to the homogenous and standardized technology a simple and comfortable handling of the technology is possible without any special technical knowledge.

The success and more important the sustainability of *Vireal Lab* is well defined since a further interdisciplinary course has already been proceeded in *Vireal Lab* for several months. Thus, the *Vireal Lab* and its innovative potential for various teaching and research concepts open a new way for all kinds of users, whether in education, research, or other branches.

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Public Feedback

Up to now there has been a comparatively large media feedback about *Vireal Lab*. All kinds of media people (TV, print and online media *etc.*) have reported on the innovative learning environment. Recapitulating the overall tenor of the media feedback, we may assume that our concept was understood and well reproduced in the various media. This feedback shows the general interest in new media technology and the concepts for their implementations for teaching, research, and other branches.

Titles of articles or contributions that have been published to date are listed below:

Public General Media:

a) *Schweiz. Depeschenagentur* (sda), 5.2.02, 'Weltweit einzigartiger High-Tech-Studienraum an der ETH Zürich. Interaktiv studieren im *Vireal Lab*' also published in French and Italian.
b) *Neue Zürcher Zeitung* (NZZ), 6.2.02, 'Bewegte Mikrostrukturen an der Bildschirmtafel – *Vireal Lab* im ETH Pharmaziestudium'
c) *20-Minuten*, 6.2.02, 'Einzigartiger ETH-Raum'
d) *Zürich-Express*, 6.2.02, 'Interaktives ETH-Studium'
e) *Teletext Tele Züri*, 6.2.02, 'High-Tech-Studienraum an der ETH Zürich'
f) *St. Galler Tagblatt*, 13.2.02, 'E-Learning, Futuristisches Schulzimmer' (short item)
g) *St. Galler Tagblatt*, 13.2.02, 'Das visionäre Schulzimmer – Der weltweit einzigartige Studienraum *Vireal Lab* an der ETH Zürich' (long item)
h) *Handelszeitung*, 13.2.02, 'Eine neue Lernform' (shortcut)
j) *Aargauer Zeitung*, 14.2.02, 'Einmaliger Studienraum – ETH Arbeiten in einem fast virtuellen Raum'
k) *Laborscope*, 26.6.02, 'Das visionäre Schulzimmer'
l) *ETH Life*, 6.2.02, 'Pharmazeutische Wissenschaften: Neues '*Vireal Lab*' 'Demokratisierung' der Information'
m) *TV RTSI*, 5.2.02, Newsbeitrag
n) *TV SFDRS MTW*, 21.2.02, Beitrag in Sendung MTW
o) Some entries are available online here: *http://www.vireal.ethz.ch/news.html* (11 entries) including various online journals.
p) Demo of *Vireal Lab* at the exhibition CEBIT 2002 and at a local exhibition: Fa. Wohnbedarf, ZH; *http://www.wohnbedarf.ch*

Scientific/ProfessionalJournals

q) *SWITCH Journal*, 2/2002, 'Vireal Lab – eine innovative, multimediale Lernumgebung' (Folkers, Hanser, Khov-Tran)