A user-centered approach to computer supported teaching in classroom environments

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Introduction

How to use computers for teaching and learning has been research for decades now. The subject needs and gets attention from different research areas. New possibilities on how to use computers have to be explored from a computer science perspective. But of course also how to best teach taking advantage of the new media and its possibilities needs research. Both approaches are closely interwoven.

New methods in teaching demand new technological solutions and new possibilities in user interfaces open new ideas on how to incorporate the tool into the teaching process. Advances have to be made on both sides in close conjunction to gain results that are both fitting the challenges and feasible for solutions. The paper therefore gives an overview over existing eLearning applications and advanced user interfaces. Furthermore it proposes a new form of using computers in classrooms and explains how this new approach could be used to teach with computer support in classes. It clearly points out the advantages and shows open research questions.

State of the art

The research methodology applied for the presented work was building an overview on the state of the art and extract main challenges and hot topics for future research from the findings. The two main subjects involved from the computer science perspective are eLearning and advanced user interfaces. Other topics like artificial intelligence and computer networks are touched in different approaches and will be mentioned and explained as far as necessary together with the described systems and ideas.

eLearning

There are different possibilities of how a computer can contribute to teaching and learning. A very simple solution is to use a computer as playback media, taking advantage of the multimedia capabilities of the device. eLearning platforms hold additional features depending on the solution they are aiming at.

Most common is the form, which puts a student in front of the desktop based application, the eLearning program. The student learns whatever the content is without the involvement of a teacher, just by the presentation the software was designed with. Measuring a student’s success is usually done by evaluating multiple choice questions. Those answers are easily stored digitally and processed automatically. In this form the computer not only works as a teaching aid, but also assumes the role of the teacher.

A classical setup involves one computer for one person without any contact to anybody else or the environment. This situation is called 'isolated learning' [Gallenbacher 2005]. The disadvantage of not being able to resolve questions is obvious and was criticized in the past, i.e. [Euler 1987]. As the computer has to know how to deal with individual learning success, all possible problems have to be foreseen and countermeasures designed during content creation. Though some existing approaches incorporate artificial intelligence [O-Shea 1986], the success is limited. Teachers are not that easy to replace.

While common eLearning software evaluates the number of questions answered correctly in a multiple choice test and the topics of the successfully taught ones, there is much more
information one can gain from an eLearning contest. For example it is possible to record a learner’s behavior during the lesson: Does he/she move the mouse quite sure to one target or does he/she show uncertainty by moving up and down between questions? How long does it take to go from one lesson to another? Etc. Collecting all those information and evaluating it statistically shows interesting coincidences for learner behavior and learning success. So in fact it is possible to determine learner types and find better suited presentations according to their behavior. An application that is able to take this into account and change its presentation style according to the learners needs, clearly has more success in teaching than a platform, which presents topics to all students in the same way [Gallenbacher 2005].

Another approach uses eLearning systems for distance teaching [Lovis 1988][McDougall 1990][Davies 1993]. The idea is to bring school to a child's home. In the basic form the student is sitting in front of his/her desktop, alone, but then a teacher or other students are available using network connections. So it is possible to ask questions that are not foreseen by the platform and content designer. But still the capabilities of communication are limited to video conferencing and typing. Most significantly the communication between parties changes with the limitation in bandwidth.

None of the approaches described here focuses on using a computer as a teaching aid in a classroom. For this situation a new type of user interface is needed, as ideally multiple students work together at the same time with the same application. The next paragraphs therefore explain new possibilities in advanced user interfaces that are not based on the common desktop setting but on other presentation forms.

User interfaces

Thinking from a program point of view the easiest way to receive input is to prompt the user whenever this is needed. Of course this is not the best way a user is working with an application. For a user to benefit the most from using an application it has to be designed with the users needs in mind, not with the applications needs. Such user centered designs have been research for decades by now. [Engelbart 1963] [Schlungbaum 1997] A lot of different aspects have to be taken into account, like cognitive load and system response time to a user's input. Many different details are responsible for good user interface. But this is a wide research area in itself and the problems are not specific to educational applications. The following paragraphs just give an overview over different types of advanced user interfaces as they are and could be used in eLearning systems.

The most effort in presentation techniques and the most freedom in interaction are given by user interfaces from the domain of virtual reality. Used display system technology goes from common PC desktops to projection based systems and head mounted displays. [Sherman 2000] Depending on the setup the user is more or less immersed and believes in this artificially created virtual reality. Images are displayed in 3D and give excellent spatial impressions.

A closely related area is the domain of augmented reality. Here real objects are superimposed with a virtual reality simulation. To a user both, the real and the virtual information are visible at the same time. Therefore this is an excellent technology for teaching purposes. The user is actually able to see and interact with the real object, just as in real life, while getting guidance through 3D visualization.

Quite often this technology is used in conjunction with a head mounted display, but this is not necessary. Other technologies like half transparent mirrors and projection screens can be used just as easily. The user still has to wear glasses as this is a prerequisite to gain 3D viewing of virtual presentations, but these glasses would be quite normal in appearance and weight. For example in [Bimber 2001] a construction of four half-transparent mirrors is used to overlay virtual data over real objects. This ‘virtual showcase’ has been successfully applied in museums to explain complex cultural or scientific content to visitors. [Wendler 2005] A quite similar approach – a ‘reach-in display’ – allows direct manipulation of the real object behind the glass.
Other directions of user interface research leave the big static setups behind and focus on small, portable devices. Handheld PDAs (personal digital assistant) and smart phones can be used to access data everywhere and interact with the environment wherever I am. Therefore, this area is called ubiquitous computing [Weiser 1993]. For educational purposes this has an interesting application if you think of students doing their homework, but in a classroom there is not much mobility for the user – though the devices are still non-obtrusive and nowadays everybody owns a PDA or phone.

Computers as teaching aid in classrooms

Using computers as a teaching aid in a classroom situation is a different aim than using a computer for distance learning or to replace a teacher. Here a computer does not have to foresee all difficulties a student might have. Moving an eLearning system like the ones described in the previous section into a classroom is a waste of resources. There, a teacher is already present and can do a much better job at teaching children than available software could possibly do. For a teaching situation in class a computer should be a teaching aid which deals with a group. It should help teachers in their job and not aim at replacing them. Also there is no need to bind student communication to typing text or video conferencing. On the other hand, it is possible to support interaction in class not only with the aim to teach science or culture, but also with the aim to teach soft skills like presentation or team abilities. A different - user centered - approach with advanced user interfaces has to be the base of a classroom suited eLearning system.

This approach leads to a different set of features that need to be addressed:

- As the system should be used in Class, a static setup is perfectly suitable and one can take advantage of the greater possibilities of such a setup: There is no need to restrict computing capabilities to small, portable systems. And achieving 3D stereo perception for the students (if desired) is easy in a static setup and very helpful in many presentations.
- The group size must be determined carefully for this platform. Learning in groups – though often desired – is more difficult with increasing group size. Also the technical possibilities (size of the presentation/interaction area, computing power needed per user, conflict resolution on input from multiple users, etc.) depend on this decision. From a technical point of view a four-user setup was already implemented with a showcase in museums. [Wendler 2005]] From an educational point of view the best group size still needs to be researched.
To not lose the advantages of teaching in groups the system should support multiple users at the same time. Ideally the users share one workspace and therefore can interact and collaborate on one user interface either by pressing buttons that are integrated into the platform or else by reaching into a common area.

A teacher should be able to easily switch in when called by the students. So whatever the students see should be easily perceivable by the teacher and whatever the students do to interact with the system should also easily be done by a teacher if he/she chooses.

The system should be built from affordable components. A setup that involves an expensive immersive 3D theater setup is not applicable to schools – neither now nor in future.

So one possible implementation of a classroom teaching platform would be a variation of the successful virtual showcase, which – by rearranging the half transparent mirrors and monitors different – would combine the advantages of a multi user platform and a reach-in display. For homework an ideal extension would be a laptop or another portable device. This would of course not deliver the same form of presentation, but it would allow a student to take home digital content for reviewing or extension of essays. The following paragraphs describe challenges and possibilities on how to use such a teaching platform in class.

**Application Scenario 1: Process visualization**

This example deals with teaching students about the human digestive tract. The teaching platform here serves as a visualization tool for a biological process – similar to a movie which runs in 3D in a showcase. Dynamically generated images, which could be watched in overlay with a real prop, illustrate the digestive process and adjust the movie’s ‘story’ according to the student’s input at any time.

Imagine the teaching platform with a plastic model of a human torso inside. The torso shows the organs involved in digestion. The platform is used by a group of students while the rest gets other tasks on the same subject. Later on the group tasks can be changed so that every student gets a chance to work with the teaching platform at some time. The presentation and the level of abstraction have to be carefully chosen according to student age and prior knowledge of the subject. So the teacher has to be able to configure the presentation before the class starts. For example the platform could project names onto the organs visible inside the torso in case it is used for teaching younger students who don’t know about those organs yet. In higher classes those names could be taken off as they provide information that would be already familiar to the students.

Regarding the digestive tract the plastic prop would show the organs and their arrangement inside the human body. Furthermore, the simulation would be able to give information about every visible organ when it is selected by the students. The students would be able to virtually ‘dissect’ the whole system and take a look inside, but also to take a look at running processes. So on button press the system would be able to ‘feed’ the plastic torso with a specific food and then let the students watch the process as it runs. Once again the freedom of student interaction has to be determined by a teacher in advance. So it might make sense for higher classes who already know about the difference in digestion of fat, carbohydrates, and fibers to allow the students to choose what is actually fed and watch the different outcomes. Younger students might only get the chance to feed a preset food and therefore watch one example digestion.

One task given to the students could be to write down how the digestion process works. Or else – in the mode where the students get to choose different categories of food – the task could be to compare the different digestion processes. Also a teacher could configure the platform to simulate constipation or another disease. Then the students had to experiment which food would be the best in dealing with the anomalism and maybe try different medications to see what happens. Again this should result in writing down what the students learned while experimenting with the simulation. In case the assignment of writing an essay would be a homework the platform could generate snapshots of the simulation at any time the students or the
teacher wants and those images could be watches at home either as print outs or else digital on a PC or laptop computer.

**Research challenges in process visualization**

For the described scenario several research topics have to be addressed by computer scientists together with teachers or educational scientists. First of all the scenario is based on a visualization of something that is usually not visible, something abstract. This means suitable symbols have to be found and a good visualization examined. This is not trivial, as it is not trivial to construct a good scientific drawing from a photograph. Furthermore, the digestion takes more time in real life than what the teaching unit should take. Therefore some time control needs to be implemented. But then questions on how it should be operated arise: should only the teacher be able to set some time frame? Should students be able to fast forward and fast rewind the show according to their demands? Should the show jump from event to event or else show a behavior in time? Should it take the same fraction of time for single steps as in real life and just speed up everything by a constant factor? Also the envisioned platform is a ‘multiplayer game’. That means that more than one student will deliver input during the lesson and this input might be conflicting. There has to be researched how to best resolve these conflicts.

From the educational science point of view different but surely equally important questions arise: How much self-dependence and how much help should be given to students to fulfill a task? Should students for example be allowed to influence the visualization according to their taste or would they easily miss important details in doing so. Are the symbols used in presentation dependent on the student age? How much freedom for interaction with the platform should be given to the students and where should input be restricted? In the extreme the platform could be used as a highly interactive tool as well as just for showing a movie. To keep a students attention it is surely an advantage to provide an interactive tool, but it might also be asked to much of a student. Again: this is a multiplayer game. So one might find out how this affects the teaching results.

**Application Scenario 2: Construction with guidance**

The second scenario is oriented on a more interactive task: the construction of molecules using a molecule toolkit inside the teaching platform to understand the principle of isomers. While the first example used the platform to show an interactive movie, the second one is more oriented on students performing a task together, using and modifying the physically touchable props.

Imagine a chemistry class in high school. The students already know about molecules, about carbohydrates and about chemical bonds. Now they have to learn about the concept of isomers, i.e. molecules which are built from the same set of atoms but with different structure in space and which gain their specific physical attributes from their structure. So in this example the teacher gives the students the empirical formula of Hexan \((C_6H_{14})\) and explains to them that obviously you can arrange these atoms in more than one way. He explains about conformation, i.e. that some appearances you can gain from rotating part of the molecule around some binding and what you get is still the same isomer. Then the students get the task of building models of all isomers of Hexan.

The teaching platform is now equipped with a toolbox that contains black balls as carbon atoms, white balls as hydrogen atoms and rods to connect them. Students have to reach inside the showcase area and construct all 5 isomers that can be built for the same empirical formula. When the students claim one model as being finished they press a button and the teaching platform collects the position of all the atoms in the molecule model. If it recognizes a new isomer, the platform displays a virtual copy of the real model, builds a constructional formula out of it, and supplements name and boiling temperature for this isomer. This information is then stored aside for later use.
If the new model is just a conformation of an already found isomer the platform highlights the previously stored image and shows in an animation the necessary rotation to transfer the newly found into the stored configuration. Once the students found all 5 isomers the platform signals completeness and the shown information can either digitally recorded or else printed out to serve as background information for homework. A suitable homework task for the students would now be to sort the isomers according to their boiling temperature, research the reason for the variation of up to 20 Celsius degrees, research the rule how isomers are named, and write everything down in an essay.

**Research challenges in construction with guidance**

The described form addresses a different usage of the teaching platform. Once again questions on didactics in using such a media arise: Which is a good group size for a task like that? Should students work together on the same model or everybody on a different model at the same time? Should it be a competition between the students (who is fastest to complete all models) or should it be a team effort to collect all isomer models? Should the platform give hints to students if they can’t find one of the variations? What would be the criteria on when to give help and what would be a good help? Will there be conflict situations, i.e. one student claims a result which the other one doesn’t believe is correct?

At the same time this version of direct interaction with the teaching platform brings new challenges on the computer science part: What should be interacted with? Which technological solution will be found for implementing the desired form of interaction? How can a computer react in case of a conflict situation? How can scenarios like the described one easily be implemented by non-computer scientists?

**Conclusions and future work**

Literature study on concepts for eLearning shows, that so far available eLearning platforms are not suitable to be used in classrooms. They focus on replacing teachers or using computers in distance learning and not on integrating the new media as an advanced teaching aid into every day’s environment of students and teachers. Taking a look at modern user interfaces as well as concepts of user centered design, and comparing possibilities of available technology to the desired features for a classroom eLearning solution, leads to a new design. Starting from a design, which has been successfully introduced into museums – the ‘virtual showcase’ – a static augmented reality teaching platform could be adapted to the specific needs in classrooms. Creating content for this new teaching platform and using it in class is a new challenge for educational scientists as well as computer scientists. The two presented examples show possibilities how to use the platform but also open questions that need to be researched. Most of all, the question of how students and their teacher best benefits from the new possibilities need to be deeply researched. Only by closely interwoven cooperation of scientists from the participating research areas answers can be found for this highly interdisciplinary topic.

**References**


Summary

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Computer supported teaching and learning, though researched for decades, focuses on using common desktop PCs in ‘point and click’ applications. Existing solutions are not suited for application in classrooms, the everyday environment of teachers and students. Advanced user interfaces open up new possibilities. Especially augmented reality allows annotating real props with virtual information in a user centered design approach. A modified version of an existing display system, which has been successfully introduced into museums, leads to using computers as a modern teaching aid in class, allowing groups of students to interact and collaborate.

The paper presents two scenarios which demonstrate how this platform could be used for teaching in class. One scenario deals with the visualization of a biological process (digestion), the other one with constructing models of carbohydrate isomers. Both scenarios demonstrate the advantages in using the new approach and point out arising research questions. Due to the interdisciplinary approach these questions need to be answered by educational scientists and computer scientists in close conjunction.

Keywords

eLearning, User interfaces, Augmented reality