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e-Chemistry for K12

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K–12 students are great candidates for e–learning, but for different reasons than adult learners. e–Learning works at the K–12 level if focus is on "how does technology enhance the learning process". This paper presents a conceptual framework and a structured set of work strategies applied in the development of educational resources within the e-learning project "Looking forward future - e–Chemistry", a project dedicated to introducing ICT tools to the K–12 chemistry teaching staff in Romania. It represented a tremendous challenge for our team, by its scale, but mostly by its specificity. The paper also provides reflections on the efficacy of the design process that resulted in formation of the design principles applied within the framework of the project.

1. Introduction

E-learning is an emerging but rapidly growing phenomenon in K–12 education. The rapid growth of e–learning in the K–12 education environments is generating significant insights about educational practice and new ideas for how e-learning can reshape cognition and support knowledge acquisition. Thus the education community can fundamentally begin to reshape formal education and improve the effectiveness of schools (Kozma 2000). K–12 students are great candidates for e–learning, but for different reasons than adult learners. First of all, this is because today's K-12 students represents the digital generation, being digital natives (Smith et. all, 2005). They live in a world in which digital technology is part of the texture of their daily lives (SEG Research 2008). They have never known a world without digital technology. Technology is their native language and they expect to use digital technology in school. Studies show that, besides the well known advantages of e-learning, for K-12 students, it encourages independent learning and develop metacognition and the culture of reflection, which also impacts on student academic performance.

The human resources project "Looking forward future - e–Chemistry" is running in Romania since September 2010 and is expected to end in August 2012. e-Chemistry is dedicated to introducing ICT tools to the K–12 chemistry teaching staff in Romania, and familiarization with teaching techniques based on dynamic and interactive multimedia electronic environments. The project is distinguished primarily by size (target group of 2250 people) and spread (implemented in 91 locations in 41 counties, both in rural and urban areas), but also by the nature of interactions between the groups involved in implementation (multimedia and content developers, specialized trainers, teachers). Also, the project stands out through the ways used for identifying methods of implementing the educational content into rich interactive multimedia applications, in order to emphasize the specificity of the chemical content. The digital content uses an original approach for many chemical subjects and it is recommend for

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partial or integral use in class teaching. Thus, this project aims not to bring an alternative way to traditional learning, but to create a tendency to shift from traditional learning to e-learning in chemistry, in K-12 educational environment.

2. Conceptual framework

Unfortunately there is still not yet a standardization of development principles of multimedia instruction and education systems. There is a trend of content developers to create environments with spectacular components rather than educational ones, what ultimately proves to be a counterproductive practice. The efficient use of technology-pedagogy relationship in developing multimedia instruction and education systems is, ultimately, a matter of usability. Usability concerns the measure of a product's potential to accomplish the goals of the user. There are different levels of usability focus in developing multimedia systems, spanning from navigation to the use of colours, text, and graphics. Usability and particularly, learner friendliness, is one of the most neglected areas in e-learning design and implementation. Too much focus on developing the application and not enough focus on the implementation is also a major problem. The main problem is that developers think the job is done when the application is developed. So, even if the applications have a high quality, the usability can be low. Increasing the quality of both content and functionality of the application provides increased value for users of e-learning products. Addressing usability issues guarantees that the learning environment doesn't become a barrier to learning (Kobbenes et. all 2003). Consequently, learners are able to work with minimal distraction or frustration. An important dimension of usability in developing multimedia instruction and education systems relates to the degree of planning and structuring of learning activities. Different learning contexts need different types of applications in order to support the goal for the activity. For example, a multimedia application that is usable in order to support the need for quick help may not be usable in order to support learning in a continuous perspective (Kobbenes et. all 2003). The content may be similar, but the context is different. This has important implications for usability, because the context partially determines how a given application will be used. Consequently, to improve usability, analysis of the learning context is vital. So, besides considering technological issues, usability principles must rely on an educational theory, somehow driving the designer in developing suitable applications for the given educational context. Such an educational theory is constructivism, which is now one of the dominant strategies used in education and is considered the ideal approach for e-learning. This theory stresses that learning is a personal process, characterized by individuals developing knowledge and understanding by forming and refining concepts. This leads to the view that learners should be assisted in some way to construct and refine concepts in personally meaningful ways. From a constructivist perspective, learners need to be encouraged to take responsibility for their learning, while generating a sense of ownership of learning experiences (Costabile et. all 2005). The constructivist view of technology-supported learning emphases that technology should provide support to the learner, making their own way through the e-learning environment, constructing knowledge and meaning through interaction and through the use of self-reflection.

Understanding the target audience will help define the communication style of e-learning environment. Also, learning is carried out in social settings, by adopting ideas, ways of thinking and how things are done. Introduction of new learning methods like e-learning will normally alter the existing learning culture. Not only what we learn, but also how we learn becomes a major issue. All our previous projects of e-learning have been addressed to adult learners, so that, to address usability issues we have not actually reported to the principles of pedagogy, but to those of andragogy (andragogy consists of learning strategies focused on adults, as pedagogy is focused on children). Developing e–Chemistry, for the first time we had to take into account the differences between child and adult learners. Younger learners have a lower degree of the autonomy needed to learn independently and less internal focus of control and intrinsic motivation to persist in their studies. Constructivist theory suggest that children may lack the rich experiences needed to construct knowledge of the world around them and would benefit from the scaffolding that e-learning environments can be tailored to provide. Thus, starting from these concerns, development and deploying of e-Chemistry was achieved by applying the principles of usability in a constructivist approach adapted to the K-12 learner.

3. Examples of good practice in terms of usability

First of all, in e-learning, usability is defined by the ability of a multimedia object to support or enable a particular concrete cognitive goal. Cognitive Load Theory (CLT) states that working memory is limited in its capacity to selectively attend to and process incoming sensory data (Sorden 2005). CLT is concerned with the way in which a learner's cognitive resources are focused and used during learning, suggesting that for instruction to be effective, care must be taken to design instruction in such a way that is does not overload the mind's capacity for processing information. The implication for multimedia and education is that if we only have a very limited amount of information processing capacity in working memory at any single moment, then instructional designers should not be seduced into filling up this limited capacity with unimportant, but flashy content in a multimedia instructional unit. Unnecessary activities should not be created in connection with a lesson, that require excessive attention or concentration that may overload the working memory and prevent one from acquiring the essential information that is to be learned. This is an important rule in any form of instruction and education; also, it is an essential rule in multimedia instruction and education because of the ease with which distractions can be incorporated. The instruction should not be designed in a way that causes the learner to have to divide attention between more tasks. It is well known that young learners have less internal focus of control; thus development of multimedia applications for K12 students must take into account of these features. The split-attention problem arises sometimes related with the way of information presentation in a multimedia application. There are situations in which presentation of a theoretical concept through a static graphical item requires a high density of information. In physics and chemistry such situations are quite common, for instance when, for understanding the studied process, punctual aspects must be presented macroscopically, but also the microscopic intimacy of the process is really useful. Presentation of the two categories of information together, in the same image, impedes the process of understanding the phenomenon, while presenting in different images dilutes logical connection between two aspects. In the frame of e-Chemistry we have faced in many cases need for simultaneous presentation, in the same multimedia application, of both macroscopic and microscopic aspects of the studied process. We have adopted a simple and elegant solution that, according to feedback collected from students, proved to be a real success. This is why we have used it excessively. When running the application, the user can watch the evolution of the process at macroscopic level; when he/she is quite familiar with it, he/she can, by moving the instrument available permanently on screen (a virtual magnifier) in a particular simulation area, to visualize the evolution at the microscopic level, only for that area (see Figure 1).

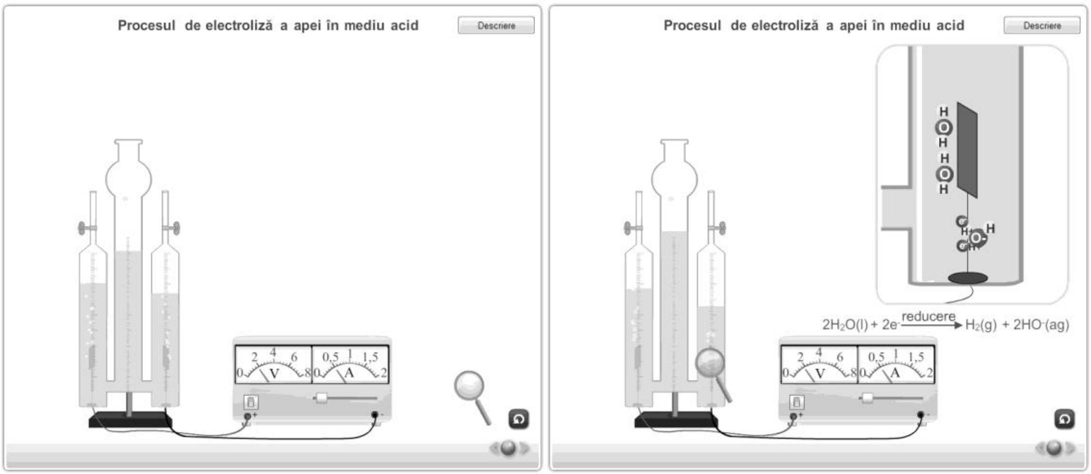

Figure 1. Visualization of the evolution of the process at macroscopic and microscopic levels

Error prevention is also a good usability practice. According to specialized studies, existence of errors in multimedia applications leads to loss of credibility, even at a subconscious level. Critical spirit is more present in young learners than in adult learners. The former are less tolerant to the mistakes of others. Thus, the design is required to predict all possible states that can be triggered by the user. Even unlikely or strange situations should be considered. Unfortunately this task is even harder to accomplish when user input parameters are quite a few. We faced such a situation in e-Chemistry, with an application that simulates a titration. The relatively large number of parameters decided by the user, as well as the mathematical models complexity (staying behind the simulation) may lead to configurations prone to errors in simulation. We have adopted (not only) for this situation a solution that has proven very effective; namely, we designed a sequential progress, wizard-type, where parameters are entered in several steps, each step being to a certain extent influenced by the decisions taken in the previous one. For instance, titrant and titrand can be chosen only at step 2, from a list filtered by the option made at step 1, when choosing the titration type. Thus, the temporal split of application may have consequences in the delimitation of those elements whose combinations represent sources of errors.

Another critical factor that must be taken into account in developing educational multimedia materials is pacing. The pacing principle states that better transfer occurs when the pace of presentation is controlled by the learner, rather than by the program. Learners vary in the time needed to engage in the cognitive processes of selecting, organizing, and integrating incoming information, so they must have the ability to work at their own pace to slow or pause the presentation, if necessary (Sorden 2005). If the pace of the presented material is too fast, then these cognitive processes may not be properly carried out and learning will suffer. Also, if the pace is too slow, that can lead to student irritation, with negative effects on the educational process. It is well known that young learners have a higher degree of irritability in relation to technological functionality problems, and they are willing to give up more quickly than adult learners. A technical solution at the reach of multimedia developers is the possibility of attaching a slider to interactive applications, through which the user can pause, rewind, and fast-forward the application. In e-Chemistry we have tried to use this technique in as many multimedia applications. An even better practice, however rarely used, is placing an interactivity instrument aimed to set to speed of application.

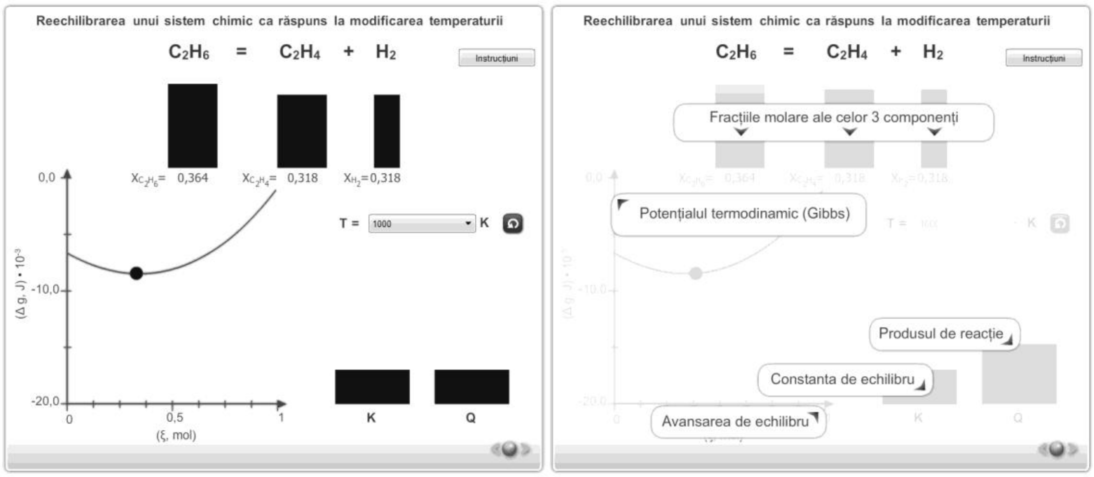

Figure 2. Information presented in a transparent layer which overlaps the main content

Much has been said in this paper about the role of usability in minimizing sources of distraction of the user in the educational process. One of the current sources is the degree of coherence of the material. More elements shown in a material are not necessarily beneficial for learning, leading the learners to focus away. Using unwarranted visuals, text and sounds are harmful for learning process. The “Las Vegas” approach by adding glitz and games to make the experience more engaging is certainly much appreciated by young learners than by adult learners, but it is not helping, being distracting and disturbing the learners’ organization of information (Kobbenes et. all, 2003). Thus, the developer of educational multimedia applications for K-12 students must resist the natural temptation to endow these applications with too much ornament that can confuse the learner. On the other hand the lack or the insufficiency of some absolutely required elements can create user frustration (especially for young learners, that, in the educational process feel the need of a more consistent tutoring system) with equally negative consequences as those caused by distraction. Consequently, finding technical solutions for achieving an optimum is the main goal. In this context, we faced, for instance, with the question of virtual equipment description for certain simulations in multimedia applications. We searched for ways to make these descriptions discrete enough that they do not load the application screen, but also sufficiently accessible and easily retrievable whenever appropriate. One of the technical solutions identified in this respect is presented in Figure 2. Thus, there is a button always present on application screen which can bring in any time of its dynamic run the necessary information for describing the equipment. This information is presented in a transparent layer overlapping the main content of the simulation which will fade in the background. For expediency, this layer stays open only as long as the user keeps pressing the button which calls the layer.

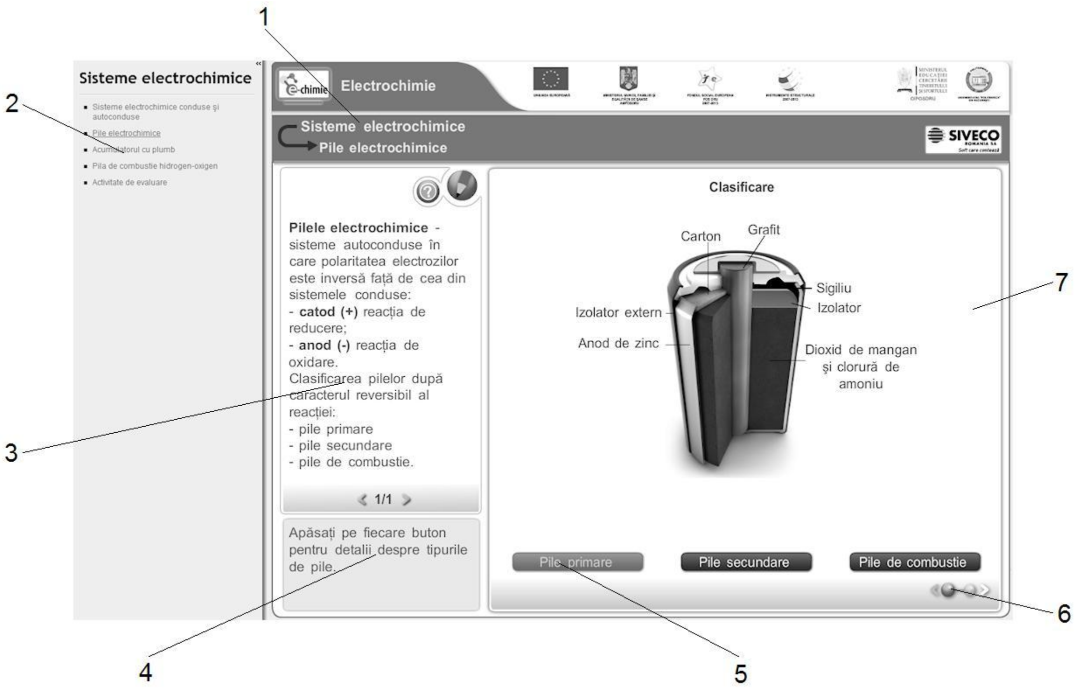

Figure 3. Principles of usability applied to a navigational system of a multimedia instruction system – the architecture of the interface of the system: 1 – Indications about the place in system; 2 – Table of contents; 3 – Information broadcasted through text channel; 4 – Instructions for use for multimedia application; 5 – Elements for navigation within the multimedia application; 6 - Elements for navigation within the chapter; 7 – Multimedia application

A particular aspect of usability is learnability. Learnability is a measure of the degree to which a user interface can be used for quick and effective learning. In developing interactive media, the design of the user interface, system architecture and navigation tools are often left to chance. An instructional interface is especially effective when the learner is able to focus on learning content rather than on how to access it (Costabile et. all 2005). Multimedia content developers must be consistent and follow standards in layout and content organization. Consistency ensures a predictable environment for learners. A standard look and feel for the course must be created. In terms of organization, the content and objects should be meaningful to the user. The colours should be used wisely and the application must not rely on colour alone to communicate a message. As it has been mentioned above, the young learner is more dependent to a tutoring and support system, so this must be, in this case, more consistent and coherent. Here are some usability best practices in this respect:

- The system should always keep users informed about the application's status, through appropriate feedback within reasonable time. This can be done through a visible indication by which the user is notified about the place he is in the application, as well as this place is related to other components available in the application. Thus, the current page number, number of pages viewed, current page address in the application architecture, the current chapter name, etc. can be specified. There is also useful general information about applications, such as status updates.
- Navigation elements must ensure fast user access to any segment of the application at any time. The existence of multi-level menus is welcomed, given that they reflect the application architecture.

Links must be identified to express clearly if they represent access to instruments other than usual content segments.

- Excessive linear navigation must be avoided. For instance, the user should not go through substantial amounts of content to reach a certain place in the application. It is a good idea to include an index and search function for extensive multimedia applications.
- The system should keep users informed about progress tracking.
- Users must be provided with alternative printer friendly content.

Figure 3 illustrates some of these principles, applied to the interface of the interactive educational system developed in the framework of e-Chemistry project.

4. Conclusions

The feedback collected from over 2000 participants within e-Chemistry project pointed out the strong and weak points of the project and suggested directions for content optimization, assuring the program sustainability. It showed that including multimedia as part of K-12 instruction can significantly enhance student learning achievements. Thus, the conclusion is that multimedia learning technology should occupy a prominent place in the 21st century instructional toolbox, as research has shown it to be a significant tool for student engagement. e-Learning has the potential to facilitate assessment of individual learning needs and ongoing feedback for improved outcomes.

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