Using Enhanced Learning Technologies to Teach Nanoscience Research Techniques to Postgraduate Physics Students

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Abstract

Progress in nanoscopic materials research requires observation and understanding of the molecular arrangements of materials by using capital-intensive equipment such as Electron Microscope (SEM and TEM), and other types of spectroscopy. There is also a great need for teaching data analysis and essential technical skills for experimentation using complicated analytical instrumentation capable of providing information about nanoscale physical, chemical and functional properties. Teaching for characterisation of these new materials and devices to fully understand the physical, structural and functional properties is of great importance. This paper addresses this demand, which led to the development of the web-based multimedia-teaching package called *Nanolab*. The paper illustrates the experiences of implementing *Nanolab* as a pilot site utilising:
(a) a web-based technology for delivery;
(b) text, graphics, sound, *Authoware*, *Flash MX* for interactivity;
(c) a number of video links to specific laboratories; and
(d) a web-based discussion group set-up to stimulate cooperation and problem solving. This paper describes the design and development of *Nanolab* teaching/learning package from both pedagogical and technical perspectives.

Background and motivation

Constructivist learning is the underlying theory for defining the learning process. ‘Nano’ derives from the Greek word for dwarf. ‘Nano’ is a prefix meaning one-billionth, so a nanometre is one-billionth of a metre. Nanoscience generally refers to the world as it works on the nanometre scale, from one nanometre to several hundred nanometres. To put that scale of measurement into perspective, a human red blood cell is about 7,500 nanometres across, and one nanometre is roughly 10 atoms wide. Industry recognises the extraordinary potential the nanotechnology field offers in the form of bulk, composite, or coating materials to optoelectronic engineering, magnetic recording, ceramics and special metals engineering, bioengineering, and micro manufacturing (Siegal 1998). The possibilities of nanotechnology are endless. Entirely new classes of incredibly strong, extremely light and environmentally benign materials could be created (Lane 1998).

Current status of nanotechnology education

Nanotechnology’s rapid growth provides challenges to our academic communities and they are reacting slowly to prepare the workforce for emerging opportunities in nanotechnology. No specific training programme exists within the Irish education system and students who are engaged in research in nanotechnology gather their information on nanotechnology from books and the Internet. A survey carried out for the purpose of this study in the University of Limerick (2001) revealed 96% of nanotechnology related research students believed there was a need for a web-based teaching package in Nanoscience materials research. *Nanolab* was developed to provide up to date information about facilities and experimental techniques, to reduce the burden on supervisors, to fully utilise the facilities created by external funding and to attain excellence in research. The system is a web-based teaching/learning package that uses the Internet as its platform for delivery. Internet applications offer the potential to combine the advantages of the traditional and new education methods when sufficient bandwidths are available. Web-based learning has the following advantages:

1) resources are circulated across international boundaries and cultures;
2) the Internet enables learning in *‘own space, own pace, own time’*; and
3) the Internet contributes to bridging the gap between educational needs and provision of educational resources. (Crosby and Iding 1997)

Design and development of *Nanolab*

The underlying educational theory for *Nanolab* is Piaget's theory of Constructivism. This assumes the learner takes control of his/her own learning, by constructing the knowledge building on previous experiences. *Nanolab* is consistent with this theory as learning starts with issues around which the students are actively trying to construct meaning. The package focuses on primary concepts rather than isolated facts. Since education is inherently interdisciplinary, the package measures learning by making the assessment part of the learning process, ensuring it provides students with information on the quality of their learning. Currently, there are no widely recognised models of web-based design. The field of instructional design (ID) is in a state of rapid change (Wilson 1997). Existing models of instructional design for both traditional instruction and for software instruction contain elements that are suited to instructional design for web-based learning.

For the purpose of developing *Nanolab* it was necessary to draw from existing models of instructional design when designing the web-based teaching package. This approach allows the development of both the technological solution and the pedagogy required to make a useful adaptive learning system. The author adapted Stoner's framework (Stoner 1996) and McNutt's lifecycle (McNutt 1991) and merged their models with educational theories to create one model that would then be the basis for the implementation and development of the teaching/learning package *Nanolab*. This model promotes a step-by-step procedure. The first step recognised the potential for development in the initiation phase through preliminary assessment of the situation. This called for appropriate research of the relevant literature, which led to the definition of course aims and objectives. The next phase analysed the required level of integration including content inclusion and the appropriate selection of learning technologies. This enabled the progression to the design phase, which considered the learning activities, course structure, interface design, media design, interaction design, and assessment integration. This was then implemented and evaluated in a cyclic format until the most appropriate system was devised.

Initiation

Current college courses in Ireland deal almost exclusively with molecules and macroscale phenomena with nothing in between. Most universities, even some highly recognised research institutions, do not even have a basic course in fundamental surface and colloid science. Survey investigations in University of Limerick (2001) revealed a demand for a system that would enhance the research of materials at the nanoscale range.

Definition phase

The explicit definition of the course objectives for *Nanolab* satisfies a number of different requirements for the later development of the project, from providing a number of metrics one can measure the implemented system against to provide prospective users of the system with an explanation of how the implemented system can benefit them. This will give them measurable learning objectives.

By using *Nanolab* the learner will be able to:
1) define and describe the nanoscale range;
2) describe nanostructered materials by classification, importance and properties;
3) reference articles on Nanonews internationally;
4) locate and contact researchers doing similar research at the University of Limerick;
5) evaluate the techniques and analysis of the Scanning Electron Microscope, Atomic Force Microscope, Nanoindentation and Nanofabrication;
6) explore the Scanning Electron Microscope and Atomic Force Microscope in virtual reality mode; and
7) observe slideshow photographs of technique samples and of the University of Limerick.

The audience that the system *Nanolab* targets are postgraduate students at the University of Limerick who are engaged in research on materials in the nanoscale range. The audience definition was compiled from online survey results of students currently researching nanomaterials and first hand knowledge of the group. At present there are approximately 20 students researching materials in the nanoscale range. They breakdown into the following categories: Thin Films, Electrochemistry, Biomedical, Magnetic Materials, and Surface Science. The researchers are based and affiliated with different departments including Physics, Chemistry, Engineering, and Materials Surface Science. The group as a whole are computer literate and have access to a computer each day.

Analysis

Nanolab adopted a hybrid structure, organising the content on the server in a combined hierarchical/network structure. The root of this hierarchical tree is the main navigation menu; the sub-sections comprising of a network of related components are directly accessible from this menu. Researchers searching for particular information will yield the best result from a broad menu system with fewer levels to the hierarchy. Information, demonstrations and illustrations were organised in ordering discrete components into a coherent flow chart detailing how the component sections interrelate to form the modules. The system employs an overview system to simplify site navigation (See Figure 1). The approach employed by *Nanolab* resembles a traditional feedback loop, by using a continuous improvement/ refinement process to integrate the technology into the university environment.

Learning technologies (LT)

Local Area Network (LAN) generally refers to a high-speed and fault tolerant data network. LANs are capable of transmitting data at very fast rates. It is at present the most popular networking protocol, used by approximately 80% of networks worldwide (Woodward, Gattuccio and Brain 1999) The LAN speed at the University of Limerick is 100 MB s-1 Ethernet LAN. This is the network structure used in *Nanolab* to allow researchers to access the course materials. *Macromedia Authorware* was the graphical authoring tool selected to produce the web-based executables for distribution of *Nanolab* to it intended audience. Animations, illustrations and possible interactions were implemented as *Flash* animations, using a browser plug-in to view the resulting program.

Interface and interaction design

To achieve consistency, the system employs the following conventions. The main menu is accessible to the user at all times and sub-sections open within this frame. This simplifies navigation for the user (See Figure 2).

Figure 1 is an overview system to simplify site navigation while figure 2 illustrates the user interface design used to navigate around *Nanolab*. Each topic starts with a new display and is labelled accordingly in the screen title. Consistent key actions are offered to navigate through the site, and forward and reverse progression are available. Global control is provided in the form of help, glossaries and termination is available at all times. There are a number of different interactions available to the researchers; these vary from direct email, to more involved possibilities such as online discussion forum. The researchers are all based at the University of Limerick, and so are in close proximity. The use of discussion forum will be to stimulate lively discussion and provide alternative views in aiding fellow researchers. For the purpose of contacting supervisors, email should prove an adequate means of communication.

Figure 1. Main menu

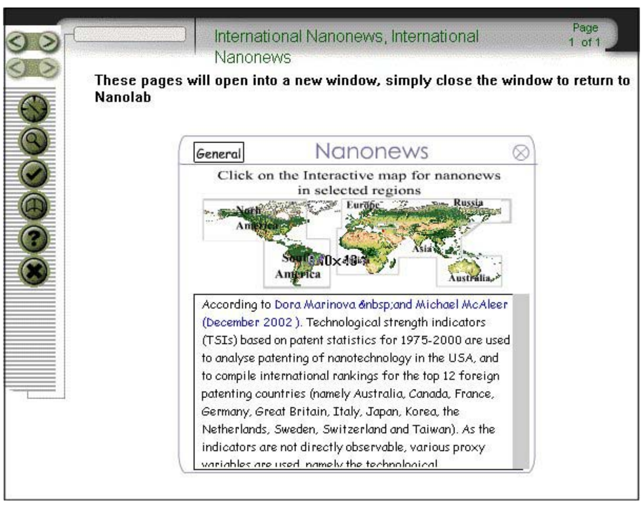

Figure 2. User interface design used to navigate around *Nanolab*

Implementation

The package is presented and subdivided into ten sub-sections:

Sub-section	Description
1	Describes the nanoscale range using animations and text (See Figure 5 overleaf).
2	Outlines Nanostructured materials by definition, characterisation, size, classification and importance.
3	An interactive map illustrating international Nanonews and research.
4	A database of the research students, projects and equipment at the University of Limerick.
5	Fabrication techniques and details including lithography and synthesis.
6	Techniques and Analysis of Scanning Electron Microscope, Atomic Force Microscopy and Nanoindentation (See Figure 4).
7	Slideshow presenting researchers samples and photographs (See Figure 6 overleaf).
8	Virtual Reality simulation of the Scanning Electron Microscope and Atomic Force Microscope.
9	Interactive Discussion Forum
10	Interactive online quizzes: evaluates the researchers learning, and instantly tabulates their score.

For the purpose of this paper examples of the sub-sections have been displayed independently of the user-template to conserve space (Figures 3-5). Researchers will log-on to the system and can work collaboratively with their peers through the use of the discussion forum. Hypotheses can be constructed and challenged, references can be shared, and they can discuss their approach and evaluate it against the work of others. Researchers can be encouraged to self-assess through the use of the online quiz after exploring the techniques and analysis sub-section. Feedback to question gives encouragement when a response is correct and an explanation when the response is incorrect.

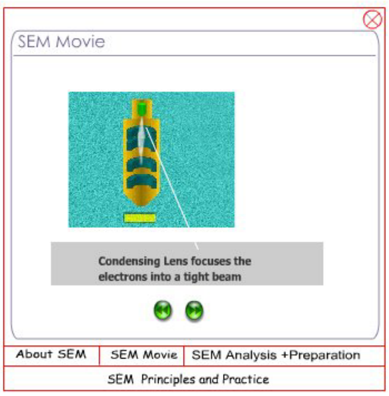

Figure 3. Movie created using *Flash MX* showing how the Scanning Electron Microscope works

Figure 4. Interactive animation of an oak leaf demonstrating Nanoscale range

Figure 3 illustrates a movie created using *Flash MX* about how the Scanning Electron Microscope works and Figure 4 demonstrates the Nanoscale range using an interactive animation of an oak leaf. The system will function as a source of information by providing a glossary of commonly used terms and acronyms used in nanotechnology research, a database of equipment and researchers at the University of Limerick and a reference sub-section of *Nanonews* internationally. The Virtual Reality (VR) subsection offers environments in which the learning is more realistic and in context. This enables researchers to use attractive and user-friendly interfaces, which encourage use of the equipment and techniques and greatly increase user involvement. The use of multimedia technology in *Nanolab* facilitates multi-sensory education by allowing users to interact with the system and receive not only textual, but also video or audio feedback. Video, audio, animation and images also make possible the production of highly memorable, illustrative explanations of concepts (Crosby and Iding 1997) This further enhances interaction and makes applications more intriguing and appealing to the user and lead to better knowledge retention on the part of the user.

Figure 5. Explains and illustrates samples collected by researchers using Atomic Force Microscopy.

Assessment

The course assessment deals with evaluating the actual course based upon the feedback information from the user to improve the system. This will be achieved by implementing an online survey for researchers to communicate information about the system. The evaluation of the package will be an ongoing process using a variety of methods such as field trials, focus groups and expert panels and this will be an integral part of the system development. This will provide useful information on user-friendliness and ease of implementation as well accuracy and currency of content.

Course management

The final section of the development of the system *Nanolab* deals with the management of the system once it is fully implemented and deployed. There are a number of different areas of responsibility that need to be considered: these include the contents update for the various modules within the system, updates to the various components of the overall management system, information module updates, and upgrades. A system of shared responsibility will be coordinated with supervisors updating the system.

Conclusions

The system *Nanolab* was designed, developed and implemented based on an adopted educational model by Stoner's (Stoner 1996) and McNutt's lifecycle (McNutt 1991). The underlying learning theory for the system is Constructivism. For the system *Nanolab* course assessment and feedback will be of primary importance in improving and tailoring the system to best suit the needs of the researchers to maximise the benefits obtained from the system whilst minimising the shortfalls. It is intended that this web-based learning system *Nanolab* will provide essential skills in various analytical and experimental techniques as used in nanoscopic materials research, accelerate learning and enhance research while reducing instructor and travel costs typically associated with traditional training methods.

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