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Abstract
The utilisation of interactive, multimedia based tools and delivery mechanisms in teaching and learning environments is becoming an important aspect of the implementation of a more innovative approach to teaching in engineering. The potential for applying such multimedia tools towards this goal has been very well recognised. One of the key elements of a multimedia learning environment is its ability to provide the learner with control, which is the essential feature of a 'democratic environment' for learning.

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Development of an interactive multimedia based package for teaching pollution control processes in environmental engineering

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The utilisation of interactive, multimedia based tools and delivery mechanisms in teaching and learning environments is becoming an important aspect of the implementation of a more innovative approach to teaching in engineering. The potential for applying such multimedia tools towards this goal has been very well recognised. One of the key elements of a multimedia learning environment is its ability to provide the learner with control, which is the essential feature of a 'democratic environment' for learning.

> Current interactive multimedia technologies can represent ideas in almost any mediated form, and provided we can generate a comprehensible metaphor for organising our functional options and the underlying knowledge structures, the student can roam through the resources, creating their own meanings and understandings of the phenomena they encounter . . . (Corderoy et al., 1996).

It is suggested by Jonassen (1988) that learning environments which utilise interactive multimedia have a number of attributes which are essential if they are to be efficient and effective. In particular interactive multimedia provides:

(a) opportunities for higher levels of engagement;

(b) improved representation of information in that there is a 'closer fit' with the formats the current generation of learners are familiar and comfortable with; and

(c) the provision contextualised feedback.

Such highly interactive environments allow for self-paced learning at a time and place which is most convenient and 'supportive' for the individual, and to be 'selective' in the overall experience he/she has while navigating the learning environment.

Recent research into learning processes focuses on the student and the 'cognitive tools' they have at their disposal as 'intellectual partners' in the learning process (Jonassen & Reeves, 1995). This relationship implies a two way interaction between the partners. Without this, the learner is not fully engaged in the task and the learning potential provided by the task is not fully realised. It is the task of the designer to ensure that the learning environment provides both the necessary underlying information structures and a means of investigating and testing hypotheses and understanding.

The purpose of this paper is to outline the process of design and development of an interactive multimedia learning environment based

on the constructivist paradigm, (Reeves, 1993, Jonassen, 1991 and Winn, 1993) which, through the use of graphics hyperlinks and a number of simulations, provides the student with a richer experiential learning environment by virtue of it being situated in a 'real world' context than may normally be provided in a more 'traditional' lecture style teaching and learning environment.

The process of design and development of such learning environments is complex and requires careful consideration of such basic elements as: a needs assessment; identification of goals; the setting of objectives; content design; screen design; instructional design; an effective and intuitive navigational system; production and publication and documentation.

As a part of a multimedia development, it is necessary to establish the need for the multimedia tool, which will lead into the overall goal. This should follow with the identification of the specific objectives for the multimedia project. A subject expert is required to outline the content of the material to be covered under the proposed multimedia project. Similarly, it is essential that expertise in the area of instructional design and pedagogy be sought to ensure the integrity of the final product. In order to make the package more attractive, all the possible instructional components (text, voice, movie, etc.) should be included.

Navigational features of the package are very important. If such systems are to facilitate improved learner outcomes, they need to provide both a user friendly interface allowing the learner to choose their own pathway through a complex learning environment without getting lost. Production and publication includes co-ordination of programming and resources, final printing and mass production. In its final form the package should also provide the user with a detailed 'user manual' which will ensure that the time spent working with the package is actually spent learning the content area rather than how to use the software.

The developmental sequence is demonstrated by taking a case of 'Sedimentation Tank Design and Operation', which is a common unit operation used in pollution control. The sedimentation process although a simple process in the overall system of pollution control, demands some imagination to understand the principles and the continuous nature of its operation. Also, there are several components of the sedimentation tank which are difficult to explain or demonstrate without the aid of 'real world' experience or laboratory simulation.

Simulations:

> . . . greatly enrich the 'quality' of the problem solving process for the user by providing unhindered access to act and become immersed in a 'real' situated process, manipulating the various causal parameters and testing hypotheses without a 'real' consequence or risk and in a time frame which is convenient and manageable for them and 'and enabling the learner to ground their cognitive understanding in their action in a situation' (Laurillard, 1996).

Many of the processes also necessitate exposure to dangerous situations when they are observed first hand. The functions and processes of these components can be easily demonstrated using pictures, hyperlinked text and simulation and modelling techniques to provide risk free environments in which the user may 'experiment at leisure' to come to terms with the difficult concepts involved and thus gain a deeper understanding of the systems at work. For example, the effect of particle size and density on the process of settling can be better illustrated using simple but effective simulation.

Sedimentation tank design and operation

A multimedia, learner centred, software package was developed for introducing the design and operation of sedimentation tanks to 2nd or 3rd year undergraduate students. The package was designed to give them some idea of the actual operation and design of a

sedimentation tank. It would also help explain the operating principle and performance of the process, while providing students with the opportunity to engage and interact with the learning environment whilst constructing their knowledge. This package is expected to supplement several print based resources (for example, Metcalf & Eddy Inc., 1991; Kawamura, 1991), which can be used to further enhance the understanding of the sedimentation tank design and operation.

Need for multimedia package

In engineering there are several processes, which need imagination to understand the basic principles behind their operation. There are four aspects which are essential for understanding an engineering process:

- Description (by words)
- Graphical representation (2 or 3 dimensional)
- Actual field demonstration
- Mathematical representation

Print based material can only satisfy the first two aspects. In order to fulfil the third aspect it is necessary to take students/trainees for a field trip. These field trips can often become very costly and cumbersome. On the other hand interactive multimedia software can actually fulfil the objective of field demonstration of the process within the class room environment through animation and simulation. In addition, the multimedia software can be used to help understand the mathematical representation by simulating the performance of the process under different conditions.

Sedimentation, though a very simple process in pollution control, requires imagination to understand the continuous nature of the operation. Also, there are several components of the sedimentation tank which are difficult to explain without the aid of visual display. The functions of these components are very well demonstrated using pictures, simulations and models, which will help form a better understanding of their functions. Consequently, the design of the package relies heavily on such methods of representation. There is a considerable volume of research into the use of such methods out of which has come a recognition that the use of graphics helps learners focus explanative information and use it more efficiently and effectively to develop their mental models (Mayer, 1989).

During interaction with text and auditory information, there is a high cognitive overhead involved in the visualising of the information (Rieber, 1990) which must impinge on the learning process, diminishing the likelihood of retention and assimilation into the existing knowledge frameworks of the student. Using graphical representations in the first instance may provide a mechanism for 'redirecting' some of this cognitive load to the process of learning.

Goals and objectives

The package is used as a teaching tool for undergraduate students. It assists them in understanding the operation and design of sedimentation process used in water pollution control.

The specific objectives of this multimedia package are:

- to explain the operating principles;
- to demonstrate the continuous operation;
- to explain the functions of various components;
- to explain the steps involved in the design and construction; and
- to explain the mathematical representation using simulation.

Content design

After a close examination of all the topics under sedimentation, the following major headings are identified:

- Process description
- Principle of settling

- Inlet design
- Outlet design
- Sludge collection facility
- Construction details
- Design criteria
- Performance

The whole subject matter on sedimentation tank design and operation is distributed under the above main topics.

Process simulation. The operation of the process is described using simulations, both simple (non-predictive) and complex (predictive and based on algorithms). The simulation is provided for different types of sedimentation tanks. During the simulation the functions of various components are highlighted. The design criteria behind the operation of each of the component can be understood through these simulations.

For example, in the case of a rectangular sedimentation tank (Figure 1), these simulations will assist in understanding the continuous operation of the sedimentation tank. In addition, the horizontal movement of the scraper in the simulation demonstrates the critical nature of its speed.

Performance simulation. The performance of the sedimentation tank depends on the settlement of particles under gravity. Under discrete settling conditions, the settling of particles is given by Stokes' equation (Metcalf & Eddy Inc., 1991):

$$v_s = \frac{g(\rho_p - \rho)d_p^2}{18\mu}$$

where v_s = vertical settling velocity of the particles

g = acceleration due to gravity

d_p = particle size

ρ_p = density of particles

ρ = density of water

μ = dynamic viscosity of water

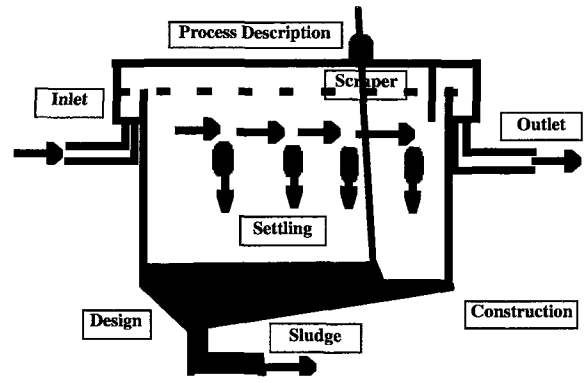

Figure 1 Horizontal sedimentation tank

Equation (1) gives the vertical velocity of the particle. However, in a continuously operating sedimentation tank, the particles are also transported in the horizontal direction as well. The horizontal velocity of the particle can be given by:

$$v_h = \frac{Q}{wh}$$

where Q = inflow rate in to the tank

w = width of the tank perpendicular to flow

h = depth of the tank

The particle removal depends on the magnitude of vertical and horizontal velocities. In order to understand the influence of vertical settling and horizontal velocities it is necessary to imagine the particle settling in a continuously operating sedimentation tank. The simulation provided in this multimedia package shows the settling of particles under the influence of both vertical and horizontal velocities. The user can change different variables such as particle size and density, tank depth, inflow, etc. and see the actual settling of the particles.

This simulation can be further used to develop user interactive tutorial sessions. One of the many possible tutorial examples which can be generated follows.

Tutorial example: Determine the efficiency of a particle of size 50 μm and density 1.1 g/cm^3, settling in a horizontal sedimentation tank of depth 2 m, length 10 m and length to width ratio of 3:1. The flow into the sedimentation tank is 2000 m^3/d.

a) Explain the answer obtained through simulation using vertical and horizontal velocity concept.

b) What will happen to the removal efficiency, if the flow is increased by two times? Explain the difference.

c) What will happen to the result, if the depth of the sedimentation tank is reduced by half? Explain the results.

Many more questions can be generated based on the simulation. These questions help students to think more about the practical aspects of operation and performance of sedimentation tanks.

Instructional components

The instructional component utilises the following modes:

- Graphical representation (sketches and scanned images)
- Hyperlinked Text
- Audio and video

Most of the aspects are effectively illustrated using graphics and hyperlinked text. Animation and simulations are used to demonstrate the principles of operation. Practical perception of the sedimentation tank is reinforced using the actual photographs. Audio is included to narrate the animation and the video is included to reinforce the practical aspects of the sedimentation process.

Navigation and colour coding

The navigation includes several icons on each page in order to take the student to a topic of his/her interest from any point within the multimedia package. In addition, the standard navigational icons such as forward, backward and home available with Netscape can also be used. Colour coding is used to indicate the functionality of some of the items:

- Brownish red – is used for indicating particles.
- Light blue – is used to indicate water
- Brown filling – indicates the sludge particles

Production and publication

The multimedia package was initially developed for delivery on the World Wide Web, using 'html' coding and 'java' scripting. On the internet, the package can be accessed through a simple registration process. The Internet provides instant access to the package from anywhere in the world. Moreover, through the internet the software upgrades will be able to be accessed almost immediately. It is intended that the software will eventually be ported to CD-ROM (using Director 5.0) for both PC and Macintosh platforms. This will provide access to 16 bit quality, realising the full potential of the detailed graphics presented in the package and the speed of access will provide superior simulation and navigational speed.

Conclusions

The multimedia package on sedimentation tank design and operation is one of 6 modules being developed at University of Wollongong by the authors. At the time of writing the multimedia package on sedimentation tank design and operation has been completed and is accessible on the web. The work on the remaining modules is in progress. The remaining 5 modules include:

- Coagulation;
- Flocculation;
- Flotation;
- Filtration; and
- Disinfection.

It is expected that by the end of September 1998, the work on the remaining 5 modules will also be completed as a web based package and a stand alone CD-ROM based package will be completed by the end of 1998. As such, during the oral presentation of this paper, all six modules will be demonstrated.

It is also expected that the package will be tested and evaluated in 1998. A report on its use by students and their feedback will be published in subsequent conferences.

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