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Interactive technology facilitates modes of processing, sharing of and interacting with information which until recently were unachievable. Discussed in this issue of CDTL Brief *on* ***Interactive Technology in Education*** *are ways that interactive technologies can be used as powerful tools and environments for students to relate classroom theory to industry practices, develop higher order thinking skills and train health care providers.*

Helping Students Relate Classroom Theory to Practice in Industry: Design Considerations for Web-based Simulations

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While many engineering undergraduate courses are structured to introduce the theory related to various processes, students with no industrial experience have little sense of how this theory relates to real-life operations in the field. To address this concern, we set out to create a learning activity dedicated to help students relate theoretical concepts of process dynamics and control presented in class to their practical application in industry. Considering the prevailing trend towards a student-centred approach to pedagogy, we wanted to provide students with a basic simulation of system components. The program, designed to enable students to visualise the relationship between input variables and their effect on outputs, would engage the students in bridging the theory and concepts to meaningful application in practice. Hence, students could benefit from a learning activity that focused on a visual representation of the critical control elements in a simulated oil refinery furnace system. This article examines the design decisions in the development and evaluation of this learning activity, a web-based simulation for process dynamics and control education, and discusses the wider implications of online simulation interactivity features.

Dubbed 'SimFurnace', the program was designed to enable students to dynamically manipulate the inputs of a crude oil furnace in the upstream end of a refinery. While manipulating the fuel feed and feed flow rates of the system, students are able to observe the system's responses. In the simulation freeform (practice) mode, students can also see how the formula calculation changes dynamically with input adjustments. Once students have had sufficient practice in the freeform mode, they can access a set of assignments designed to bring forth key process control concepts while problem-solving common industrial challenges. The program, developed using the Macromedia Flash MX authoring environment, is accessed from the university web servers at the convenience of the user. Srinivasan, Doiron, & Song (2003) offer a more in depth description of SimFurnace.

Considerations for Design

Before creating a simulation, the rationale and the aims of the project, the constraints and limitations in its development and implementation, and a review of existing programs all contribute to the initial graphic design and interactivity specifications. For example, the screen features and user input modes in SimFurnace are simple yet dynamic. Taking into consideration the limited scope of refinery operations being targeted and the fact that students were not expected to know every detail of chemical plant systems, a high fidelity system representation, such as those with complex and detailed displays available for industrial training, was not deemed necessary for meeting the learning objectives. However, emulating basic system dynamics was very important.

After a review of existing online programs designed to help students visualise process dynamics and control, we found that many online simulations were still stand-alone applications developed with Matlab/Simulink software. Applications created with such software have three major weaknesses:

1. Many programs process 'batch' type simulations in which the parameters/variables are specified at the beginning of the simulation run are not manipulated by the user during the course of the simulation.
2. The level of user interactivity with the model during the learning exercise is minimal.
3. The visualisation of the underlying process being simulated is limited: most use only simple state equations and block-diagram graphics to represent system elements and transfer functions. In most cases, there is no dynamic visualisation of the input/output relationship.

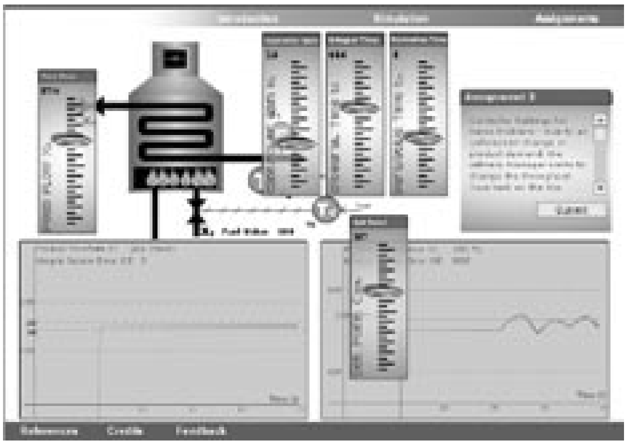
According to Fishwick (1995), these shortcomings are a serious impediment to the effectiveness of simulations as a learning tool. He emphasises that because computer simulations embody the principle of "learning by doing", even a geometric model that looks good may not be satisfactory unless it has graphical representation of the system dynamics. Furthermore, these existing online simulations make little use of what Ranky, Bengu & Spak (1997) call "anthropocentric technologies" which, through intuitive interaction and immediate feedback, enable the learner to explore and implement concepts to a much deeper level.

Program Structure

A standard feature of simulation programs is a freeform interaction with the simulated system. This enables students to gain an intuitive sense of the interrelationships between the variables in the simulated process. In SimFurnace, students can direct the feed flow rate and the fuel flow rate into the system while monitoring and controlling the product output flow rate and temperature. The effects can be observed in real-time as the product flow rate and temperature are charted in the lower half of the screen. Students also have access to information on the system's underlying logic, a first-order-plus-dead-time transfer function, and the ability to toggle the screen presentation to reveal a dynamic flow diagram of the process. This freeform section is also designed to familiarise the students with the simulation environment that they will encounter in another section: the assignment section (see Figure 1).

Although not all programs challenge the user to apply what they practise in the freeform interaction with the simulation, the design of assignment scenarios based on real-life problems is of utmost importance. In SimFurnace, the objective of having students complete the assignment section is to anchor their learning by getting them to instinctively react to system changes in a meaningful context. In doing so, students become aware of the relationship between real-life issues such as environmental factors and plant production requirements, and how these aspects of production affect the system input and output variables studied in class.

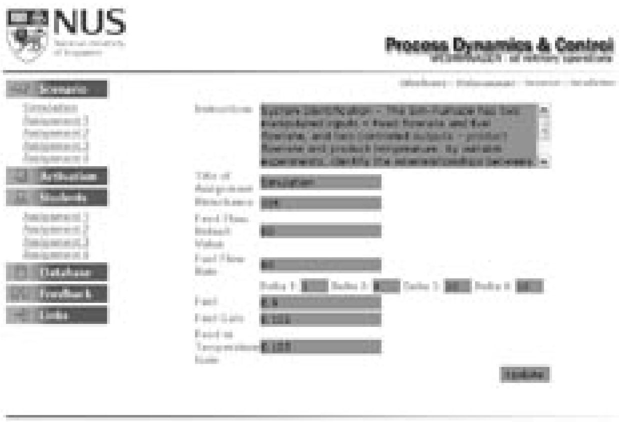
Figure 1: Assignment 4



Other Design Features

In order to provide feedback and some measure of control for the instructor, the design of online simulations should include a transparent tracking of user performance. As well as controlling access to the program, the instructor needs to enable and disable exercises, set new target ranges (parameters) for the simulations and control exercises, and browse student performance data and feedback comments. Hence an appropriate Learning Management System (LMS) needs to be considered (see Figure 2).

Figure 2: Custom Learning Management



Discussion

Taking into consideration what Yang & Alty (2002) describe as the "need to develop the student's intuition for bridging the gap between theory and practice", simple web-based simulations like SimFurnace can be created with existing off-the-shelf web authoring tools. Such customised web-based simulations, with a specific context and focus, can overcome the constraints of the classroom and enable students to associate concepts in theory with an experience of their meaningfulness in a setting related to their future profession.

Many new models for integrating online learning into the curriculum are needed and their appropriateness in meeting specific learning objectives in varied settings can only be assured through a systemic approach to creating online learning activities, designing meaningful interactivity, prototype testing and learning outcome validation. Using SimFurnace as an example, we have presented some of the design features that we believe help students relate classroom theory to practice in industry. Field trials investigating student learning gains from using SimFurnace are underway and preliminary results are encouraging.

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Design and Evaluation of a Chemistry Computer Software for NUS Students

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Introduction

Subject matter learning at the university level is not all about memorising isolated facts but understanding concepts and drawing connections between them. To facilitate university students' learning, more authentic problems which provoke the use of so-called higher-order cognitive skills (HOCS) (Roth, 1995) should be assigned instead of structured exercises. With the widespread availability of modern computing and networking facilities, computers are now widely used in education. In chemistry, spreadsheets and visualisation platforms are useful tools for data analysis and illustrating chemistry ideas. In particular, computer-assisted instruction (CAI) which takes the form of virtual tutorials can be utilised for intensive teaching of *conceptual* chemistry (Lower, 1997). Furthermore, it is proposed that the use of CAI as a supplementary teaching tool could foster the development of HOCS in individual students. The CAI, through careful sequencing of instructions, while acknowledging the differences in students' abilities, makes it possible for the instructions to be customised to stimulate any individual student to first remember and review what one already knows and later, guide one to solve authentic problems by analysing and evaluating the knowledge.

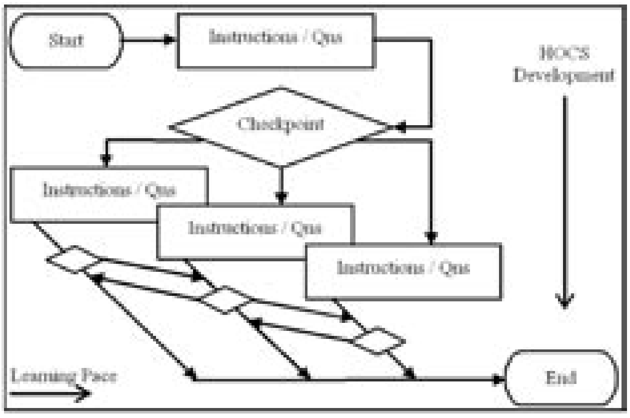
This article aims at reporting the initial design and evaluation of an Organic Chemistry (specifically in nucleophilic substitution reaction mechanisms) CAI software in NUS. Suggestions for future work are included.

Design Process

The initial schematic describes an 'ideal' situation whereby any individual user's progress in learning could be reasonably accommodated. Challenges that had arisen during the development of the CAI prototype based on the initial schematic prompted further development according to the revised schematic.

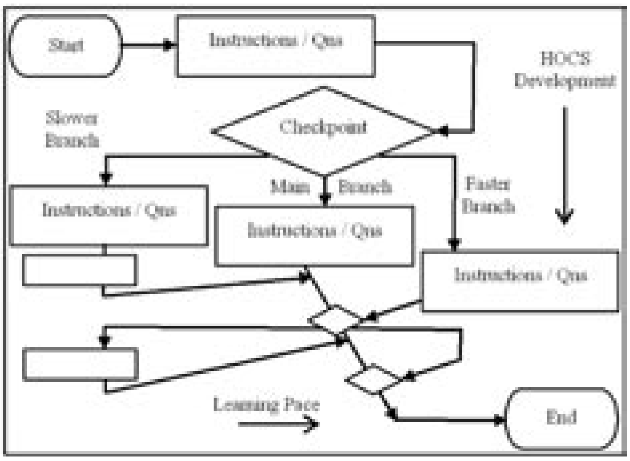
After attempting to develop the CAI software from scratch, we realised that it would be difficult, although

Figure 1: Initial CAI Schematic



A number of possible 'paths' of learning with the flexibility for a user to 'jump' from one path to another are offered. As a user progresses from the basic to the advanced questions, one's HOCS is gradually developed.

Figure 2: Revised CAI Schematic



Most users would be expected to progress along the main branch. The 'fast track' bypasses certain easier questions to allow for more rapid development in HOCS. The slower track accommodates users who need more help with basic understanding of concepts. Flexibility to 'jump' between the branches is retained.

* The study reported in this article is based on an Honours Year project in Chemistry completed by Nah Wee Kiak, Daniel

not impossible, to have numerous though finite paths of learning in the CAI software. Hence, the revised schematic took into consideration that the general distribution of learning abilities of students would follow more or less the normal distribution. In addition, an assessment was administered to a small sample of NUS students in Organic Chemistry to determine the prior knowledge of the targeted main branch students so that it was possible to gauge the appropriate level of difficulty of the questions in the main branch, the fast and slow tracks.

Trials

15 first-year undergraduate students were asked for their opinions after they each had been given an opportunity to spend time using the trial version of the CAI software. Responses indicated a mixed assessment of the CAI. Some students' positive comments on the CAI were that it stimulated thinking (see Table 1) and helped reinforce concepts. In addition, the interactivity available on the CAI was something which the textbooks could not offer. Since time was not a factor, the learning with the CAI could be reviewed at one's own pace which is an advantage over time-critical lectures.

With regard to features that the students disliked, one user claimed that the content, which was initially too easy for her, subsequently became too challenging. Others suggested that more personalised feedback could be included. The lack of ability for the user to pose questions (not available in the trial version of the software) constituted another drawback as the users were restricted to the contents available within the programme.

Users were also asked to select from a list of CAI features (Hannafin & Peck, 1988)—with associated cognitive basis not revealed to the users—that they felt would be useful to incorporate into the CAI to teach chemistry via HOCS (see Table 2).

Most users (80%) indicated that the ability to stimulate recall of prior knowledge should be incorporated into the CAI. Users also ranked features such as the ability to assess performance, guided learning, interactivity and distinctive stimulation as important. Incidentally, these mentioned features could be regarded important in the development of lower-order cognitive skills (LOCS). Few users selected features like individualisation, allowance of appropriate degree of user control, enhancement of learning as well as

Table 1: Types of cognitive skills used as reported by the fifteen students in the trials

User	Pace of Learning	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1	2, 2	•	•		•		
2	3, 3	•	•				•
3	4, 4	•	•	•	•	•	•
4	3, 3	•	•	•		•	•
5	3, 4	•	•	•	•	•	•
6	2, 3	•	•	•			•
7	3, 3	•			•		•
8	4, 3	•	•				
9	3, 4	•	•	•	•		
10	4, 3	•	•	•	•		
11	3, 3	•	•	•	•	•	•
12	2, 4	•		•	•	•	•
13	1, 1		•	•			•
14	3, 4		•	•		•	•
15	3, 3	•	•	•	•	•	•
Total (%)		87	87	73	60	47	73

On a numeric scale of 1(slow)—5(fast), users rated the pace of general learning and pace of learning chemistry. E.g. (1, 5) indicates that the user rated pace of general learning as slow (1) but pace of learning chemistry as fast (5).

Table 2: CAI features with associated cognitive bases

S/n	Feature (Cognitive reason for it)	%
a	Captivating interface (Stimulate alertness)	47
b	Information of lesson's objectives (Satisfy user expectancy)	40
c	Stimulation of recall of prior knowledge (Retrieval to working memory)	80
d	Distinctive stimulation of user interest with distinctive features (Cater to selective perception)	60
e	Guided learning (Semantic learning)	67
f	Ability to obtain desired performance (Retrieval and response)	20
g	Provision of information feedback (Reinforcement of idea)	20
h	Ability to assess performance or aptitude (Cue retrieval of knowledge)	73
i	Enhancement of learning (Ability to generalise concepts)	53
j	Individualisation (Increase user interest; Conceptual anchor for new knowledge)	27
k	Interactivity (Strengthens cognitive ties)	60
l	Allowance of appropriate degree of user control (Ability to focus on desired portions)	40

provision of user feedback which would in fact be more useful towards the development of HOCS. Such results might indicate that students still believed that they were expected to grasp the subject matter by knowing the facts using only LOCS.

Recommendations

Based on our experience with the initial design and evaluation of the CAI software, we would like to make the following recommendations for future development and enhancement of the CAI software:

- The CAI prototype had some limitations due to the few and restrictive nature of the features incorporated. It was lacking especially in the ability to provide sufficient personalised feedback that goes beyond pointing out mistakes. Such features are essential to the development of HOCS as it allows one to analyse, evaluate and learn from one's own mistakes.
- Users also had limited means of backtracking to review information on previous frames. Such allowance should be taken into consideration in the design process because one needs to consolidate what he/she already knows in order to receive new information.
- More captivating visual and audio effects might aid in the understanding of how organic reactions occur and this would improve assimilation of knowledge and synthesis of the concepts.
- A potential difficulty would be that to obtain an accurate trend of user's knowledge standards, one would have to evaluate numerous statistical samples over a period of time. However this would render the CAI obsolete by the time the statistical result is produced based on past sampling.

Concluding Remarks

It is envisioned that further development and enhancement of the proposed CAI may be carried out by building upon its merits and using feedback drawn from this study to enhance its effectiveness as a (supplementary) teaching instrument. Other future work may include reviewing the effectiveness of commercially developed CAI to stay current with the advancements in CAI software development.

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Interactive 3D Computer Technology in Orthodontic Education

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Computer technology may be harnessed to facilitate learning. In the area of biomedical health education, computer technology is especially useful in the training of health care providers who deal on a daily basis, with people who are diseased or deformed through birth and accidents. In this context, the training of dental surgeons can be optimised through the use of interactive 3D computer vision technology. In a well-designed system, human-computer interaction would provide an engaging learning experience for the user.

Advances in software and hardware technology permit the creation of any virtual 3D environment. In such environments, learning is facilitated by computer techniques such as 3D visualisation, simulation as well as animation. These environments may incorporate virtual learning maps for the learner to navigate with purpose by checking in at learning stations. In addition, the flexibility of repeating a learning station reinforces learning.

The essential component of effective learning in a virtual environment is the **input-feedback** capability of the system. Against a dynamic multimodal database of knowledge, the software can be tailored to provide accurate feedback to the learner while he/she navigates through each learning station. Building artificial intelligence into such a system permits the knowledge database to recognise trends in user input. An added dimension of interactive technology is the ability to add the sense of touch—haptic sense and prehension (reach and grasp). Together with a capability to integrate the different modes of data (text, sound, 3D images and time), an intelligent 3D learning environment has the potential to engage the learner, recognise input and provide real-time feedback.

In orthodontics, the use of interactive 3D technology is particularly appropriate as a learning platform. Orthodontists manage the dentition, modify growth of the facial skeleton and improve the function of the orofacial musculature. The craniofacial skeleton, the dentition and the facial soft tissues are three-dimensional structures that are ideal for virtual representation in a learning environment through spatial and temporal visualisation as well as simulation. The representative 3D virtual shapes of these facial and skeletal structures may be *altered*, *cut through*, *moved in parts or whole* and *animated*. The surfaces of these 3D shapes may also be coloured and textured.

The potential of using interactive 3D computer technology to teach orthodontics is highlighted in a selection of orthodontic topics taught in the undergraduate and graduate curriculum at NUS. For example when teaching orthodontic techniques, 3D reconstructions of orthodontic appliances (devices) may be viewed in any preferred orientation by the user who could possibly visualise how a complicated wire pattern is constructed or how a particular device works through 3D animation. The training of students for accurate bracket placements may be first conducted by getting the graduate student to place a virtual bracket as accurately as possible on the virtual tooth. The computer system will recognise whether the bracket has been positioned correctly and gives the error margin. In planning orthodontic treatment, the decision to extract or not to extract teeth may be simplified through an interactive system which permits the teeth to be moved around to find the best possible arrangement. Similarly, surgical management and the approaches used to correct abnormal jaws may also be simulated. The optimal arrangement of a set of teeth and the sense of depth and touch may be simulated prior to actual surgical procedure for both the orthodontist and surgeon respectively. Biomechanical information may also be incorporated into 3D appliance models for simulation of how the teeth may move.

The applications of interactive 3D technology in orthodontic education are numerous. Not only is 3D technology applicable to biological sciences and clinical management, it also has a huge potential to enhance direct and distance learning. Thus, 3D technology should be viewed as adjunctive and complementary to the clinical practice of orthodontics. With the availability of high speed computers, learning the basics of orthodontics has never been easier. In fact, learning the nuts and bolts of orthodontics is now more fun and exciting especially with interactive 3D technology. ■

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The Centre for Development of Teaching and Learning (CDTL) engages in a wide range of activities to promote good teaching and learning at the National University of Singapore, including professional development, teaching and learning support, research on educational issues, and instructional design and development.

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