THE USE OF ONLINE INTERACTIVE MODELS AND SIMULATION IN ASSISTING STUDENTS' DEVELOPMENT OF MATHEMATICAL CONCEPTS.

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ABSTRACT

The authors of this paper teach mathematics to engineering and business students at the Higher Colleges of Technology (HCT) in the United Arab Emirates (UAE). This system of post-secondary colleges for UAE nationals was established to provide students with vocational and technical education. To further enhance student success, the HCT, in line with current trends, has moved to a more learning-centred education, with the creation of independent learning centres, custom designed labs for integrated learning and increasing use of technology and the Internet. Laptops are now becoming quite commonplace in classrooms around the system, and laptop technology is being integrated into learning goals. The development of online modes of learning is being encouraged in order to provide students with more flexibility in their learning. Students are familiar with the Internet and, in general, quite comfortable with computers. Students' laptops are fitted with PCMCIA cards, enabling a wireless intranet connection. The majority of classrooms are equipped with smart-boards, and teaching with technology is being encouraged.

In teaching Arabic-speaking students, learning through the medium of English, particular attention is needed in providing meaningful understanding and sound concept development. With students having immediate access to the college intranet via their laptops, on-line materials can be used effectively as supportive tools in the classroom to enhance learning. The authors are involved in the development of such 'online' materials, which offer students opportunities to interact meaningfully with mathematical content. The emphasis is on concrete and visual approaches with a high level of interactivity. This paper outlines some of the methods the authors have found useful in creating interactive and simulation models for the learning of engineering and business mathematics, and presents examples of such models.

Keywords: Online learning, Interactivity, Pedagogy, Concept development.

1. Introduction

The authors teach mathematics to both business and engineering students at the Abu Dhabi Men's College (ADMC), Higher Colleges of Technology (HCT), a system of post-secondary colleges for nationals of the United Arab Emirates (UAE). Students at the HCT are currently able to enter into four types of programs: Certificate, Diploma, Higher Diploma, and the Bachelor in Applied Science. The Certificate programs are two years in length. They introduce students to general and specific occupational skills and develop basic proficiency in English, computing, and mathematics. The Diploma requires a further year of study in which English proficiency is further developed and occupation-specific skills at the technician level are emphasised. Students following a Higher Diploma (HD) program are required to successfully complete a one-year Foundations course before being permitted to enrol in HD. The HD programs are three years in length and involve a combination of theoretical knowledge and practical applications at the technologist level.

All classes are delivered in English, and entry to programs is dependent both on high school performance and ability in English. All students are native Arabic speakers and are required to successfully complete all their courses in English. Students, coming directly from schools where Arabic is the mode of instruction. At the HCT, therefore, constant attention must be paid by teachers in assisting students from making the transition from students' previous traditionally based classroom experiences to the more student-centred HCT learning approach using the medium of English. Many of the learning difficulties in mathematics are closely related to limitations in the English language. While students at the HD level have less trouble in coping with English, teachers, nonetheless, have to be alert with their diction and phraseology. The language and terminology associated with a particular mathematical topic are easily open to misinterpretation and much care has to be taken to ensure that each of the related mathematical concepts are treated with a meaningful approach to students. Sensitivity to the social and cultural background of students would bring further relevance and meaning to the students' learning.

In the span of its relatively short history, the HCT has grown and developed at a rapid pace in trying to meet the educational needs of the UAE. As needs of students and employers continue to change, there is a continuous review and adaptation of the curriculum and teaching and learning methods. This is being achieved through a series of strategic plans, which identify priority issues for each academic year. One of these priority issues for the academic year 2001 – 2002 is evolving the learning paradigm with a focus on technology. In line with this, one of the goals at the Abu Dhabi Men's College is to expand the use of technology in the curriculum and look for innovative ways to enhance learning. This has brought about a shift from providing instruction to producing learning, with the creation of independent learning centres, custom designed labs for integrated learning and increasing use of technology and the Internet. An online e-Forum has been created with its main aim of promoting independent learning among our students.

Technology is a rapidly becoming a way of life for our students. They are familiar with the Internet and, in general, are quite comfortable with computers. Many now possess laptops and these are quite commonplace in classrooms. The integration of laptop technology into learning goals and the development of online modes of learning are being encouraged amongst teachers in order to provide students with more flexibility in their learning. Classrooms are also now equipped with wireless cover, giving students instant access to the college intranet via PCMCIA wireless cards connected to their laptops. Students can obtains these cards on a refundable deposit basis through the college IT services. Students show eagerness to incorporate technology into

their learning. While this may be so, students have yet to develop effective techniques for learning independently. Much teacher guidance and direction is still necessary, and an effective pedagogy needs to be developed before our students can be expected to cope with an online course in its true independent sense.

2. Online Pedagogy

The term 'online' is open to a wide range of interpretations, and there are many 'modes' of online learning. Modified and newer ones continue to evolve with improvements in access and usability. In a standard 'fully' online course, the students would be quite diverse and unpredictable, coming from a range of backgrounds and cultures. The online resources and material would be accessed and interacted with in a variety of sequences, differing times and locations. Each student's knowledge, skill level and learning style will have an impact on how he/she relates to the material and has success with the course. The geographic and time constraints could create additional difficulties.

In comparison with this, our task in the UAE is relatively easier than that of the 'fully' online course designer. We are catering to a particular class of users and with predefined assumptions on students' behaviour and styles of interaction. We know our students and can create learning activities that build on differences in students' learning styles so that students can be directed to the learning activities most suited to their preferred learning styles. Although our pedagogy involves using the available technology and working with our students to foster learning and independent thinking, there is a real need for face-to-face interaction between teacher and student as an integral part of the learning. Our UAE students come from a 'non-western' culture with their particular customs and experiences, where traditionally they have learned from family and elders. Much of their learning was and is done through doing, listening, observing, and imitating parents and others. Interaction with their peers as well as with the environment play further developmental roles. Any instructional environment which incorporates teaching and learning methods related to these existing familiar traditional approaches would have a greater likelihood of succeeding. They suggest more hands-on practical work, more concrete approaches, more collaboration and group work amongst their peers, and face-to-face student and teacher dialogue. Human contact is necessary, not only for learning content, but also more importantly for encouragement, praise, feedback and assurance that students are on the right learning path.

English is not the first language for the majority of students, and considerable care is needed in keeping communication at their level, both in the classroom as well as on any medium for independent learning. Most teacher's at present are 'western' and, quite often without realising it, make assumptions, or take for granted, that certain background knowledge or ideas pre-exist in students' minds and are expected to be automatically understood as in any western setting. The authors have been working in the UAE for several years and have developed some familiarity with the students' background and perspectives on their learning. If we want to communicate meaningful ideas to our students, it is essential to know what they are thinking and visualising, and how they are interpreting our words and actions. It is essential that our online pedagogy should include simple and meaningful language while not losing sight of the students' experiences and extant knowledge. The following design features have been adopted by the authors for an online mode:

- Use of language which is both simple and meaningful in the local context
- Student ability to investigate concepts and ideas through interactive learning models

- Provision of immediate feedback to student responses
- Adaptability to face-to-face classroom use
- Student ability to concentrate their efforts on areas of particular difficulty

These suggest that a pedagogy that is likely to be successful in the UAE is therefore one that employs a complementary online model in which the material provided online adds to face-to-face classroom delivery. The material is seen a supportive and provides interactive learning experiences to investigate concepts more deeply. They could be used both in by the teacher and students in the classroom, or by students working and exploring independently. The teacher's role of a provider of information, becomes more as one of a guide and facilitator of information. The classroom interaction with the online components would further stimulate work in small groups and discussion. Students, either individually or in groups, need to interact with learning materials that allow them greater choices that meet their particular learning needs. They need become engaged in active "doing" in the learning process, which goes beyond merely reading text. The authors believe that a richer online learning environment can be provided to students through interactive simulations that can be actively manipulated, provide engaging and challenging tasks, and that supply instant feedback on performance.

3. Interactivity and Simulation

The interactivity we are concerned with in this paper is that related to student interaction with teaching-learning resources, as opposed to the social interaction between student and teacher. Bates (1991) referring to these, respectively, as social and individual, states the need for a balance between the two in a distance-learning context. This can equally well apply to any form of learning, whether it is distance, online, or in the classroom setting.

Computer-based learning programs often follow a page-turning format where material is presented very much as an electronic textbook. Such formats are frequently encountered on web pages and are far from being student-centred and present little or no interactivity. They are static and unable to personalise the interaction with the user. Rather than trying to replicate a teaching model online, the idea is to create what has been called a ‘resource’ model, an environment in which students interact and wrestle with learning materials directly (or in teams), under the tutorial guidance of a mentor (Twigg, 2001). The rapid feedback that computers can provide needs to be tapped as much as possible. It is through interactive resource-based models that this can be made possible. The use of animations, simulations and virtual environments that may simulate real world settings can help to simplify a concept by way of interactive processes and bring the concept to life. For such interactive models to succeed, they must be pedagogically sound, engaging and flexible. They should enable students to focus on their areas of weakness and provide practice and investigative opportunities at different levels of complexity.

The authors see these interactive mathematical models as being central to the learning process. Students will be able to investigate mathematical situations by varying parameters to explore different possibilities and interpret outcomes. It is hoped that these models will assist students in developing appropriate learning techniques and help to improve investigative thinking. Students will be in control of their learning and can experiment with a model as long as they need. This could stimulate the students' interest in the given topic and further motivate learning. Their interaction with simple real-world type modelling can bring insight to the mathematics met in the classroom and promote independent learning.

The interactive learning models are being developed mostly with the use of Toolbook Instructor[1], a very powerful authoring package, which the authors have used extensively and which is highly suitable for interactive learning. Toolbook uses a plug-in called Neuron, which enables it to be used in a Web browser. Each Toolbook model is designed with a small number of interactive pages to minimise its download time. Brief descriptions of some examples follow.

4. Examples of Interactive Models

1. Break-Even Analysis: Figure 1 shows an example of an interactive graphical model to investigate the concept of break-even analysis. Students are able to input values for the selling price per unit, variable cost per unit, fixed costs for the period and the capacity for the period. They can then observe the total revenue and total cost graph and investigate the break-even point.
2. Volumes of Revolution: Figure 2 shows an example of an interactive model to investigate finding volumes of revolution by summing up disks. The model allows students to visualise rotations about the *x*- or *y*-axes, as well as the number of disks. By changing different parameters, students can investigate inner and outer volumes and develop a concept of the integration technique used.
3. Compartmental Analysis: Figure 3 shows an example of an interactive simulation model to investigate the mixing of fluids is a tank. A basic one-compartment system consists of a function $x(t)$ that represents the amount of a substance in the compartment at time t, an input rate at which the substance enters the compartment, and an output rate at which the substance leaves the compartment. In mixing problems we have a fluid flowing into a tank, along with the concentration of the substance in the fluid. We also know the initial concentration of the mixture in the tank. The problem is to determine the concentration of the substance in the tank at any given time if we are given the exit rate of the mixture. Students will usually solve this problem by setting up and solving the differential equation
$$x'(t) = \text{input rate} - \text{output rate}$$
Students to visualise the rate of change in concentration, by colour variation, and can simulate the mixture problem by changing input and output rates, and concentration levels.
4. Linear Regression: Figure 4 shows an example of an interactive model to investigate the linear regression line. Students are able to add up to a maximum of twenty points, each with a mouse click, anywhere on the grid. The line of best fit is shown, and varies with each additional point. At the same time, the slope, the y-intercept, and the equation of the line can be observed.

In addition to the type of interactive models described, further interactivity is provided through the use of WebEQ[2] to create interactive equations, and LiveMath Maker[3] to enable step-by-step stages in working through calculations and solving equations.

[1] Click2learn.com, Inc. (formerly Asymetrix), http://home.click2learn.com
[2] Design Science, Inc., http://www.dessci.com.
[3] Theorist Interactive, LLC., http://www.livemath.com.

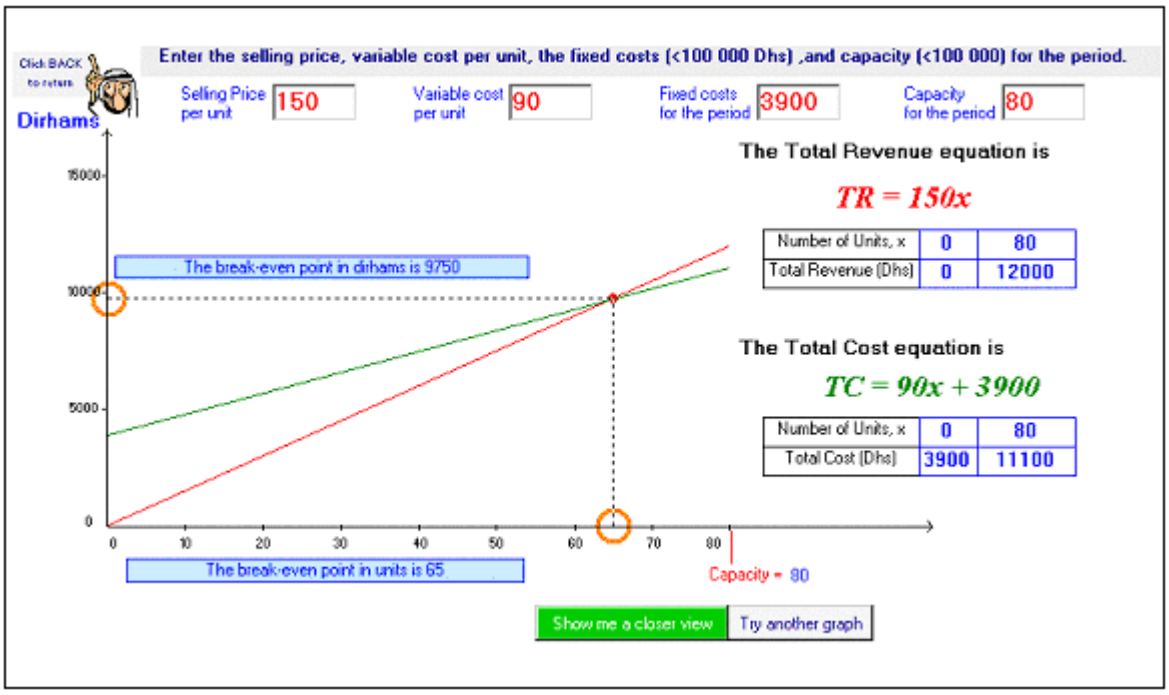

Figure 1

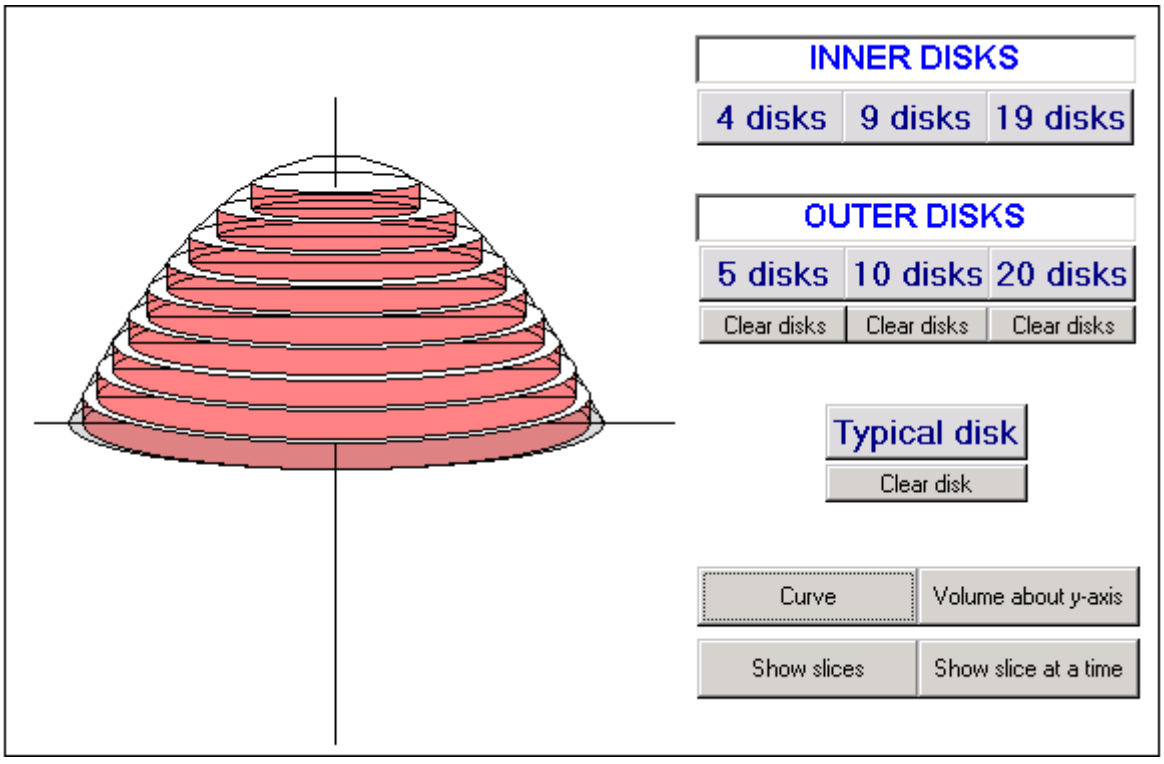

Figure 2

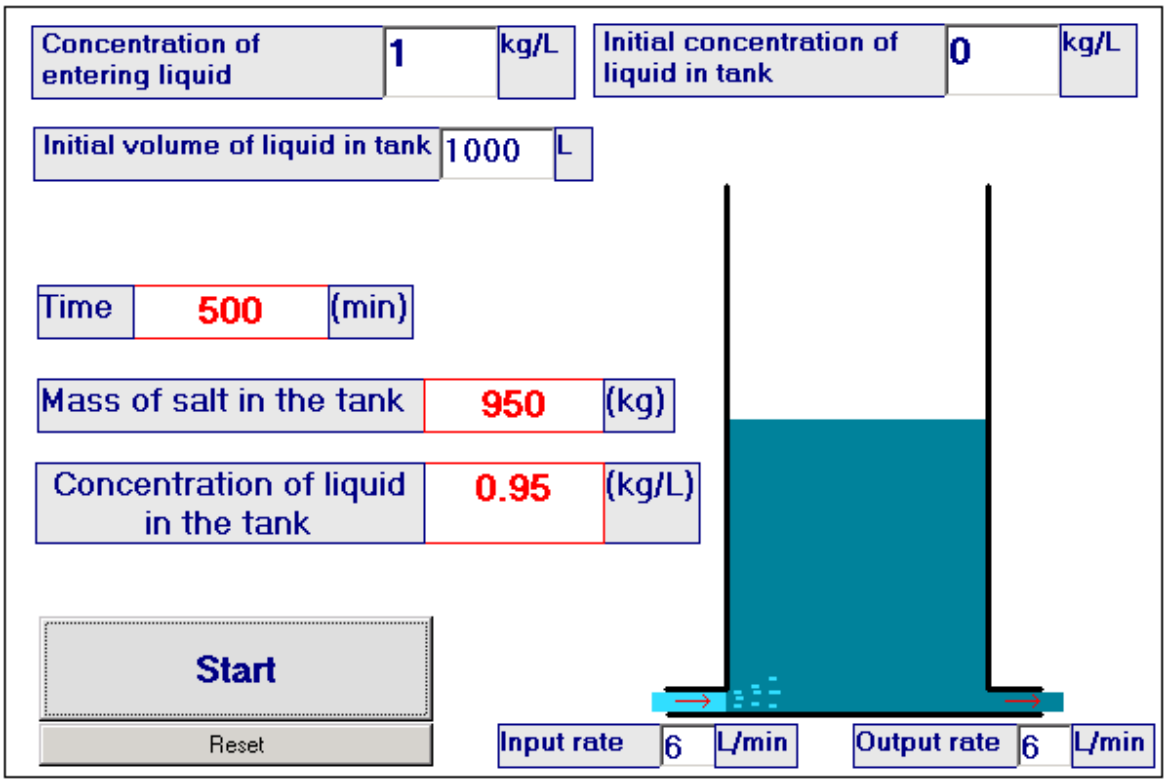

Figure 3

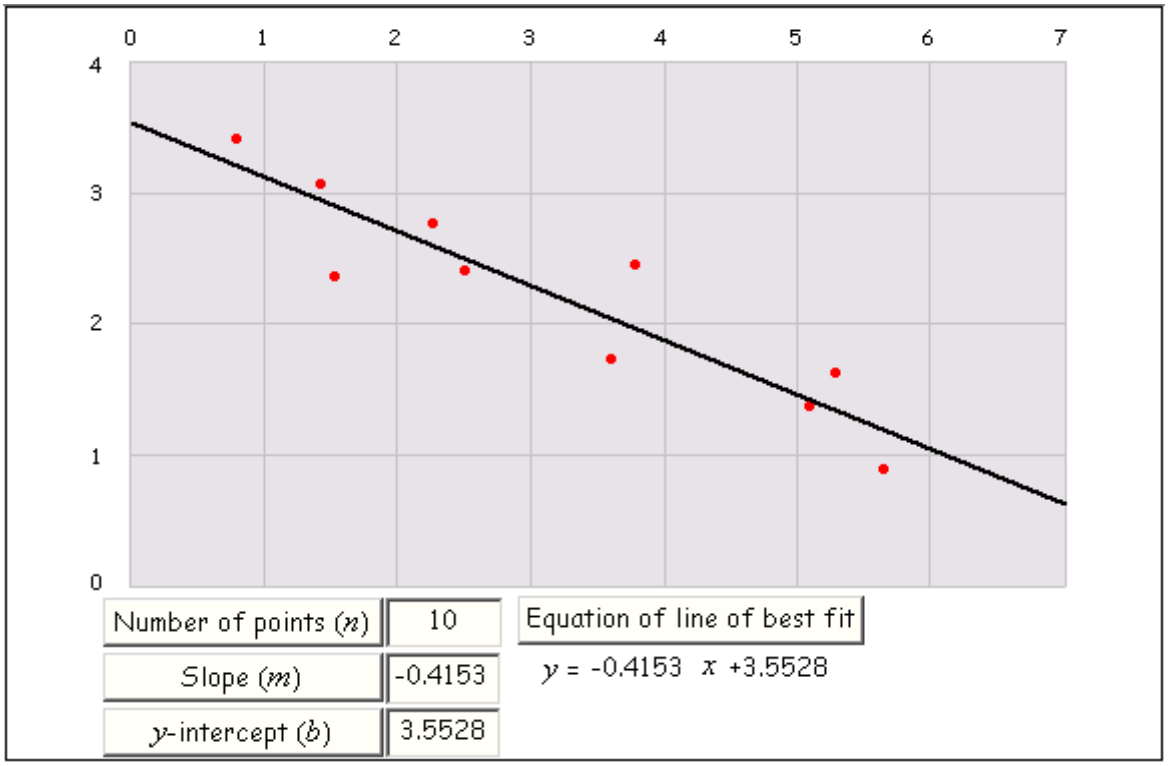

Figure 4

5. Conclusion

The authors are working on projects to produce online courses in business and engineering mathematics. The initial stage is to develop something fairly compact, but effective, manageable and applicable to the 'computer classroom'. Students should have the opportunity to use interactive learning models as central to their learning process. The intent in developing these on-line courses has been to structure them in a way that they can be used as effective learning tools primarily in the classroom, making it possible for students to participate in a synchronous communication learning environment. It remains to be seen if this modification to the learning environment brings further motivation to students and stimulates their interest in the mathematics.

As teachers foremost, who are interested in bringing mathematics to students in a meaningful and enjoyable way, we believe that an online learning environment that is developed from the students' enquiring perspective and allowing investigation of concepts through interactivity can produce successful outcomes. However, what goes on in the students' minds is not visible and far from clear, and as designers, we must be constantly aware that what really matters is 'the quality of the instructional message, rather than any inherent characteristics of the instructional medium used' (Taylor, 1996). Clark (1983) also reminds us that educational technologies are 'mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition'. We can surround ourselves with technology without producing a significant increase in pedagogical efficacy. It is therefore important to ensure that we are not simply providing students with learning resources and materials online, rather we are providing them with the means and techniques to get the most learning out of those resources. In terms closer to the UAE, the analogy would be "It's not how fast you ride your camel; it's how you ride your camel fast!"

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