Use of distance learning to teach discrete event simulation

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Summary

The increased demand for training in discrete event simulation prompted innovation in the manner in which learning materials are packaged and presented to students. Analysis revealed that professionals responded better to a non-linear, interest-driven approach to learning versus a standard classroom environment and presentation. This approach was also appealing as it allowed course information to be organised and stored in granular chunks, permitting the creation of a database of reusable learning objects. By leveraging the global penetration of the Internet with Flash technology, it is possible to offer an economical new style of learning to an essentially infinite classroom size. An electronic learning system for discrete event simulation was designed and implemented that embodied each of these concepts.

Key words: discrete event simulation, online distance learning, Flash, learning objects

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Introduction

There is an increasing demand for training in discrete event simulation (DES), yet there are a limited number of instructors available in this newly applied area in medicine. This rising interest level is not surprising given the advantages of this technique over existing approaches[1], coupled with the growing sophistication of the decision makers who use models to address those aspects that clinical trials cannot. DES is a modelling technique that conceptualises the course of a disease and its management in terms of the events that happen and the impact these have on patients and other components of the system. Its greater flexibility and realism allows researchers to address actual questions in relevant, credible ways without extensive simplifying assumptions. However, an important drawback is that this requires analysts to abandon familiar territory and to learn new methods. Although DES has been used extensively in other fields[2–4], its application in medicine has so far been limited. For these reasons, the use of online learning to allow rapid dissemination of expertise in this area was explored.

Online learning is increasingly moving from the ranks of complementary education and becoming a desired avenue both for professional and institutional (post-secondary) learning[5,6]. With a large number of colleges, universities and corporations offering online and distance learning options[6,7], both students and managers have greater choice when it comes to deciding how to spend their education dollar.

This paper describes the process of teaching DES online. It examines the decisions that were made regarding curriculum, presentation and deployment, and it discusses the impact of an online DES course for the parties directly involved, as well as what distance learning brings to pharmoeconomics.

Methods

The starting point for the online course was a lecture series on DES[8]. The bulk of the presentations consisted of traditional in-person discussion using slides as visual aids. The initial challenge was to decide which type of online presentation would best synthesise these two elements. A conscious effort was made to ensure that the online learning system would not be merely 'slides with narration', as it was felt that this would not engage a student, nor would it provide the desired level of interactivity. Instead, several 'screen types' were conceptualised to reflect specific approaches to conveying a point. Serving as general templates, these screen types were organised along the lines of the types of information being presented. These broke down into screens that displayed a dynamic video of some action taking place (Figure 1), screens that were text or graphically driven (Figure 2) (images, graphs, charts), interactive screens (Figure 3) (where users manipulate on-screen objects, for example) and screens that employed animation (Figure 4). The majority of screens, regardless of type, were to be complemented by narration; not repeating what may be written on the screen, but going beyond the text to provide an in-depth explanation of the concept being illustrated.

Figure 1. A screen image of a video lesson illustrating a working DES model of a distribution terminal.

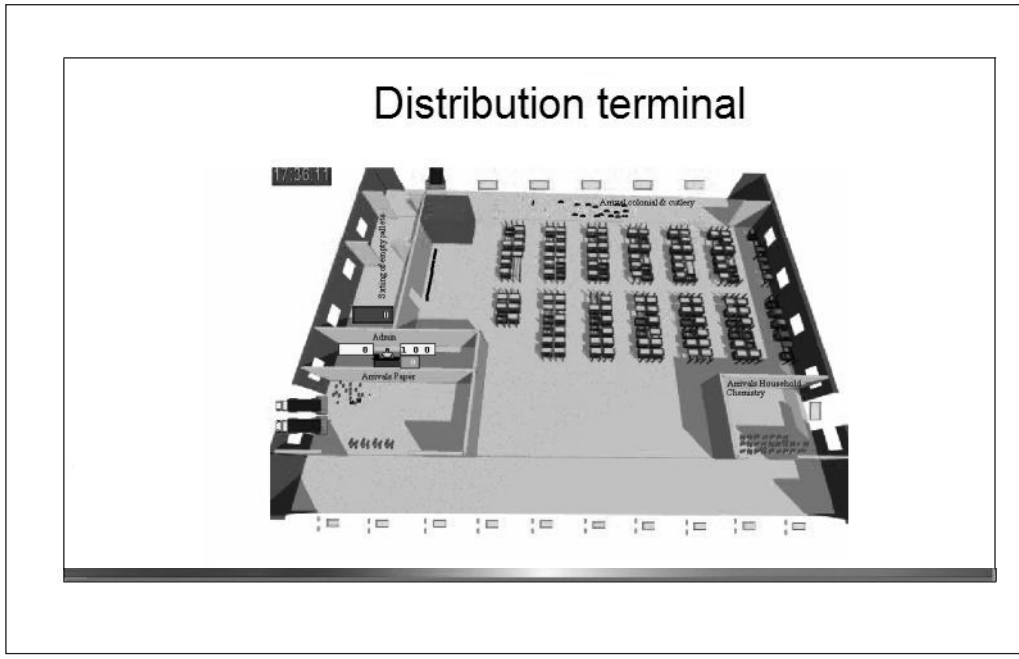


Figure 2. Screen image of a typical text and graphics type lesson screen.

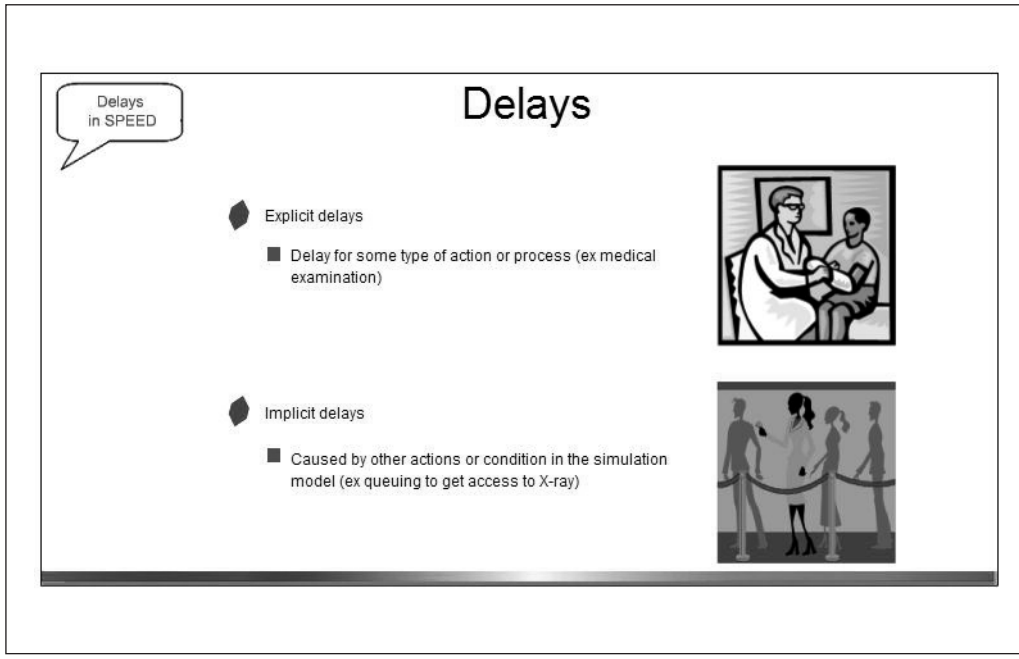


Figure 3. Screen image of an interactive lesson screen type. Student can drag and drop flowchart logic with the mouse.

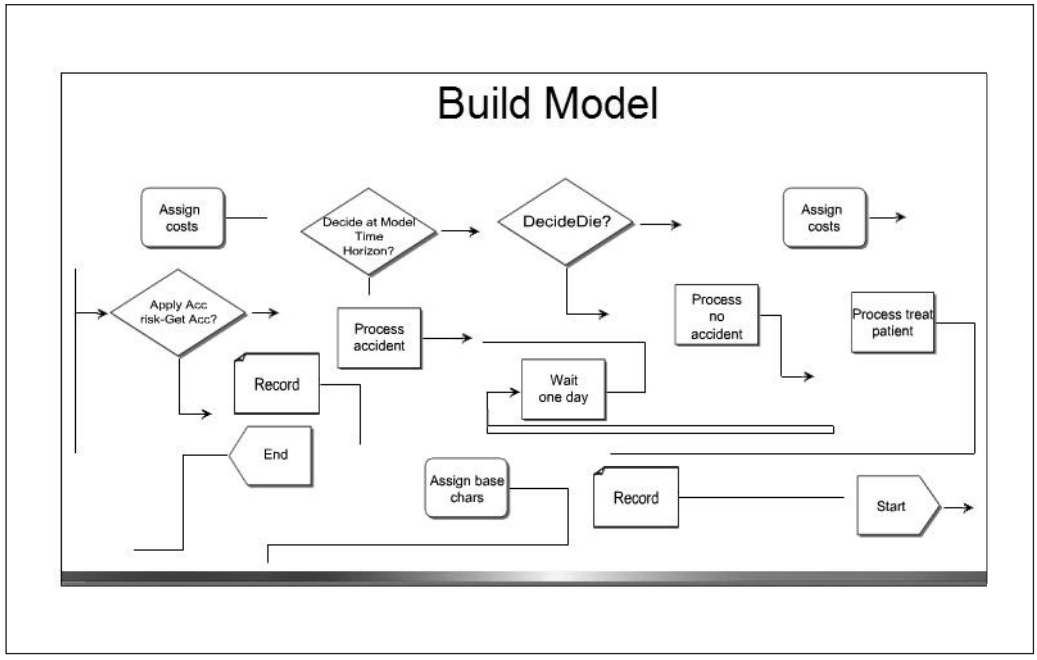
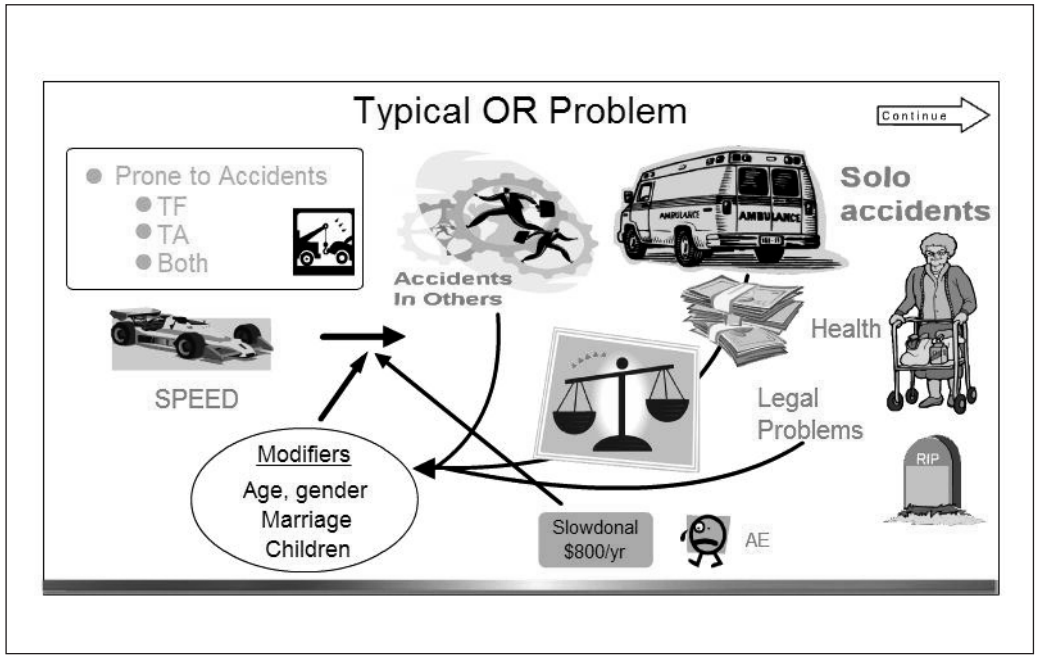


Figure 4. Screen image of a typical animation-based lesson screen type.

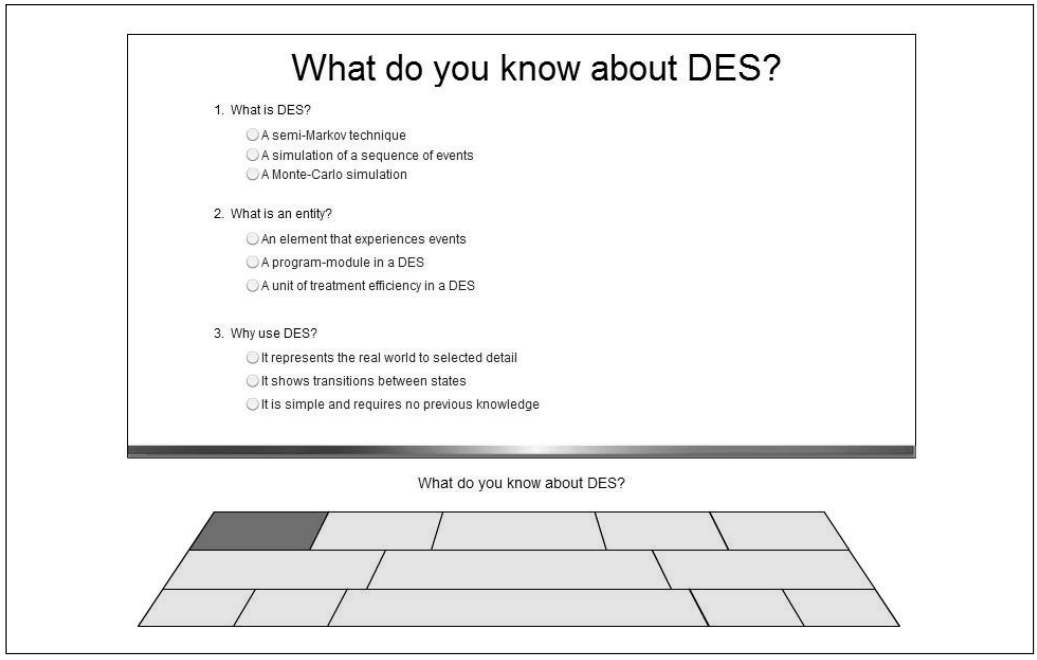


Next to be addressed was the organisation of the curriculum and how that would affect the learning experience. The decision to organise the course into discrete learning objects[9] was made for several reasons. A learning object is a discrete 'chunk' of knowledge that is free-standing and non-sequential. The appeal of such objects is great: they can be pooled in a database to be reorganised and reused in future courses and in different contexts; they facilitate interest-driven, explorative learning; and their granularity allows customisation of course contents to a large degree. The course was divided into six modules representing specific interest areas of the curriculum. Each module contains a certain number of 'lesson screens', which are the learning objects. Ultimately, the design permitted the student to access any screen in any of the modules and be able to understand what was presented to them by that lesson without the need for any explanatory context. A positive side effect of this design is that it allows a student to use the course as reference material, even after it has been completed. By separating knowledge from a sequential or explanatory context, it becomes applicable at any time in the learning process. In a similar vein, if desired the current course structure could also be moulded into an inline help system for a DES application.

The following step was to choose the technology that could best present these desired screen types on the World Wide Web. Since multimedia content was integral to the subject matter, a solution that allowed for the packaging of audio and video into a reasonably sized streaming file type was required. Several options, such as proprietary software[10] or educational service providers[11], were examined but it was ultimately decided to use the Flash format from Macromedia. Flash is an internationally accepted Web standard that creates an interactive multimedia experience over broadband connections[12]. It is cross-platform (meaning that it can be run by any type of computer operating system) and has the advantage that most Internet users are already familiar with it; 96% of all computers worldwide with Internet access have the Flash player installed[13]. Flash files are embedded within standard hypertext mark-up language (html) files and then viewed in any Web browser. For the purposes of the DES course, Flash file content is linked to xml files at the server level to facilitate rapid updates to course information. For students to access this multimedia content adequately, even in this compressed and streamed format, a broadband connection is deemed to be a requirement.

The navigation system for each module (i.e. the method for getting around the system) was designed as a panel divided into smaller tiles (Figure 5). Each tile gives access to a lesson screen. The student can click on the tiles in any sequence, including repeating previously accessed tiles. Thus, the lessons called by the tiles are designed to be free-standing without requiring viewing of any other lessons. Nevertheless, some guidance is provided for the student by arranging the tiles so that clicking on each one from left to right loads the lessons in a suggested learning sequence. The first

Figure 5. Screen image of the navigational system for each module.



Each navigational tile is associated with a lesson screen. A lesson is located by clicking on a tile. The lesson name associated with the highlighted tile is displayed above the navigational panel.

tile loads a summary of the module's objective and content, and the final tile loads a quiz that allows the student to self-certify that they have understood the knowledge presented in the module. Once a module has been marked as completed, the student can use it as reference material, but cannot retake the quiz.

Additional navigation is provided to access complementary information for selected lessons. More in-depth information on a given subject can be found by following what are called 'tangents'. These tangents are additional lesson screens that are not essential for conveying the point of the lesson. Tangents are represented by special icons displayed in lesson screens (Figure 6).

The use of tangents allows for the preservation of the non-sequential navigation system, while at the same time providing an in-course appendix of examples and explanations.

This design permits the student to access any screen in any module quickly and to be able to take in what was presented to them by that lesson without the need for any explanatory context. It also allows a student to use the course as a reference material, even after it has been completed. Students are able to track their progress through the course in real-time; an interface exists wherein a student can verify which lessons they have self-certified as complete (Figure 7).

Figure 6. Tangents appear most often as clickable bubbles at the end of a lesson screen's presentation.

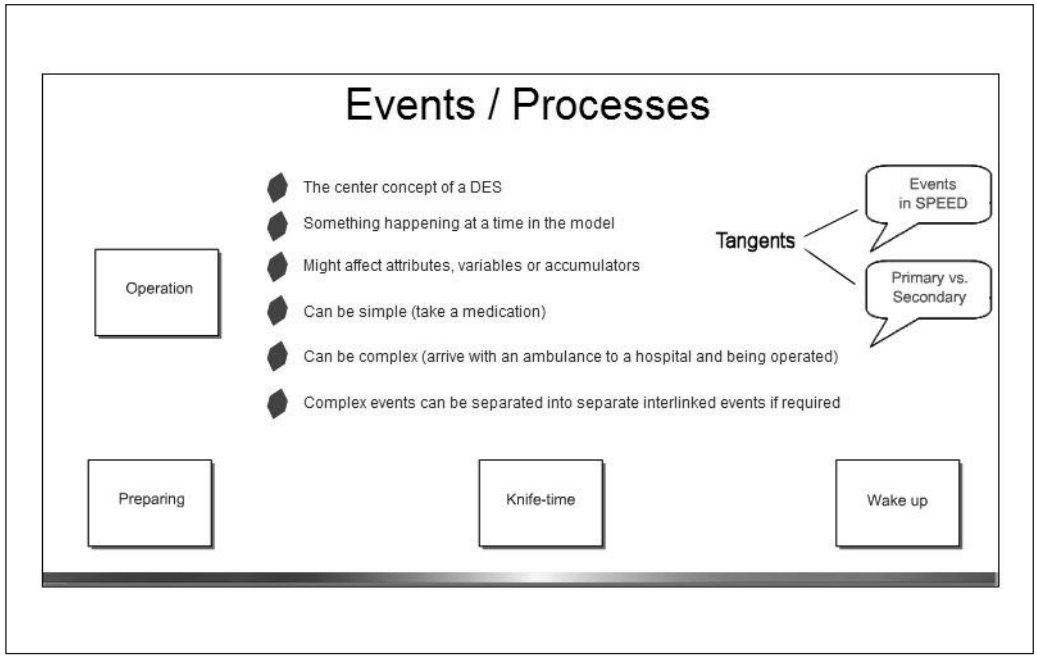
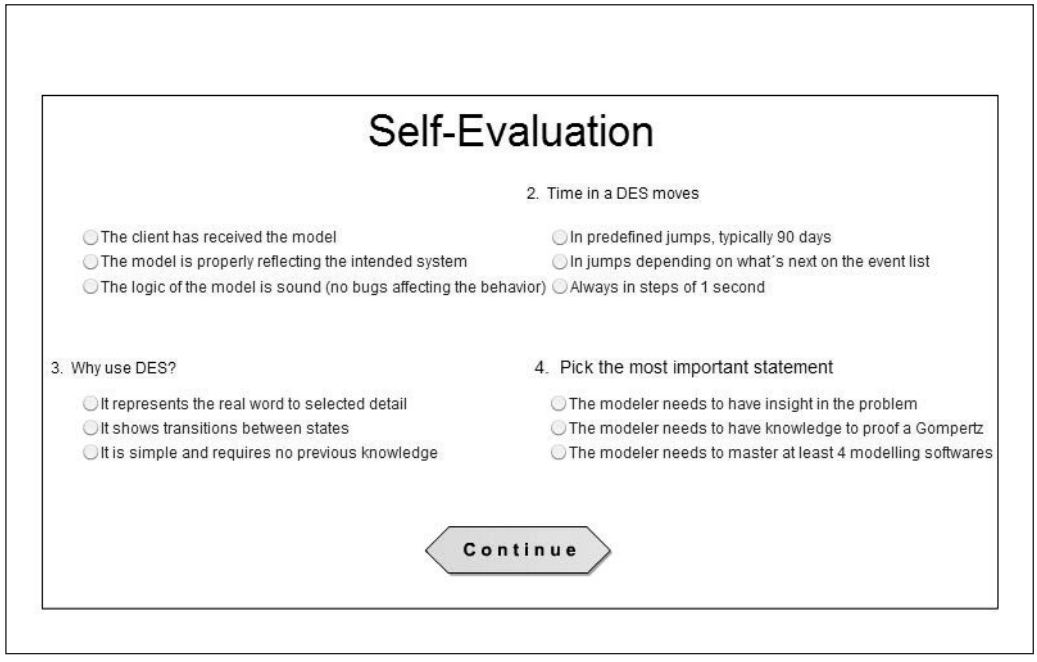


Figure 7. This screen image is part of the self-certification system for each module.



Results

Whilst the online DES course was designed to be non-linear, initial user testing indicated that although this approach was not necessarily confusing, certain aspects of the course framework should bear a measure of familiarity. Building on the recommendation of these early testers, the course is served by several recognisable organisational aids. The first of these, the main course menu, is encountered after the student has logged in. Much like an index in a book, the main course menu is divided into 'chapters' called modules. These modules are collections of lessons, (i.e. screens of information that each convey a specific DES concept). To provide a suggested roadmap for progressing through the course, the modules are ordered from one to six, beginning with an introduction to the basic concepts of DES. The remaining modules include but are not limited to: a focus on specific DES concepts; details on how to construct a simulation; an interactive module wherein the student is given the chance to create their own simulation logic; and examples and reference materials relating to real-world applications of this modelling technique.

Other screens accessible from the main menu include the user help information and progress meter. The progress meter allows a returning student to view a list of which modules he or she has self-certified as complete, whilst the user help information explains the interface and navigation and allows the user to contact the course administrator via e-mail. In fact, the user help screen is loaded and displayed immediately after login. The decision to do this followed the revelation by several students that they had discovered the help screens only after making significant progress through the course. They informed the development team that the information contained in these screens, particularly with regards to navigation, would have been much more valuable had it been encountered at the start of their course experience.

Individual lesson screens, themselves free-standing learning objects, are complemented by tangents. Tangents are an organisational concept allowing students to go deeper into a certain topic without interrupting the flow of a module. The original plan for using tangents was to function as a sort of glossary for terms or ideas that might have been unfamiliar to the student. During development, this was expanded to include examples to bolster the information found on the lesson screen as well as to provide greater background on modelling theory and practice. Similar to hyperlinks in both function and form, tangents are accessed via clicking on labelled icons that appear on a lesson screen following narration.

Initially, narration was going to be used selectively in order to expand specific lesson screens that contained too much information to be comfortably represented by text and graphics alone. However, as development progressed, it was difficult to find lessons that would not benefit from narration. As a result, almost every lesson screen contains an audio element. In practice, this proved to be somewhat

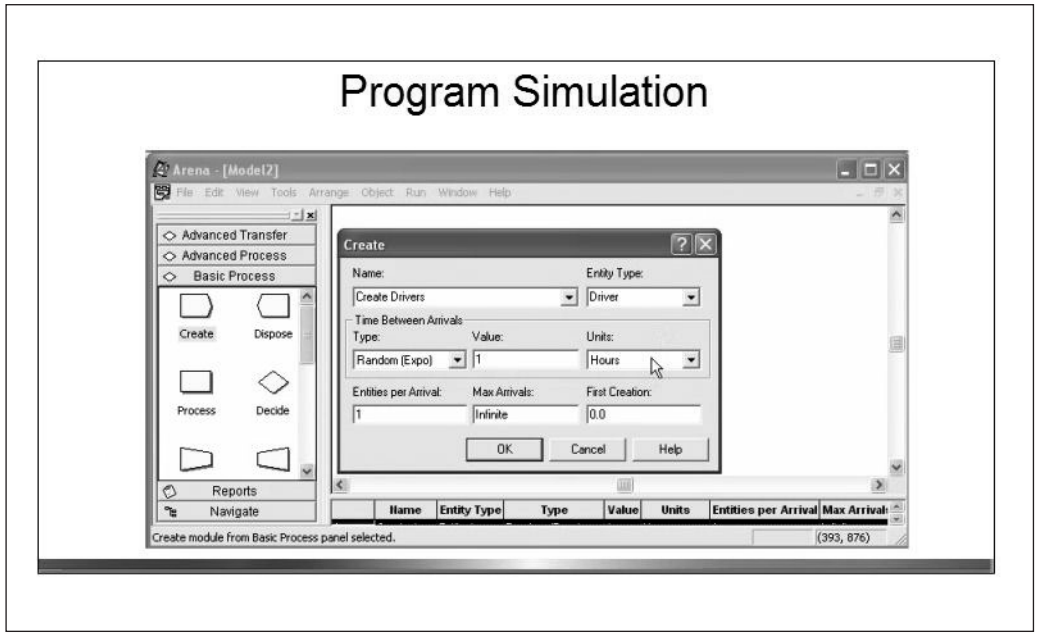
problematic; students came to expect that every screen would be narrated, and some commented that when they encountered a 'silent' screen their first impression was that perhaps an error had occurred. This required an addendum to the course's help file to explain that some screens did not have any accompanying commentary.

Narration is tied to specific timelines in lesson presentation; rather than being a lecture, the script and timing of the person speaking is linked to the animation, video or flow of presentation on the lesson screen. This also caused confusion amongst some users. Certain video presentations or animations contained breaks in the narration, much in the same way that a human presenter would pause during a demonstration. However, in the online environment, certain students interpreted these breaks as audio 'drop outs', and assumed a technical fault. To combat this perception, visual progress meters were added to several of the longer videos so to give an indication that all was proceeding normally despite the absence of sound. Students can repeat the narration at any time during lesson presentation by re-loading the lesson screen.

There are some aspects of DES that require a different method of presentation in order to describe their attributes properly. One advantage of DES is the ability to assign unique characteristics to each entity in a simulation. Entities can represent anything from patients to jet airplanes. Since each entity is unique, their interactions with elements of the simulation and ability to experience individual events create a more accurate representation of reality[1]. The online course employs animation to illustrate the possible uses of DES in pharmoeconomics. One such example centres around entities experiencing the effects of a fictional medical condition. As DES is an event-driven type of simulation, students see each entity, represented by a visual avatar, move through the simulation. Each entity experiences events such as treatment, complications, lifestyle decisions and changes in risk factors. Each event affects the outcome of the simulation for each entity. The example also provides for a comparison between different types of treatments, and the effect that these choices can have on patient outcomes.

Video is also used to demonstrate examples of DES in action, both in pharmoeconomics and in other industries such as air transport, train stations, industrial factories and distribution. Through the use of an application called Camtasia[14], it was possible to expand the role of video to include walkthroughs of software such as Arena, which is used to construct simulations. By recording the actions of an Arena user as they used the software, and then displaying this as a video along with narration, the effect is similar to standing over the shoulder of an expert modeller and watching them build a DES from scratch (Figure 8). In addition, these videos are re-watchable as many times as is necessary for the individual student to understand the points being made. Flash technology also

Figure 8. This screen image illustrates a video lesson demonstrating the construction of a DES with Arena software.



DES, discrete event simulation.

enables students to drag and drop modelling 'building blocks' to create their own simulation logic. Both of these lesson forms are not easy to duplicate in a seminar or classroom setting.

One of the main challenges faced during the development process was to present a rich multimedia experience while at the same time maintaining as small a Flash file size as possible in order to preserve the smooth delivery of course content. On average, a file consisting of both narration and video demonstration encoded to approximately 2 megabytes, with the largest such file being just over 16 megabytes. This is in contrast to non-media heavy files in the same course that averaged 500 kilobytes. Whilst these file sizes may seem large, their size is made a non-factor by the capability of Flash to 'stream' a file as it is downloaded; that is to say, a student is not required to download the entire lesson screen before they may begin viewing that lesson; loading occurs synchronously, in the background.

After extensive user testing, it was discovered that the average time for a student to complete the course was 1 day; an improvement on the 2–5 days required to teach the same content in a live classroom setting. Student reaction was also favourable regarding content. The primary concern when developing any new curriculum is whether it will effectively educate the audience on the chosen subject. This was slightly accentuated during development of the online DES course due to the fact that it was intended as an improvement of a highly

successful in-person course. Fortunately, initial student feedback in this area has been positive. Early classes indicated that in fact, they found the online course to be more informative than some of the introductory in-person training they had received regarding DES.

Discussion

Fundamentally, training employees has always boiled down to a question of logistics. Operating on a timeline restricted by the demands on internal projects and duties, managers have had to make difficult decisions regarding the best manner in which to invest their finite education budgets while at the same time maintaining employee productivity. The act of sending employees away to seminars or training centres can be quite disruptive both to the day-to-day working of a company and also to the decision-making process, particularly if key personnel are involved. Conversely, these concerns also manifest themselves on the other side of the coin: for learning content providers, scheduling the requisite number of students to appear in one place at one time in order to make a course profitable enough to undertake can be difficult, time consuming and stressful.

An online learning system allows educational content to be delivered to any point in the world with an Internet connection. This allows students to access the curriculum at their own convenience and on their own schedule. The online DES course is able to provide an in depth curriculum while allowing for all the necessary feedback and student interaction that is so important in creating a successful learning experience. It also offers significant savings. Elimination of the costs and problems associated with providing a traditional in-person course, combined with the reusability of learning objects, is a practical and economic advantage both for the administrator and the student.

Whilst there was a significant time investment associated with the development of the learning system, as well as the need for new technology training, the return on investment for this online course is quite favourable both for students and the developer. From an administrative perspective, once the initial infrastructure for course deployment has been completed, the only recurring costs associated with the DES course are maintenance costs. What this means is that unlike a classroom setting, there are no costs associated with each new instance of the course being accessed by a student. A further advantage to online learning is that instead of having a finite number of expert trainers who can teach a limited number of students at a time, you have a system that can be concurrently accessed by as many students as are interested in enrolling. The online DES course in sense opens the floodgates, allowing a limited resource (DES modelling experts) to be tapped by an unlimited number of students.

It takes 50% less time for a student to complete the DES course online versus the in-person seminar. Indeed, most online courses will return a 35–45% decrease in this area[15]. While students may be spending less time with their learning materials,

studies have indicated that technology-based training fosters a 24–34 % greater 'learning gain' in comparison with traditional classroom teaching[15,16]. This 'learning gain' translates into greater content retention, higher motivation to learn, and an increase in job performance[17]. When combined with the savings experienced by students in wages, opportunity cost and travel costs, the overall value of distance learning is clear. Typically, return on investment for corporate off-the-shelf online multimedia training versus traditional training approaches 30% in the first 2 years and more than 100% over 3–4 years[15].

It is the 'distance' in 'distance learning', however, that is usually the focus for critics of this type of system. Whilst it is true that during the past decade the Internet has radically transformed the way the world does business, there are those who still harbour what could be termed 'traditionalist' views in training and education. Elementary and high school classrooms have made great leaps integrating laptops[18], and universities have integrated online student services and curricula[7], yet it has taken the business community a bit longer to come out from under the notion that training videos or server-hosted PowerPoint presentations represent the apex of computer-assisted learning. The absence of a teacher or training leader can be a difficult conceptual roadblock for management and even students to overcome. Recalling the correspondence course model of years gone by, many worry that students will feel isolated and apathetic, and that distance learning resembles more of an independent study than a dynamic, interactive educational method[19]. It is natural for people to erect mental barriers against the unfamiliar, but fortunately the many appealing and demonstrably useful aspects of this learning technique have been winning increasingly open-minded converts[5].

One of the key challenges in education is engaging the student in such a manner that the curriculum you offer them becomes meaningful. It is through such engagement that the knowledge offered in a course is properly taken in. At first glance, it might seem that removing a guiding figure such as a teacher from the equation could be a barrier between the student and the materials. In a traditional classroom setting, teachers are typically regarded as sherpas guiding their students from one salient point of interest to another. But a traditional classroom setting does not always translate well in the business world, and at worst can devolve into a figurehead behind a podium reading bullet points off of a projector, which tends to make people think more about the next coffee break than the curriculum itself.

One of the best solutions to this problem is to allow the student to assume the role of their own guide through the course and to use their interest level to direct their navigation of course materials[5]. This was the approach taken in the online DES course and it has proven to be beneficial. By providing a framework that encourages interest-directed exploration and by providing meaningful milestones that give

the student a feeling of accomplishment and allow them to gauge their own progress, it has been possible to create an educational environment where people felt comfortable advancing at their own pace. Another advantage of this approach is that by removing the learning system from the classroom environment, a student's experience is at no point derailed by other students; whether it be by those who cannot keep up with the rest of the group or those who would force the class down unplanned tangents with off-topic questions.

Whilst distance learning removes both the student and the curriculum from the standard classroom environment, that is not to say that the avenues of communication between the student and course administrators have also been severed. Communication with administrators is easily accomplished via e-mail. In fact, e-mail allows for more detailed questions and answers, as both parties have the luxury of time to compose their messages; especially as the student is not battling the clock and other students for extra attention.

Some of the more difficult aspects of creating the online DES course were, as is usually the case, unforeseen elements of the process. Recording and editing narration so that it closely matched the flow of lesson screen presentation proved to be quite time consuming and, in fact, after content creation, was the single greatest area of resource expenditure. The proper audio equipment for such an enterprise is essential for cutting down on the amount of time spent in this area. Compression of the video into a manageable file size also required time-consuming experimentation at first.

The next largest hurdle came at the conclusion of course development. It may initially seem as though once a learning system is completed and coded the project is essentially finished, but this is not the case. Offering a course of this nature posed several important questions. How will a company support such a course? Who will answer the remote student's questions? What kind of infrastructure is required to undertake such a thing successfully? These three points were the subject of much debate amongst the administrative team and should have been more clearly dealt with from the project's initial conception.

It can be concluded that there is no one-size-fits-all solution when it comes to deploying a distance learning solution. Many of the questions that must be asked are questions of scale: the projected size of the student audience and, just as importantly, the size of the organisation offering the course. These two factors alone can drastically affect the level of interaction and service that can be offered to students taking the course, from determining how many staff will be able to serve as contact points for student questions and to what level of interaction with students is expected (and what level is desirable). It also affects something as ostensibly straightforward as managing billing and tracking of the students and organisations matriculating throughout the system. Even if the decision is made early on to start small

and offer the learning system to a controlled number of students, it is critical to create an infrastructure that will easily scale up should more users be added in the future. In addition, not all companies may be capable of or comfortable with handling the technical end of administration, which can include organising and maintaining a Web space, processing electronic commerce and troubleshooting individual users' technical issues. In this case, the choice could be made to subcontract these aspects of a learning system, provided there is adequate and open communication between the management contractor and the internal course administrators.

Beyond the nuts and bolts of implementation, however, there lie several interesting and perhaps overlooked aspects of teaching DES online. Whilst DES is an industry standard simulation technique in many other spheres of interest (airlines, manufacturing, shipping etc.), it has yet to be widely applied in pharmacoeconomics. This can be attributed in no small part to the number of modelling techniques already established in this field (such as Markov modelling) and the low percentage of professionals knowledgeable in DES.

Whilst inroads for DES have been made by presentations at international conferences and manuscripts published in pharmacoeconomic journals, these forms of discourse serve at best to build awareness. A more detailed survey of DES can be provided through workshops at conferences, but the time constraints imposed by the nature of these events, coupled with the substantial amount of time between each conference and the logistical nightmare of attempting to attend more than a limited number per year, do not lend themselves well to actually learning enough about this form of simulation in order to put the technique into practice.

The online DES learning system has the potential finally to tap into the large number of pharmacoeconomic professionals who are looking for more than a cursory introduction to this modelling technique. Each presentation of this course has only drawn more and more inquiry, indicating that there does indeed exist a groundswell of interest in DES training. Offering an in-depth DES curriculum to all pharmacoeconomic professionals with Internet access is a chance to level the playing field versus the more established modelling techniques, and at the same time create new champions of this particular method of pharmacoeconomic analysis.

Online learning systems represent a similar opportunity in many fields of interest. One of the more impressive aspects of the Internet is the rapid, worldwide dissemination of almost any type of information. Such an environment has rapidly altered several industries as older, and in some cases dogmatic, methodologies have been forced to compete on their own merits with newer philosophies in front of a global audience. The prospect of an organisation being able to offer millions of people a directed and in-depth presentation of a particular technology, process or methodology is both exciting and finally cost effective.

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