

**THE VIRTUAL ANESTHESIA MACHINE:  
AN EDUCATIONAL EXPERIMENT  
IN INTERACTIVE, REAL-TIME  
WEB SIMULATION AND PHILANTHROPY**

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**INTRODUCTION**

Traditional didactic materials such as textbooks are often primarily text interspersed with static pictures and graphics. Descriptions based on text and static graphics of complex, inter-related processes that evolve and branch over time may be tedious and hard to follow for visual learners who respond better to graphical interactive representations (Ohrn et al., 1997). Static graphics lack the elements of time and interactivity. Additionally, some processes, such as gas flow, are by nature invisible and thus made harder to visualize and understand (Lampotang et al., 2000).

With the introduction of the personal computer (PC), computer-based, electronic training became popular. Some earlier computer-based training consisted primarily of glorified, electronic "page turners," based on a textbook metaphor. That is, pictures and text from textbooks were reproduced in electronic format and, effectively, the power of the PC was used mainly to decode the bits comprising the data and "turn the pages". Arguably, computer-based training implementing a textbook metaphor did not fully exploit the power of the PC and may have been a

confounding factor in studies that found no difference in learning between computer-based training and traditional didactic materials (Vichitveipaisal et al., 2001).

With the advent of the Web, some educational Web sites replicated the textbook metaphor. While placing educational material on the Web certainly increased accessibility, it can likewise be argued that the potential of the Web may not have been fully maximized with “page turning” Web sites. Other reasons why some educational resources failed to reach large audiences include: 1) they were not originally designed for Web dissemination and could not be readily posted on the Web; 2) they charged a fee for use, excluding potential users without financial means; and 3) they were platform specific and could not be used on both Mac and Windows PCs (Lampotang, et al., 2000).

The major purpose of this paper is to describe the development, implementation and results of the use of a simulation designed to counteract problems identified above in the use of computer-based electronic training tools. The study provides not only the data collected in usage, but also describes the outcome of a specific funding scheme for such developments.

## **DESCRIPTION OF THE STUDY**

### **Background Information**

Anesthesia machines are used to induce and maintain a state of general anesthesia so that surgery may proceed with a minimum of pain. Patients are, during certain phases, utterly dependent on the anesthesia machine to breathe for them and failure or misuse of the anesthesia machine may lead to patient harm. Anesthesia machines therefore function as life support systems and as such, it is

essential for users to have a sound understanding of the anesthesia machine and its potential failure modes.

Obstacles to understanding the anesthesia machine include: 1) gases used in anesthesia are invisible; 2) piping is often hidden and it may not be obvious how components are interconnected; and 3) electronics and software are integrated with the basic pneumatic system, making the anesthesia machine even more complex.

### **Objectives of the Study**

The objectives of the study were twofold. The first goal was to create an engaging, interactive, real time, Web-based simulation of an anesthesia machine that addressed the previously stated obstacles. Secondly, this study would explore the viability of a funding model based on the hypothesis that free, high-quality materials would attract heavy traffic that would in turn attract sponsorship and donations.

### **Development of the Simulation**

To address these objectives, the “Virtual Anesthesia Machine” simulation, accessible at <http://www.anest.ufl.edu/vam>, was created using Director 8.0 (Macromedia, 2001). The Virtual Anesthesia Machine is an interactive, real-time, animated simulation of gas flows in a generic anesthesia machine, based on the premise that *if a picture is worth a thousand words, then an animation is worth a thousand pictures* because the crucial dimensions of time and interactivity are added.

Instead of complex, dimensionally accurate drawings of an anesthesia machine, the Virtual Anesthesia Machine presents a simplified, yet conceptually accurate, mental model designed to help viewers appreciate and retain basic concepts. To assist visualization, gas

“molecules” are made visible and color-coded (US/ISO gas color codes). Mathematical models drive the simulated flow of gas molecules.

Users can adjust 30 controls and observe in real time the essential effects of their interventions on gas pressures, flows, compositions and volumes (lung, bellows and breathing and scavenging bags). The simulation can be paused to capture fleeting events that may be easily missed.

Machine faults that represent potentially life-threatening situations can be simulated. Gas molecules can be made invisible for teaching situations where gas color-coding interferes with the learning process because color-coding would give away the fault being simulated, e.g., blue nitrous oxide “molecules” flowing in a green oxygen pipeline.

On-line help to use the simulation is available as an animated tutorial. The simulation features Arabic, Chinese, Dutch, English, French, German, Italian, Korean, Russian Spanish or Turkish legends and represents roughly seven person-years of work.

The Virtual Anesthesia Machine is made available only via the Web. The Macromedia Shockwave Web player (a free download, if not already pre-installed on newer PCs) is required to view the simulation from the Web. Upon first use, user registration is required. Instructions for off-line use at teaching locations without Web access are provided at the site.

### **Charges for Use and Funding**

When exploring different modalities for disseminating the simulation, a deliberate decision was made to engage in an experiment in Web philanthropy. Consequently, all materials on the Virtual Anesthesia Machine Web site, including the simulation, were made available free of charge so that financial means would not

be a barrier, especially for students from less developed countries.

Because no income to fund continued development of the Virtual Anesthesia Machine project would be generated from charging for use of the simulation, an alternative funding model based on leveraging traffic at the Virtual Anesthesia Machine Web site into institutional and corporate sponsorship and individual donations was adopted. A working assumption was that manufacturers of anesthesia equipment and drugs would be willing to use part of their public relations budgets to sponsor a high traffic Web site because they would be afforded additional visibility and would share in the goodwill associated with distribution of free, high-quality educational content. The stated goal was that the Virtual Anesthesia Machine project would be financially self-sufficient through funds generated by sponsorship and donations.

### **Measuring Traffic on the Website**

Because the Virtual Anesthesia Machine funding model depended on leveraging traffic into sponsorship, it was essential that visitor statistics be accurately compiled and trusted by potential sponsors. Webalizer 2.01 (Barrett, 2000) was installed on the server hosting the Virtual Anesthesia Machine Web site to monitor traffic on the site. Based on credibility criteria, Webalizer was selected because it did not artificially inflate hits when compiling visitor statistics. For example, request of one web page containing five graphics and audio clips would be counted as one hit by Webalizer instead of five, as certain other monitoring packages might report.

Users were prevented from saving the simulation to local hard disks in their PCs because that would provide a "download once, use many" capability such that Webalizer statistics would underestimate actual use frequency. To

obtain a hit for each use of the Virtual Anesthesia Machine simulation, the simulation was implemented in such a way that it must be downloaded from its Web site for each session. Users have also been required to enter into a legal contract that clarifies that the Virtual Anesthesia Machine is free to use, but not free to copy onto any media, including hard disks, by clicking on an "I agree" button. Users who have not agreed to the contract have been denied access to the simulation.

## FINDINGS

Monthly traffic on the Virtual Anesthesia Machine Web site for November 2002 was 137,174 hits and the total for the five month period of July-November, 2002 was 516,016 hits. The number of registered users, to date, with genuine e-mail addresses is 6,951. User feedback has been unanimously positive—two representative samples follow:

*What a great idea! At last truly useful medical education on the net...* by a resident at Norfolk and Norwich University Hospital, United Kingdom.

*This is one of, if not the best, Web-based educational resource I have ever encountered. Keep up the great work!* by a veterinarian at the Armed Forces Institute of Pathology.

Since monitoring of Internet search engine listings began in March 2002, the Virtual Anesthesia Machine Web site has remained the top entry when performing a Google ([www.google.com](http://www.google.com)) search on "anesthesia machine", establishing the site as the Internet portal for learning about

anesthesia machines. Olympio (2002) also recently gave an overall favorable review of the site.

In addition, use of the Web has facilitated version control and allowed instant dissemination of new Virtual Anesthesia Machine versions (6 versions in 2002) as soon as they are completed, for minimal distribution cost. Emphasis on graphics, instead of text, significantly lightened the translation load and facilitated finding volunteer translators.

Sponsorship currently covers 10% of the annual costs of updating content (including the simulation) and maintaining the web site. Donations total only \$10.

## **CONCLUSIONS AND RECOMMENDATIONS**

Preliminary data and unsolicited user feedback suggest that interactive, real-time Web-based simulation driven by mathematical models appears to be an efficient, engaging and popular means of learning. It remains to be established whether the unanimously positive user feedback is due to the philanthropic approach or the content or both. A study by independent, third party, education experts comparing a computer-based training method using animated simulations driven by mathematical models such as Virtual Anesthesia Machine vs. traditional didactic materials is recommended.

In the short term, the philanthropic funding model has been a failure, funding only 10% of annual operating costs; long-term viability remains to be seen. While the technical objective has been achieved, the other stated goal of financial self-sufficiency has remained elusive. It may be difficult to balance a philanthropic policy with fiscal autonomy, especially in the current economic downturn.

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