Some Educational Technologies Under Development at NASA

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NASA Learning Technologies

1.0 Introduction

To realize one of NASA's major goals, "To inspire the next generation of explorers," many NASA professionals dedicate some or all of their time to creating educational materials that help educate and inspire students in science and mathematics. NASA scientists, engineers and professional educators collaborate to develop interesting and effective materials for K-16 teachers and students, drawing from the tremendous wealth of NASA data, earth and space mission information, and the substantial behind-the-scene knowledge that go into planning and executing space missions.

In this report we describe four new educational software technologies currently being developed at NASA. The teams who proposed these applications were selected from dozens of proposals in a competitive process to receive three years of funding to prototype and complete their ideas, for deployment in classrooms by FY 2006. All these applications are now in their second year of development, and several are available in early-access form and free. (See http://learn.arc.nasa.gov.) At completion, all the project software will be freely available. NASA does not intend to charge for its distribution or use, or for the use of the NASA data these applications visualize.

2.0 Animated Earth

The phenomenal increases in performance and decreases in price of computer technology has made what was once "high-end" capability now available to everyone with a simple desktop or laptop computer costing less than $800. Many software applications we once saw only in museums, universities and large enterprises are now available to elementary school students at school or at home.

One of our projects that takes clear advantage of this is Animated Earth. (See Figure 1 on page 2.) This software displays a model of the Earth in full 3D, and allows students to interact with it the same way they would a video game. The surface of the Earth is textured with real photography taken by NASA astronauts and satellites. The detail gets more precise as the user zooms in, and place-names of physical and political features fade in and out as the student moves over the planet. The student has effectively a virtual globe. Until recently, this capability was available only on very expensive and unique computers.

Figure 1. NASA Animated Earth showing a portion of North America. By simply using the mouse, students can zoom in and out to get more detail and smoothly move to other parts of the globe. Tools exist for measurement of surface features and for overlaying still or animated images of physical or political phenomena such as the motions of hurricanes or the migration of populations.

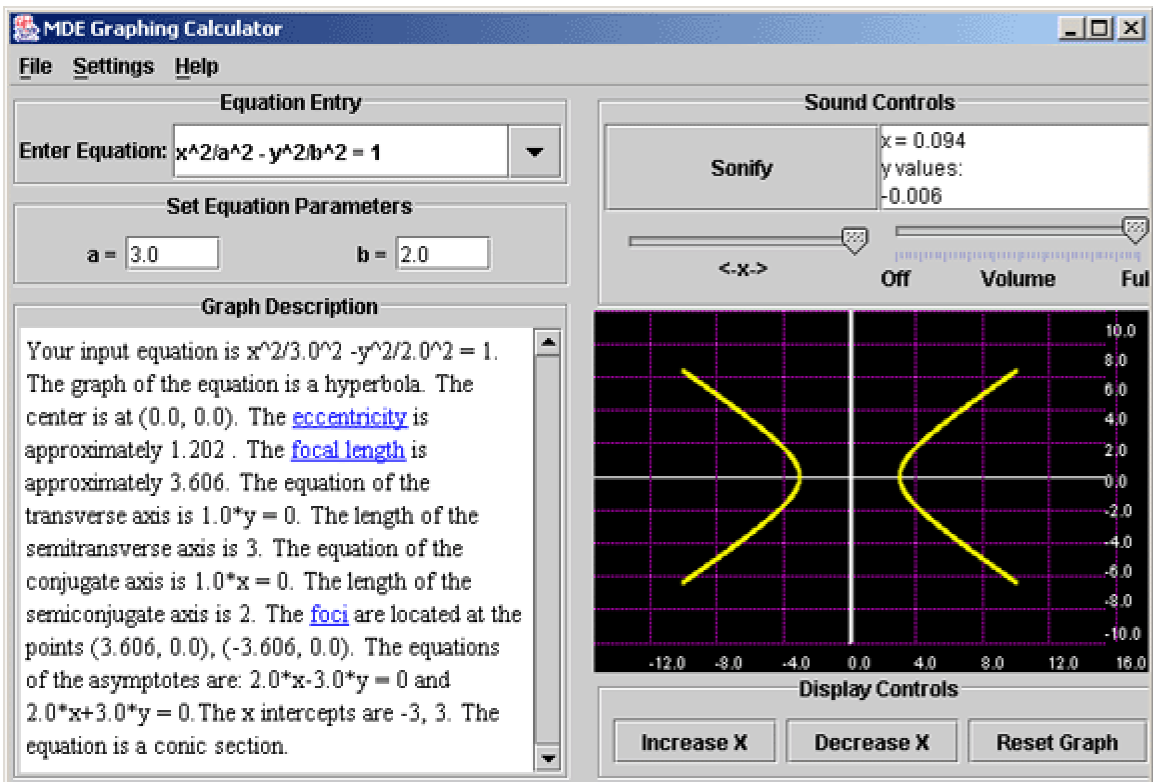
The Animated Earth globe displays more than static information. A second aspect is the display of physical-phenomena animations that overlay the 3D model and can be "played" forward and backward in time. Students can thus interactively study hurricanes, temperature distributions and changes, land usage or population changes, animal migrations, currents, or any of a huge number of phenomena for which there is available data, all in the context of an accurate and visually exciting Earth model. The Animated Earth project team is creating many animations, all of which will be freely available over the internet and seamlessly displayed at the student's computer.

Additionally, the project team is creating an open standard and open-source server software to provide a means for organizations other than NASA to publish, serve and receive animated earth-science information. Ideally, developers of new and existing earth-science applications will design them to utilize this new standard and thus establish broad support for the creation and use of this type of animated information. The project is also using several existing standards such as the Web Mapping Service [1] and XML [2].

3.0 Information Accessibility

Imagine being able to *hear* mathematics. Type in a function, hear how it sounds — in stereo — as the independent variable moves forward in its domain, all the while seeing the function graphed on the computer screen. This is the first goal of NASA's Information Accessibility project, and it's been realized in software technology we call the Math Description Engine, illustrated in use in Figure 2.

Figure 2. Math Description Engine Graphing Calculator showing the curve for $x^2/a^2 - y^2/b^2 = 1$. The equation's description is given on the left, and it is graphed on the right. By pressing the "Sonify" button at the upper right, a sonic description of the graphed equation is generated.



Although originally envisioned as an aid for sight impaired students, Math Description Engine proved to make math more accessible to blind *and* sighted students. Each receives an additional sensory input about the graph of a function they're studying. Math Description Engine provides sonic feedback on virtually any two-dimensional function in rectangular or polar coordinates. Students either type in an equation or select one from a list. The equation is then graphed on the screen, and tones are played that vary in pitch and intensity to sonicly describe the shape of the curve and the relative locations of its points. For example, a simple linear curve with positive slope would generate a tone of increasing pitch from left to right.

Sight impaired students using a computer invariably use "screen reader" software to help them navigate the screen and control the computer. Screen reader software reads aloud text on the screen, and gives audio guidance and feedback for interactions such as keystrokes and menu selections. It enables a blind person to efficiently use a graphical user interface. Math Description Engine participates in this by providing textual descriptions of functions as well as sonic descriptions. The screen reader software reads the textual description out loud to the student. These textual descriptions are not precomposed; they are generated on-the-fly by software that analyzes the function and determines its characteristics. Indeed, this is one of the major innovations of the software. Similarly, the sonifications and graphs of the functions are not precomposed. This run-time analysis allows Math Description Engine to evaluate most functions of two variables.

The Math Description Engine is only the first product of the Information Accessibility project. The project team is now developing software to sonicly describe three-dimensional information such as temperature and pressure fields. Imagine yourself moving through the atmosphere and hearing the subtle changes in wind, temperature and moisture. Imagine an astronaut — or yourself as an astronaut — hearing the radiation streaming from the sun during a space walk. By adding an audible dimension to these phenomena, we hope to enable students to achieve a better understanding of them.

4.0 Virtual Lab

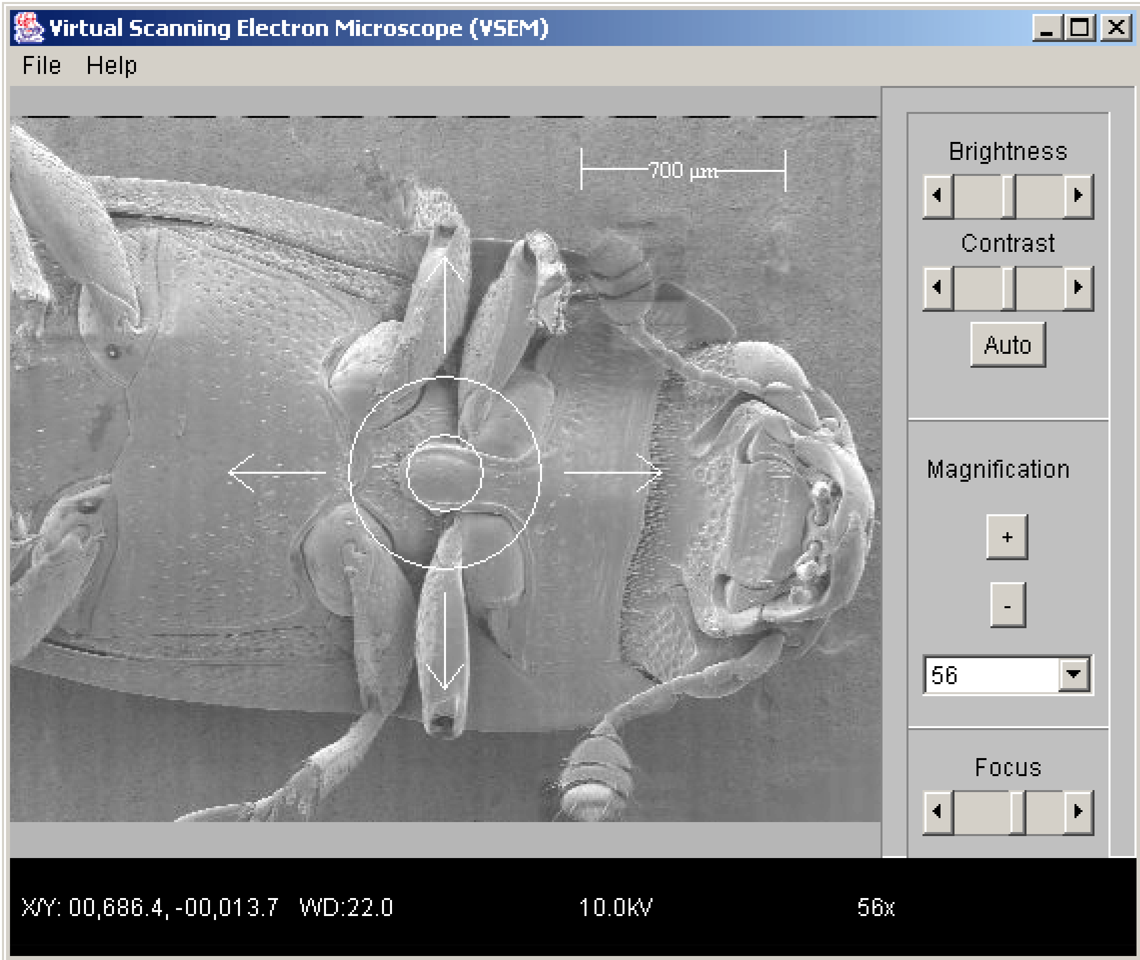
NASA scientists and engineers use many sophisticated instruments in their work. Scanning electron microscopes, mass spectrometers, and X-ray microscopes are examples of devices employed continually within NASA to assist technologists performing design, investigation and analysis. In fact, these instruments are used widely throughout science and engineering, and mastery of their use is necessary for many practicing researchers and designers. Because these instruments are very expensive, students have limited access to them. And since the instruments are fragile and in some cases dangerous, student use must be monitored closely.

The Virtual Lab hopes to alleviate this situation by providing *virtual* instruments: software implementations that have the same feel and feedback of the actual instruments, and can be used in training. Students can use these to gain familiarity, practice procedures and protocols, and even explore precomposed specimens that illustrate the investigative details they'll encounter or search for in real investigations.

A virtual instrument example is shown in Figure 3 on page 5. Here is displayed Virtual Lab's scanning electron microscope. A beetle specimen is "under the gun." The user interface is very similar to that of a real scanning electron microscope: it contains contrast, brightness and focus controls, a measuring instrument (the movable ruler currently at the upper right of the window), and magnification controls. Movement of the electron beam is controlled by the mouse and keyboard, just as it would be with a real electron microscope.

The specimen displayed in Figure 3 — the beetle — is of course virtual as well. Within the software it consists of thousands of individual images taken at different magnifications and using different focal points.The software automatically and seamlessly displays the correct images for the current beam position, focal point and magnification. These parameters are all under control of the virtual-instrument user, and the feedback is immediate.

Figure 3. Virtual Lab's scanning electron microscope with a beetle specimen. The virtual instrument has the same controls as the real instrument: brightness, contrast, focus and magnification controls, and an interactive measuring device (currently displaying 700 um).



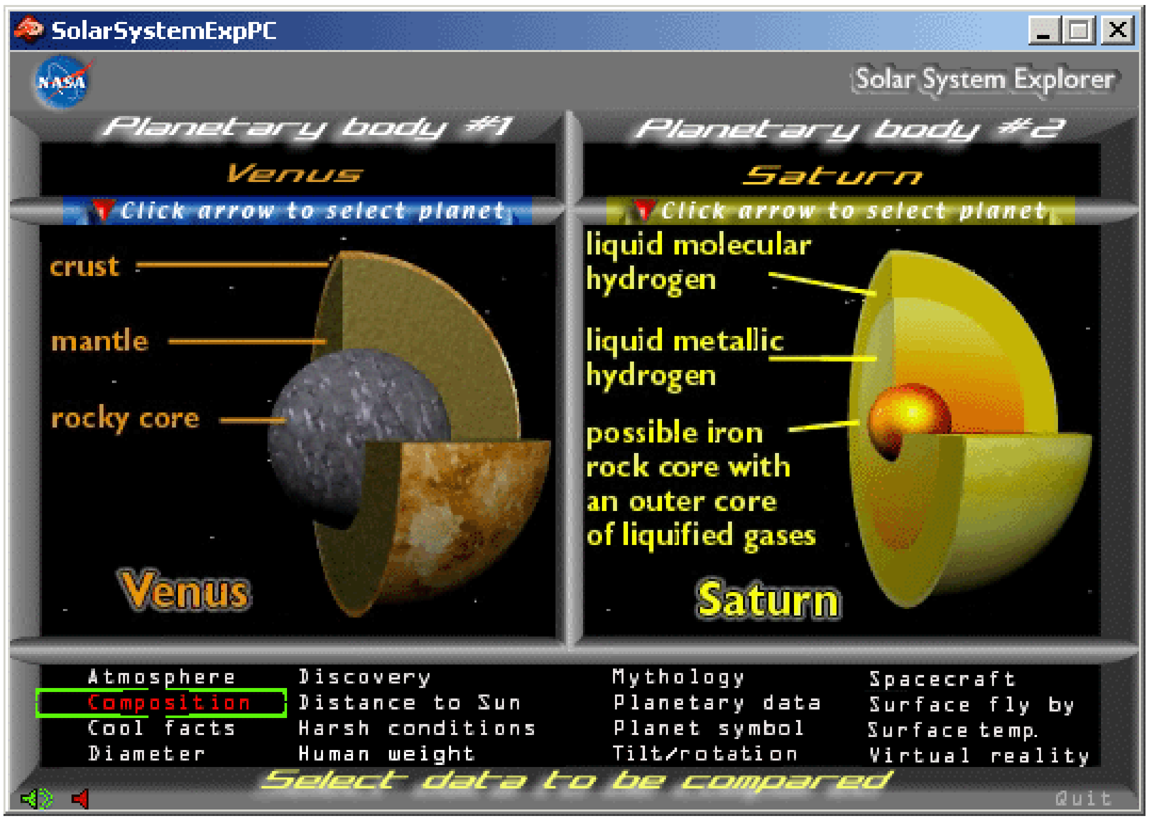
The original images were generated by automated software driving a real scanning electron microscope. This makes it very easy to continually generate additional images of interesting specimens.

The virtual specimens and the virtual instruments are described in XML [2]. The XML schemas for them are publicly available, thereby enabling other organizations to develop additional instruments and additional specimens that interoperate with existing ones. The goal of Virtual Lab is to develop up to five virtual instruments by project completion in FY 2005, and at least 20 specimens for each instrument. Ideally, the specimens will be coordinated among the instruments so that an array of the instruments can be employed to study a common specimen in different ways.

5.0 What's The Difference?

Comparison can be an effective teaching technique. What's The Difference? is a software application that displays side-by-side similar information about different things. The composition of planets, for example, is more interesting and understandable when shown in comparison, as in Figure 4, than it would be shown in isolation. In Figure 4, the planetary composition of Venus and Saturn are shown together, giving a clear comparison between the two and providing the student with a mechanism to understand the information in context and to help her remember it.

Figure 4. What's The Difference? showing space-science information. Planetary composition of Venus and Saturn are compared in this image. Below the images is a list of all the information available to the student. By selecting an item there, the student chooses the type of information to compare in the two planetary body windows. Other planets or their moons can be displayed instead of Venus and Saturn by the student's selecting the desired planetary body from a drop-down menu under the red triangle in the "Click arrow to select planet" bars.



What's The Difference? can provide this comparative presentation for any type of information, not just planetary data. Information from Chemistry, Physics, and Biology have been suggested by educators who have used What's The Difference?. You can imagine, for instance, comparing various aspects of molecules such as their molecular structures, weights, uses, and the polymers they form. For such a topic as "Molecules" the lower selection window would display the comparative aspects, while the drop-down menu under the triangle would allow selection of different types of molecules. Of course, the window annotation would change as well, to language appropriate to the topic, perhaps "Molecule" and "Molecular Explorer" in our example.

The infrastructure and data definition standards for What's The Difference? will be clearly documented to allow curriculum designers to prepare topic material. In addition to graphics similar to those in Figure 4, video, sound, Flash™ and interactive programs can be configured to display in What's The Difference? windows. Many commonly used industry standard formats are accepted so that curriculum developers may use industry standard tools to create content.

The What's The Difference? project team is currently extending the application to allow for more data windows and other useful capabilities.

6.0 Conclusion

The technologies described above were selected from a large collection of prototypes and proposals submitted by NASA employees to the NASA Learning Technologies Office in fiscal years 2002 and 2003. The selection process was competitive and rigorous, requiring not only that the technology be compelling but that it be evaluated by teachers, students, and independent scientists and engineers within NASA. The ongoing development, too, will be evaluated by these groups to affirm or correct the technology directions and to determine the most practical and effective ways to use the technology.

All of these tools are freely available to the general public in early-release versions. They can be obtained via the internet at http://learn.arc.nasa.gov.

7.0 References

[1] *Web Mapping Service Implementation Specification*, Version 1.1.1, 2001-11-27, OGC 01-068r2, Open GIS Consortium Inc., http://www.opengis.org/specs.

[2] *Extensible Markup Language (XML) 1.0 (Second Edition)* W3C Recommendation 6 October 2000, Tim Bray, Jean Paoli, C. M. Sperberg-McQueen, Eve Maler., at http://www.w3c.org/XML/.