Astronomical Data Analysis Software and Systems VII
ASP Conference Series, Vol. 145, 1998
R. Albrecht, R. N. Hook and H. A. Bushouse, eds.

Cyber Hype or Educational Technology? What is being learned from all those BITS?

C.A. Christian[1]

Office of Public Outreach Space Telescope Science Institute, Baltimore, MD 21209, Email: carolc@stsci.edu

Abstract. This paper discusses various information technology methods being applied to science education and public information. Of interest to the Office of Public Outreach at STScI and our collaborators is to investigate the various techniques through which science data can be mediated to the non-specialist client/user. In addition, attention is drawn to interactive and/or multimedia tools being used in astrophysics that may be useful, with modification, for educational purposes. In some cases, straightforward design decisions early on can improve the wide applicability of the interactive tool.

1. Introduction: What is the Big Picture?

As recipients of federal funding, the interest and pressure has increased on U.S. agencies to provide to taxpayers some direct benefit from their investment in our research and technological developments. Clearly, part of this effort was intended for direction towards the improvement of science, mathematics and technical education. The increase in attention by the public in examining the benefits of research has resulted in some redirection of funding to produce quality educational materials and public repositories of information, but also offers the research community an opportunity not only to share scientific results with the public and to encourage them to continue their investment (funding), but also to give them a vested interest in our scientific enterprises.

Through appropriate conduits, scientific and technical data can be mediated in such a way so as to be useful to a wide audience. One such channel, cited in this paper, is the Office of Public Outreach (OPO) at Space Telescope Science Institute (STScI), which translates scientific results to the public through a variety of mechanisms: 1) news releases, 2) science and technical background information, 3) online curriculum support materials and 4) a variety of ancillary products. This paper addresses instructional technology used in astrophysics-related public programs and will explore issues related to the clientele, resource design and budgetary issues.

---

[1]Director, Office of Public Outreach, STScI

2. The Audience

It has been said that the largest global information enterprise is Education. This idea is worrisome considering the apparent poor public understanding of science, but it does offer a context for the development of at least educational resources (curriculum support) and therefore it is worth taking some time to understand the relevant user clientele.

2.1. The Classical Approach to Formal Education

Those who have adopted the *Classical Approach* to formal education often adhere to the following principles:

- Student development occurs as a result of the injection of content via the educational system
- The teacher is the sole subject matter expert
- Evaluation of the success of the classical method has been demonstrated through rigorous content testing via recall or rote exercises
- The classical approach is further proven through learning of the "classics" - that is, logic, mathematics, and Latin

Therefore, in the classical approach, "instructional technology" (IT)is seen as a threat because it can only replace teachers – clearly an undesirable and philosophically distasteful result. In this view, computers, obviously inferior to human educators, have no place in the classroom. Sometimes, IT is grudgingly accepted if proponents can convince the classicists that: 1) information access is the only problem needed to be addressed with IT, 2) textbooks fill specific educational needs, so the "books on line" represent the IT sufficient to serve education, 3) IT can provide quick reference material for teacher/expert and 4) the only IT development required is hyptertext linkage, good content and a decent index.

2.2. Other Approaches

Fortunately other views are held also:

1. *Individualistic* - education focus is on realizing the potential of each individual by providing development of skills, abilities and interest
2. *Social* - education is intended to create a literate workforce. This is a reformist approach based on raising student awareness concerning technical, ethical and legal issues.
3. *Process* - education develops the individual's ability to think

Happily, each of these approaches can rationalize or even embrace the use of IT.

3. Specifications for Resources

3.1. Framework

Accepting the above, a framework for creating resources based on science and technical information can be adopted, containing several components.

- Information, data and algorithms are bricks in the structure of all resources
- Interactivity is needed to engage the user and to make available specific tools and environments
- Presentation and design of information about a discipline are important, especially for the non-expert
- NASA missions such as HST must consider the broad audience, eg., national/international distribution and use
- Resources must be modular and easily used separately by users and other developers
- Resources must be adaptable to educational contexts and support rather than replace substantive activities. That is, the resources offered are curriculum supplements, not surrogates.
- Resources must be tested in different situations with a variety of demographics

3.2. Science Applications

Where should the research community start? For example, consider astronomical "information bases" which are characterized by the following:

- On-line living archives
- "Standard" formats - astronomy has a real advantage in the early adoption of standard data exchange formats which can be readily converted (certainly with some loss of information) to popular formats
- Globally distributed infrastructure - the astronomical community adopted, at least philosophically that data is geographically distributed and should be globally accessible
- Search engines, location services, security mechanisms and conversion services - critical items for *robust* data location and access
- Client-server and peer-to-peer technology

These attributes in data systems are laudable. They also are critical but not sufficient characteristics for developing public interfaces based on scientific information repositories. Therefore the further implications for developing access methods for existing and future scientific data systems should be considered.

First, the data must be mediated to a palatable form for the target clientele. For example, simply providing a conversion of "FITS" to "GIF" as a front end to an archive is insufficient. While access to digital libraries is crucial, it is not a sufficient condition for satisfying the requirements of a broad audience because every piece of precious data, each enchanting bit of research and clever algorithm is not inherently educational or of public interest or utility.

Furthermore, developers are wise to make judicious use of multimedia and use new technologies when and if they are appropriate and useful in context. Specifically just because a technology is *cool* does not mean it is appropriate. The balance of data, algorithms, technology and information must be integrated wisely to be useful.

3.3. Interactivity

Many terms in the field of instructional technology (including the term "instructional" or "educational technology") vary widely with the context and particular community which use those terms. The word *interactive* is no exception. The types of interactivity referenced here include:

- Computer mediated communications
- Real time or near real time
- Collaborative learning
- Distributed learning
- Multimedia systems
- Simulations, modeling and games
- Intelligent agents
- Adaptive tutoring systems
- Virtual reality based learning

In this paper, systems are characterized as *interactive* if they provide feedback which depends upon user input. That is, the result of the interaction is not deterministic, or if it is digital or parametric, it involves a significantly large number of possible responses.

4. Interface Design

The design of the interface pertaining to the visual presentation of information is often the component that is taken least seriously in scientific information systems. However on the Web, the use of an engaging presentation is a time honored tactic to grab attention and increase transient clientele. It also is effective for *retaining* users if the services offered are innovative, unique, and implement imaginative processes built on interactive tools. Further, the public interfaces into scientific and technical resources should relate to the user. Part of the presentation should give users a context and a specific connection to not only the content but also to the individuals involved in the research or technology being made available. For example, profiles and interviews (audio, video, real-time) with observatory scientists and engineers are useful: Who are they? Why do these individuals pursue scientific research and what technical challenges related to telescopes, instrumentation and methods are encountered?

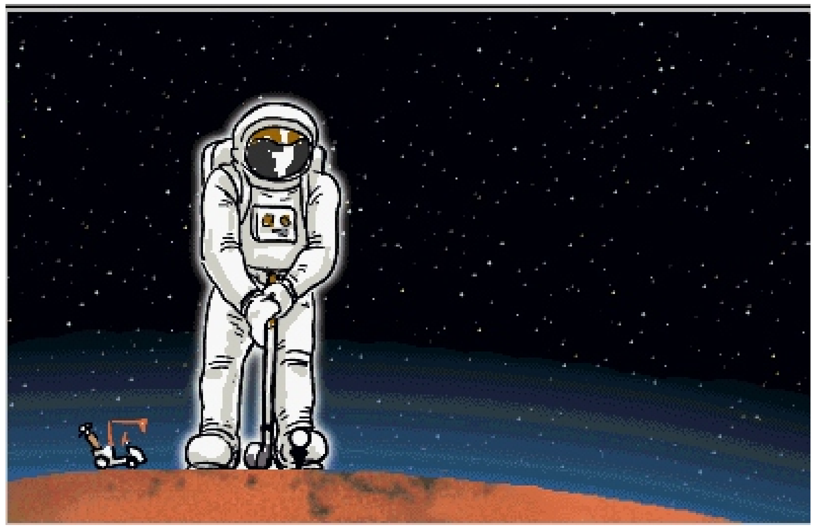

Figure 1. The user (eg., students) provide test velocities to the astronaut for hitting a golf ball while standing on the surface of a planet, asteroid or comet in the Amazing Space module on gravity and escape velocity. If the astronaut hits the golf ball with a sufficient stroke, the golf ball, naturally, is launched into orbit.

Interfaces should provide some user control over selection of resources, data, and information rather than appearing to be restrictive and proscribed. The presentation, though engaging and clever, should not interfere with or obscure the usability or relevance of the resources. These principles are not trivial to implement and are far more important for users who are not experts in the subject matter being presented. Such users do not generally "need" access to the resources, and therefore interface design is critical for retaining clientele and reducing their frustration at finding relevant information in a consistent way. "Web hits" on the graphically engaging "top page" are a far cry from exhibiting actual user interest in a suite of resources.

4.1. Further Design Considerations

Once the user is "committed" to delving deeper into the resource structure, the underlying content must continue to be marketed well. The use of each resource encountered must be clear, and structures which are tiered in complexity and interactivity are recommended. Designers must plan for high bandwidth, but create low bandwidth options. Clearly browse products must be included so that users can identify precisely that the data and information is what is expected. Scientific developers should recognize that raw data online is NOT interesting or useful to the non expert user. Science data must be made relevant within the context of the resource and for the target audience.

Figure 2. The robot is a mascot who guides interactive modules for understanding the basics of various kinds of waves in the Amazing Space resource: "Light and Color". The robot actively performs various activities (generating waves and measuring temperature, etc.). In this graphic, the robot uses a prism to disperse sunlight. The switch at the robot's left opens the window shade

5. Content Creation Best Practices

As discussed previously, the public audience often does not perceive a "need" for the science and technical content that the research community can provide. The user base is drawn from a population of varied demographics, that is, wildly heterogeneous in expertise, motivation, interest, and sensitivity. Scientific and technical fields are highly competitive, and are drawn from a population which is often introspective. These two communities often have divergent approaches, concepts and motivations (and sometimes actual mistrust) which should be addressed in building public interfaces to scientific content.

At the Office of Public Outreach / STScI we find that direct involvement of the user in the design of services is critical. This philosophy is espoused in other venues, including industry, but it is often actually just "lip service". Our programs in OPO insist that representative users are not just temporary critics of resources, but rather, collaborators and co-authors. In this way, compromise and balance are achieved which suit users from varied backgrounds. The collaborative teams we create include representative users (eg., teachers, science museum personnel, journalists – depending upon context), scientists, engineers, programmers, graphic artists and animators.

Note that often, knowledge of this *team*, face-to-face approach frequently tempts the software engineer or scientist ("who knows better" and who would prefer to lecture on content rather than collaborate on resource creation) to disengage from the process before it starts! Managing collaborative projects aimed at producing useful public access to scientific research is a challenging proposition and must include talented brokers to engage and mesh the expertise of the various participants productively.

It should be noted that an initial period of building of intra- team trust and rapport is essential. Careful consideration of design issues is worth the effort, otherwise expensive multi-media resources may be only of fleeting interest to the intended users no matter how compelling or astonishing the technology to be used appears to be.

5.1. Evaluation

Evaluation of publicly accessible resources is a key issue for determining effectiveness, for reviewing level of effort to be devoted to resource creation, and for planning new development. At STScI/OPO, we test resources in a variety of environments with users both local to our area, but also across the United States. Some resources are piloted internationally. Key topics addressed in the evaluation of specifically curriculum online materials are:

- Product concept
- Overall design, and design of specific modules or objects in the resource
- Usability by target clientele and other users, and relevance to users requirements and unforeseen needs
- Pedagogical approach for curriculum resources
- Customer feedback - acquired through *in situ* testing at workshops, seminars, and classrooms, and further through a network of remote testers
- Ancillary usage: modules used in new ways in varying environments and as integrated into new products

Note that educational hard copy products are evaluated similarly. The specific evaluation procedures and results of resources are the subject of separate papers.

5.2. Copyrights

Copyrights are a growing, serious problem and are a concern at many levels. A full discussion of the issues is well beyond the scope of this paper. Clearly educational resources must obtain copyright permissions for material reproduced from external sources and this procedure is not trivial. Conversely, resource authors must consider carefully what copyright permissions will be allowed. At STScI/OPO the copyright policy [2] is derived from the NASA policy and basically gives reasonably liberal permissions to research and educational users for content re-use.

6. Budget Model - Can you afford it?

The creation of meaningful and useful resources based on scientific research data and results is non-trivial and demands consideration of many issues including budget. The typical costs to be considered include:

---

[2] **http://www.stsci.edu/web/Copyright.html**

– Overall development time including pre-planning
– Longevity of products and resources
– Cost of maintaining currency including ease of upgrade
– Overall maintenance and other overheads
– Marketing costs (even the design of an enticing frontispiece may be attributed to "marketing" costs)

6.1. Cost Effective Strategies

The cost effective strategies that have been tried and true in resource development are to create usable and easily upgradable modules. The modularity also should encourage re-use by both the original authors and by new users who add value to each item. In addition, avoidance of duplication where possible, resisting the temptation to reinvent resources with small modifications that may be transparent or even useless to the user. Well designed resources separate the interface layer from the underlying content, code and objects and include rational handles to encourage re-use through changeable interfaces.

6.2. What is NASA Doing?: The Leverage Power Model

The NASA community has considered seriously attempting to understand how resources are created and disseminated, and has taken a look at the "leverage power" of projects and programs. This model is used widely in commercial ventures particularly for cost effective sales and marketing.

Consider that for a single module or activity A is created. That activity, if created efficiently, optimally and with high quality (an exercise left to the reader) has a particular leverage power depending upon how it is mediated to the audience. For example, if the activity can be replicated and further amplified through one-to-many dissemination methods and then made available to a wider audience through connections and networking, the item can be characterized with a leverage power:

$$Leverage\ Power = L = \rho\alpha\gamma \tag{1}$$

$$\rho = replication \text{ including re-use and duplication}$$
$$\gamma = connections/networking \text{ through cross links}$$
$$\alpha = amplification\text{, that is, one-to-many}$$
$$\text{(e.g.., content source} \rightarrow \text{master} \rightarrow \text{teacher)} \rightarrow \text{student}$$

For example, a classroom activity presented in a workshop to 30 regional science curriculum supervisors who in turn transmit the information to 30 local science teachers and these teachers in turn share the information with other (2) science teachers, then the leverage power is 1800. If the workshop is replicated in 10 regions, the leverage is 18,000 for the one example module. Clearly the "leverage power per student" is multiplied by the number of students in a class (conservatively, 25).

$$\alpha = 30,\ \gamma = 2,\ \rho = 30 \times 10$$
$$LeveragePower = 18,000$$

However if the same "activity" is presented by an outsider, visiting one classroom of 25 students, then the leverage is 1 x 25 rather than 18,000 x 25. Therefore, the leverage power of "scientists in the classroom" is low, particularly if the teacher in the classroom is unable to replicate the activity presented by the scientist or engineer in the future.

6.3. Brokers

It is clear that a variety of networking, replication, re-use and amplification techniques are possible. Through the use of organized mediators and brokers, the leverage power of educational resources made available from astrophysical sources can be impressively large. Within the NASA Office of Space Science, a system of "Education Forum" and "Brokers" have been created to serve the networking, replication, and dissemination roles, α and γ above. Each Forum provides handshakes between the public and the science community through a variety of means, including electronic multimedia. Brokers provide dissemination networks, spreading the word and demonstrating use of Space Science content (hosted and linked) through the Forum. This system is intended to provide effective methods that allow public access to scientific data, technology and expertise in a useful way which does not disable the research enterprise.

6.4. Launching a Project

STScI/OPO is the site of the NASA OSS "Origins Education Form", and thereby has the mandate to help researchers find ways to craft effective educational programs through pragmatic approaches. The Forum provides models for effective, tested processes and advice on best practices. There are also mechanisms for obtaining funding and links to existing successful programs as examples.

7. Summary

Information technology methods are being applied and evolved to provide exemplary materials for science education, curricula and general public information about research and technology. A variety of successful techniques are emerging and interactive resources are now being offered and tested to allow users with an interest in science to experience scientific principles and research environments. It is clear that the algorithms, archives and data representations in use within astrophysics are necessary building blocks, but must be mediated and culled to address the needs of the user. Design considerations and presentation must be weighed carefully when planning the budget and necessary human resources to be devoted to the public interface.

References

Recker, M., 1997, *Educ. Technol. Rev.*, 7, 9

Reeves, J., 1997, *Educ. Technol. Rev.*, 7, 5