So You Want to Make a Science Educational CD-ROM?

Ten Basic Questions to Consider

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The document is one in a series, written primarily to support NASA-funded scientists and scientific research groups at universities and scientific institutions who are attempting to respond well to the charge of contributing effectively to K-14 education and public outreach (EPO). The information may be of special value to the EPO managers who are assisting scientists in making a meaningful response. [For a working definition of "EPO", please see "A Framework for Developing Education and Public Outreach Programs Associated with Scientific Research Programs"].

Contents

Purpose of this Document

"So You Want to Make a Science Educational CD-ROM" invites would-be CD-ROM producers, such as NASA flight projects, to examine critically their motivations, intentions, and processes associated with science educational CD-ROM development. The problem being addressed is that too many well-intended CD-ROMs have become little more than drink coasters: they go unneeded and unused, even though they may have been developed with good intentions and freely disbursed at conventions. This document is intended to help candidate CD-ROM producers avoid this fate. It provides guidance on the process of developing and disseminating useful and valued CD-ROMs in support of science, math, and engineering education in classrooms, museums, and elsewhere.

The document's format includes answers to ten basic questions, which refer out to three Attachments and two Tables. The Attachments provide detailed advice about how to get started in CD-ROM development (i.e. by careful identification of the needs of a clearly identified audience), how to manage cost and increase the value of CD-ROMs, and how to involve scientists. The Tables contain information on a small sample of existing CD-ROMs in space and earth science, offering an invitation to explore some of the possibilities.

We have distilled the advice presented here from a variety of experiences and lessons learned in CD-ROM development and dissemination. We have also liberally incorporated the perspective of educators who use (or do not use) CD-ROMs. Although much of the information provided is specific to CD-ROM's, a large portion of the advice (especially that regarding establishing educational need, identifying your audience, assembling appropriate expertise on your development team, involving scientists, field testing your product, and accounting for dissemination costs up front) applies to almost any science educational product.

We welcome comments and additional perspectives based on readers' experiences. These should be sent to both authors [see email addresses above]. We would be very pleased to hear from you.

Ten Basic Questions to Consider

1. What are some advantages of CD-ROMs?

1. Large capacity: 640 megabytes: could represent 1500 pages of illustration and over 300,000 words of text. Video, sound, and animation can also be included. Full color is standard. Related software can be included.
2. Most computers in schools, homes, and businesses have CD drives.
3. Fast access time: no waiting for slow Internet downloads or dropped connections
4. Inexpensive in large quantities compared to print documents
5. Can be sent by conventional mail at lower cost compared to heavier print documents

2. What are some disadvantages of CD-ROMs?

1. Not universally useable by classrooms because of limited access to computers
2. Teachers are often more comfortable teaching with print materials even when they have access to computers
3. Cannot be updated or distributed as easily as web-based materials

3. How are educational CD-ROMs used?
CD-ROMs are best used when you need to access large data sets, images, files, and movies, particularly those too large to be delivered easily over the World Wide Web. Various types of CD-ROMs are useful to teachers, students, home-schooled students, curriculum and exhibit developers, educational TV and planetarium show producers, textbook authors, publishers, and journalists. CD-ROM applications are diverse and may include data/image archives or libraries; interactive displays for museum kiosks; collections of printable or project-able teacher resources; interactive lessons for students; and full featured instructional packages. Table 1 and Table 2 provide more detailed descriptions of the contents and intended audience for a sampling of CD-ROM applications.

4. What do CD-ROMs cost?
Currently, duplicating and packaging CD-ROMs in volume makes the cost about $1-2 each. However, the total cost of CD-ROM development, testing, and dissemination can cost anywhere from $5K to $1.5M depending on the CD-ROM's intended use and audience, and the kind of long-term support provided for the product. Table 1 shows the range of costs for a variety of types of CD-ROMS. Attachment 2 provides a more detailed discussion of considerations that drive the cost of a CD-ROM project. Table 2 lists specific features for a sampling of existing space- and earth science-related CD-ROMs in rough order of cost and complexity (from low to high).

5. What types of expertise are needed to develop a science educational CD-ROM?
Creating educational value does not usually occur directly as a consequence of the good intentions of the creator. It comes from building a development team with sufficient skill, enthusiasm, and experience to create a product that is needed and useful for its intended audience. It also comes from implementing a plan to maintain, improve, and disseminate the produced product with adequate training over significant periods of time.

Depending on the application and complexity of the product being developed, there are up to twelve types of expertise that may be needed to produce and disseminate a good educational CD-ROM. These include:

1. Project leadership and coordination
2. Financial management
3. Legal and copyright (permissions & protections)
4. Science (relevance, quality, and accuracy)
5. Education (curriculum design/pedagogical approach)
6. Education (evaluation & field test)
7. End users (need/practicality/ease of use)
8. Multimedia design (computer graphics, video, sound)
9. Computer programming (e.g., C++, Java, Internet issues)
10. Science writing/editing (clarity, age-appropriateness)
11. Publishing (or other duplication)
12. Planning and implementing dissemination

Evidently, teaming for product development is important. It is important to talk with experienced people who can help you avoid the pitfalls and embrace best practices of CD-ROM development. Find the developers of educational CD-ROMS that you like and discuss with them potential partners and organizations to help with the planning and creation of the CD-ROM you envision.

Good partners are competent, experienced, and passionate about their work. The project should have importance and visibility to their organization. This is why some of the best partners can be individuals, consultants, and small businesses who believe strongly in what they are doing. Including partners from outside the producer's main organization can offer a wider perspective on how the project might be done and generally enriches and informs the development process. Long-term support for a CD-ROM educational product requires a commitment and sustained investment. Teaming with organizations that already have close and trusting relationships with the education community is one approach to providing long-term services centered on the product you create.

6. What can scientists do in support of educational CD-ROM development?
Scientists have been essential contributors to many exemplary CD-ROM development projects. They can provide advice about scientific content or process, facilitate access to data, review material for accuracy /currency, do presentations in dissemination workshops, and so on. See Attachment 3 for a more complete discussion of scientists' roles.

7. What if I cannot afford to develop a full-featured educational CD-ROM from scratch?
The costs associated with educational CD-ROM development and dissemination are often higher than most people realize. Projects with limited funds can become less ambitious about the scope or application of their CD-ROM (see Table 1), or they can provide highly useful resources or components in support of larger on-going development or dissemination efforts. See Attachment 3 for some ideas of how scientists and others can contribute to CD-ROM projects.

8. How do I get started in developing an educational CD-ROM?
The four basic steps for a CD-ROM development project are: Define, Design, Develop, and Disseminate. The definition and dissemination stages are often the most critical to success. *The success of your product will be largely due, not to the quality of what you create, but rather to how well your product relates to an educational need and to how well you plan its dissemination.* It is absolutely critical to begin by defining your audience and users clearly and how you will ensure your product is of value to them and available to them. Unsuccessful CD-ROMs are sometimes referred to in jest as "coasters". Don't let your CD-ROM become a "coaster"! See Attachment 1 for more details.

9. What are common pitfalls in educational CD-ROM development?
1. Failure to identify and understand target audience(s) clearly. See Attachment 1.
2. Failure to define the educational need for your product. See Attachment 1.
3. Underestimation of the cost, time, and types of expertise needed to produce and promote a useful product (e.g. omitting plans and funds for field testing and evaluation, training and/or dissemination; failing to involve users in development and test)
4. Failure to address intellectual property and copyright issues early in development
5. Failure to consider multi-platform issues
6. Failure to design "user-friendly" navigation strategies (e.g. entry, exit, path option overload, or too many layers)
7. Filling up the CD with extraneous material because there is space available

10. What are best practices in educational CD-ROM development?

1. Use of a design document (see Attachment 1) to achieve clarity and maintain focus about the product being developed.
2. Partnering with a reputable CD-ROM developer and consultants who have the necessary background in science, education, and technical skills.
3. Including adequate field-testing to ensure ease of use and value to intended audience.
4. Involving intended audience in development and testing throughout the project
5. Using a clear writing style consistent with age appropriateness for the intended audience
6. Including sufficient information for users (e.g. succinct description of the CD on the cover; user guide to go along with the CD; contact information for assistance with use of the CD-ROM)
7. Providing good introduction, navigation, and installation instructions.
8. Ensuring that materials intended for printing are formatted for easy, high quality printing (e.g. Adobe Acrobat).
9. Ensuring that programs or software needed to read or print CD-ROM content are included on the CD-ROM.
10. Providing appropriate Internet links on the CD-ROM (ones that are steady and won't break)
11. Creating a feasible dissemination plan and accounting for its cost at the outset.
12. Creating a realistic plan for updating or maintenance

Attachment 1: How to Get Started in Educational CD-ROM Development – the Importance of Defining Your Audience and their Educational Needs and Capabilities

The four basic steps for a CD-ROM development project are: Define, Design, Develop, and Disseminate. The definition and dissemination stages are often the most challenging and the most critical. *The success of your product will be largely due, not to the quality of what you create, but rather to how well your product relates to an educational need and to how well you plan its dissemination.*

To start the development process, write down answers to the important questions listed below. Written answers will provide a start on a "design document" that will help to guide your project throughout the design and development phases.

Who is your target audience?
CD-ROMs of various types are useful to teachers, students, home-schooled students, curriculum and exhibit developers, planetarium educators, educational TV and planetarium show producers, publishers, and journalists.

If you are developing resources for teachers or students, ask yourself what grade levels are relevant. One must be mindful of the cognitive abilities of students at different ages. There are virtually no products that are suitable for the entire range of K-12 grades. If you do not know how to determine age-appropriate content, it is important to consult an education expert who does.

Studies show that the average reading level of adults is about five grade levels lower than their last grade completed. Science information for the general public is often pitched at about the 8th grade level, widely considered as the average adult reading level. However, some experts in patient health literature have recommended that all new materials be created at the 6th-grade reading level, which would allow for at least 75% of adult patients to be able to read and understand them.

It is extremely valuable to spend time with representatives of the intended audience, observing, conducting surveys, and generally learning more about what they know and what they need. What does your audience consider relevant, valuable, easy-to-use, and accessible? What misconceptions do they have about the science content? Depending on the scope of your project, you may want to ask a professional evaluator to lead such a front-end evaluation with support from the rest of your development team.

How will your product help to improve understanding or scientific concepts, processes, or principles?
The National Science Education Standards (NRC) and Benchmarks for Science Literacy (AAAS) provide valuable guidance about scientific concepts, processes, and principles that are the most important for people to learn. The NRC Standards document also provides information about inquiry-based instructional strategies that facilitate this learning. These strategies can be used in both formal and informal learning environments. If your CD-ROM has associated learning goals and you are unfamiliar with science education standards, it is important to consult with educational specialists who are familiar with both the content and application of the

available NRC and AAAS resources . Aligning an educational product with standards is more challenging than is commonly presumed [see "Misconceptions Scientists Often Have about the National Science Education Standards"].

For NRC standards, see http://www.nap.edu/readingroom/boks.nses.html/
For AAAS standards, see http://project2061.aaas.org/tools/
For an integration of various education standards documents, including, science, math, technology, and geography, see http://www.mcrel.org.

Why should people use your product?
People will use your product if it meets their educational needs, it is easy-to-use, and it is readily accessible to them. YOU MUST FIELD TEST AND EVALUATE YOUR PRODUCT WITH THE INTENDED AUDIENCE, and this generally requires the involvement of a professional evaluator on your development team.

For example, if your CD-ROM is an information or image repository, remember that students and teachers do not typically have the time, expertise, or interest to take scientific data or images and figure out what to do with them. On the other hand, book publishers or developers of planetarium shows, museum exhibits, and web sites might be happy to make use of such a resource if the data are well described, the images clearly captioned, and the information can make new or unique contributions to their products.

In general, you should be able to say what data, content, concepts, and/or activities your CD-ROM provides that are not currently available to your target audience. If you are unaware of how your product will build on (or relate to) previous and on-going development efforts, ask around and find people who know the breadth of the field and can counsel you about how you can design your product to complement or improve upon existing products.

No matter how needed, if your product is difficult to use, then people won't bother. A rule of thumb is that if they put it into their computer and cannot make it work in a minute or so, they probably will not use it. It is especially important that users can easily determine how to enter and exit the CD-ROM. In addition, the format of the images or information ought to be instantly accessible by your audience. For example, materials intended for printing should be formatted for easy, high quality printing (e.g. Adobe Acrobat). Any programs or software needed to read or print CD-ROM content should be included on the CD-ROM.

How will you get your product to your intended audience?
It is essential to address this question up front lest you produce a well-needed, easy-to-use CD-ROM that your audience cannot find or afford. It is important to consider the size and capabilities of the intended audience and whether your dissemination methods make sense for them in terms of accessibility, and for you in terms of cost. As an example, for CD-ROMs intended for the classroom, it is important to disseminate in concert with workshops that train teachers about how to use the CD-ROM.

Dissemination options can include: distribution as handouts at conferences or workshops; marketing and distribution by an appropriate publisher; web-based mail order; NASA education networks (e.g. CORE, Educational Resource Centers); readily accessible commercial catalogs (e.g. ASP); museum stores; museum kiosks; and so on.

Remember that product distribution and dissemination often can take years. Is your organization ready to support the product for an extended period of time? If not, you may want to team with an organization that is ready for the long haul.

How will you create a design document?
Creating a design document is an opportunity to work out the details of the project scope. A design document will guide you as you proceed through the design process and development stages of a CD-ROM project. Good, detailed design documents are the work of the development team, with each team member contributing in their area of expertise. Depending on the complexity of CD-ROM being developed, there are up to ten types of expertise needed to produce and disseminate a good educational CD-ROM (see FAQ 5 for a list). For smaller projects, the design document will serve as the final word in creating the product. For larger or longer projects, the design document may have to be revisited several times during the course of the project to reconsider new issues as different software or content becomes available.

Example Design Documents
Examples of design documents (sometimes called "preliminary applications description documents") are available for reference. One is from the NASA-funded program to develop the Astronomy Village: Investigating the Universe CD-ROM, and the other is from the more recent, NSF-funded program to develop the Astronomy Village: Investigating the Solar System CD-ROM.

To assist with educational product planning in general the NASA Education Division has developed the NASA CURRICULUM SUPPORT PRODUCT PLANNING SOURCE FORM at http://ehb2.gsfc.nasa.gov/edcats/product_initiator.html.

Attachment 2: Managing Cost and Increasing Value

Table 1 illustrates that there is an enormous range of costs associated with the various types of CD-ROMs. There are sensible reasons for this. In product development of virtually any kind there is always a tradeoff between the cost and its value to your customers. The challenge is to add value (thereby increasing the product's use and longevity) while managing costs within reasonable bounds. In CD-ROM development, issues that drive cost include: 1) scope and complexity of content; 2) multi-platform considerations; 3) nature and scope of evaluation and field testing; and 4) the types of customer support provided (e.g. dissemination, training, updates). Strategies for successful cost management often include using the capabilities of the development team efficiently, taking advantage of external resources, looking for cost sharing opportunities, not being overly ambitious, and conducting appropriate field tests and evaluation.

Leveraging Costs

Two similar CD-ROM products may have widely varying costs depending on whether key contents are created from scratch or leveraged from other work. For example, suppose a CD-ROM developer wants to use a simulation of a supernova explosion. One option is to research the content and hire a team of animators to create animation from scratch. This is time consuming and costly. An alternative approach might be to use an existing supercomputer visualization created by university researchers. If the visualization were already in the right form, the cost would be considerably lower (such as the cost of a videotape).

Limiting Ambition and Sharing Costs

There is always the issue of how ambitious a project is willing to be in broadening and supporting its population of users. Decisions to provide user training and support, to make the product work on Macs and PC, and to have a printed guide to your CD-ROM can add considerably to the costs. Some costs can be shared and distributed. For example, having a printed companion guide is expensive and adds to distribution costs. Thus, many projects include a guide in an easily printable format on the CD-ROM (such as Adobe Acrobat PDF format) itself. If this is done, each teacher has to go to the additional trouble of printing out the guide, but the project saves a great deal of money in printing and distribution costs.

As another example of sharing costs, scientist-educator partnerships with smaller budgets can support and implement workshops for educators on how to use existing exemplary educational CD-ROMs in their classrooms. This kind of assistance is very valuable to larger on-going CD-ROM projects who often run low on funds to adequately disseminate their products. Such workshops also provide good perspective on what it takes to be sure that a CD-ROM you might develop will be useful to teachers.

Appropriate Field Testing and Evaluation

Both field testing of your product and evaluation of your development program cost money, but they add tremendous value to the success of your efforts, perhaps determining whether your CD-ROM becomes a classic or a coaster.

Ideally, the product should be field tested on its intended audience regularly, at the early, middle, and the late stages of development. This is called "formative evaluation". Testing early can be used to validate and refine the approach. It enables you to make some changes immediately to enhance usability. Testing in the middle stage serves as a useful reality check on what is being

developed. End-stage testing is critical to make sure the finished or almost finished product as a whole actually works. A quick test of functionality and interface design takes only two minutes and two steps.

Step 1: If a user plugs in the CD and, without reading the directions, can make use of the software in the first 60 seconds, then the CD passes to Step 2. If extra software is needed or needs to be downloaded, the CD-ROM will likely fail this test. If additional needed software is on the CD and can easily be installed, it might pass. It the CD-ROM is not designed for cross-platform, or requires an unusually powerful computer, extra programs, or plug-ins, it will probably fail this test.

Step 2: If the user can explore the CD without failing or running into dead ends for another 60 seconds, then it passes step 2, and there is a good chance that it will be used. However, if the first two minutes are frustrating, the CD-ROM may be put away to become a coaster.

If the CD-ROM passes these two steps then it can be explored in detail for its educational value and utility. If it fails these two steps, then the CD-ROM needs to be revised to make it easier for the novice to use. In general, teachers will reject software that cannot pass these tests. You might want to remember that teachers might be examining software after the end of a stressful teaching day, or at home at 11 o'clock at night. They often do not have the patience to follow complex installation instructions unless they have been already convinced that the investment in time and frustration will be worth it. The last test is to see if you can exit the program easily and gracefully at the end of the second 60 seconds.

Like formative evaluation, evaluation of the program that creates the CD-ROM is an ongoing process. Program evaluation is best done by an outside evaluator or outside evaluation agency that works with the program throughout its course. The evaluator insists on the articulation of the goals of the project and evaluates whether the development process is achieving those goals. The evaluation can be used in concert with the design document to help keep the project on track and within cost constraints.

“Summative evaluation” is the term used to describe an assessment of the impact of your product on its intended audience. Is your CD-ROM well used? Well liked? Effective in promoting student learning? Summative evaluation and the later stages of program evaluation can be combined.

<u>A Summary List of Items Affecting Cost</u>

Scope and Complexity of Content

1. Number of video clips to be created
2. Number of articles to be written
3. Number of simulations/animations to be created
4. Number of interfaces to be created (especially new easy-to-use interfaces)
5. Amount of new software to be created
6. Amount of data and images to be reformatted
7. Complexity of intellectual property issues (difficulty of obtaining permissions for data, images, and software needed to read or print CD-ROM content
8. Creation of versions in other languages (e.g Spanish)

Multi-platform Considerations
1. Making your product multi-platform (useable on both PCs and Macs)
2. Developing features specifically tailored for different platforms
3. Porting of old software to a new platform

Scope and Nature of Field Testing
1. Number of versions before the final draft
2. Extent of field testing (e.g. local, regional, national)
3. Front end, formative, AND summative evaluations – or formative only

User Support
1. Using multiple distribution and dissemination methods (e.g., NASA CORE, on-line, NSTA catalog, ASP catalog, commercial publisher, workshops at professional society meetings).
2. Conducting workshops or tutorials on how to use the product (e.g., local, regional, national, on-line)
3. Including a printed guide to the CD-ROM
4. Providing real-time (or near real-time) user support (e.g. toll free number, email, website)
5. Providing supplemental advice or resources to enhance usefulness in the classroom (e.g. suggestions of projects students can do; a web site where student projects can be posted; suggestions for using the product in a one-computer environment)
6. Having a regular revision/updating schedule (e.g. issuing new versions; using a website)

Maintaining links to the web that are used on the CD-ROM. A new strategy is gaining acceptance. The idea is to provide links to long-lived portals instead of to individual URLs that can come and go. If the URL included in the portal goes away, the supporting organization can choose a new URL for the portal. The change is transparent to the CD-ROM user who always sees the same portal link, thus allowing the CD-ROM to remain up-to-date with new URLs without requiring any direct change to the CD-ROM content. For example, portal links such as "Today's Astronomy Picture" leads the user to a site chosen for them. Each day, the supporting organization can choose a new URL to which the user can be sent, without changing the portal link itself.

Attachment 3: What Can Scientists Do?

Scientists have been essential contributors to many exemplary CD-ROM development projects. They can also make important contributions to dissemination. Below are listed several ways a scientist can contribute to CD-ROMs of any degree of scope and complexity.

How Scientists Can Contribute to Educational CD-ROM Projects
In general, scientists can:

1. Facilitate access to the best and most interesting data and images; evaluate quality of data and images.
2. Contribute experience with image processing and other data manipulation tools that can be used to create images or data sets useful in an educational product
3. Contribute programming or design talent (e.g. specific Java interactives)
4. Provide explanations of fundamental scientific concepts or approaches to solving scientific problems that can be adapted for educational use.
5. Provide perspective and guidance about what is fundamental rather than superfluous subject matter
6. Review science educational materials for science accuracy and for currency
7. Do presentations in workshops to disseminate or field test the CD-ROM
8. Write small grants to contribute to a large, ongoing development project in one or more of the above listed ways

Scientists have a tremendous feel for the process of science, and are particularly valuable in projects that emphasize a process-based or problem-based approach. Many of the more extensive CD-ROM projects such as *Astronomy Village: Investigating the Universe*, or A*stronomy Village: Investigating the Solar System* emphasize a problem-based, data-intensive approach, and could not have been created without the assistance of scientists. The scientists on these projects worked to ensure the authenticity of the problems and of the scientific approach modeled for the students in working to solve problems.

How Scientists Can Collaborate on Educational CD-ROM Projects
Scientists must also recognize and appreciate the experience and expertise of educators (e.g. evaluators, curriculum designers, teachers), multi-media designers, programmers, science writers, and others likely to be involved in the development of a science educational CD-ROM (see Question 5). A spirit of mutual respect, collegiality, and collaboration is essential.

If the end users are teachers or students, it is important to involve all three types of educators listed parenthetically above. Classroom teachers have ties into existing curriculum and know what works and what excites students in the classroom. Curriculum designers know about how to apply the science education standards in lesson development and have a working awareness of educational research (e.g. cognitive development , common misconceptions, effective assessment methods). Evaluators know how to develop and use evaluation methods that determine how well your CD-ROM works with the intended audience.

Collaborations between scientists and professional science communicators (be they teachers, science writers, etc.) can be challenging due to differences between the professional cultures, including vocabulary and communication style. For example, science writers are apt to use

metaphors and descriptors that make a research scientist nervous because of their less-than-precise relationship to a purely scientific description. There is a trade-off. The value of metaphors is their efficiency: they can carry the gist of a scientific idea on the strength of what may already be familiar to the audience without having to introduce all the scientific terminology and background. Meanwhile, the more complete understanding a scientist has is essential to ensure that the science writer's language does not go too far afield, leading the reader to wrong ideas or serious misconceptions. Scientist-science writer collaborations generally require a good measure of patient dialogue to ensure that the writer really understands the fundamental science concept and that the scientist really understands what level of science sophistication the intended audience can handle. Only then can appropriate text be generated.

For more discussion of collaborations between scientists and educators, please see an on-line paper entitled "What are the Similarities between Scientific Research and Science Education Reform?"

Table 1. A Sample of CD-ROM Applications

CD-ROM APPLICATION	DESCRIPTION	AUDIENCE/USE	COST/ TIME*	EXAMPLES
Data Archive/Image Archive	Data with limited explanation of contents or guidance about how to use or navigate it. Data is often in catalogs in ASCII form and images are often compressed.	Scientists or advanced science students make use of these data for research. Usually not intended to be used in schools.	$5K-10K Weeks to a few months	--The 2MASS Sampler U. Mass, IPAC @ Caltech --EOSDIS DAAC CD-ROMS --Sloan Digital Sky Survey (V1) --Extreme Ultraviolet Explorer Science Archive (Center for EUV Astrophysics and NASA GSFC)
Data/Image library	Collections of well organized data and imagery with explanatory notes and any software tools needed for viewing. Explanatory material may in the form of quick time movies	Developers of curriculum, exhibits, planetarium shows, textbooks can make use of these resources in their products. Expository material can be used directly by students.	$10-40K 6 months-2 years	-- The Hubble Library of Electronic Picturebooks (STScI) --Perspectives on an Ocean Planet (NASA JPL)
Teacher resources	Lesson plans or classroom activities that utilize movies, images, and simulations. Extra data and background information may also be provided.	Tech savvy master educators who have in-depth content knowledge and teaching expertise can make use of these resources. In general, teachers must print out lesson plans. Images and other resources may be projected from the computer or downloaded to individual computers for student use.	$ 50-500K 1-3 years	--Dynamic Sun (NASA GSFC) --SIR-C (NASA JPL) --High Energy Astrophysics Learning Center (NASA GSFC) -- The Real Reasons for Seasons: (NASA Sun-Earth Connections and Lawrence Hall of Science) --Imagine the Universe, includes StarChild (NASA GSFC) Imagine the Universe web site http://imagine.gsfc.nasa.gov/docs/homepage.html StarChild Web site http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html

*** See Attachment 2 above for discussion of cost ranges**

TABLE 1. A Sample of CD-ROM Applications (continued)

CD-ROM APPLICATION	DESCRIPTION	AUDIENCE/USE	COST/ TIME*	EXAMPLES
Interactive lessons (for students)	Purposeful interactive lessons or structured activities that allow students to learn science content or process skills. May also include teacher resources and evaluation instruments. Very strong and extensive teacher resource areas. Links to other content on web, and strong awareness of national science standards	Students navigate CDs directly as individuals or in teams. Teachers use the product as a resource or to print out lessons and background material included on the CD-ROM. Movies and other visual material can be shown by teacher using large monitor or by computer projection.	$60-$750K 1-3 years	--Winds of Change (NASA JPL) --Windows on the Universe (U. Michigan)
Full-featured Instructional package	Includes some of all of the above categories. Organized to promote student inquiry and to support student research. Usually a strong emphasis on science process and has a problem-centered, investigative approach. Shows strong awareness of learning cycle with exploratory activities as well as activities involved knowledge synthesis and going further.	Classroom Teachers with access to computer technology and the expertise to manage such a product's use.	$300K – 1.5M includes testing and training 2-3 years	--Astronomy Village: Investigating the Universe (Wheeling Jesuit University) --Astronomy Village: Investigating the Solar System (Wheeling Jesuit University) --Geoscience Education Through Interactive Technology (GETIT) (Cambrian Systems and Geological Society of America)

*** See Attachment 2 above for discussion of cost ranges**

Table 2. A Sample of Some CD-ROMs in Space & Earth Science

(in rough order of complexity and cost, with least cost first and greatest cost last)

Note that NASA developed CD-ROMs are available to educators for a minimal fee. You can find links to on-line catalogs and web sites highlighting NASA CD-ROMS at http://spacelink.nasa.gov/Instructional.Materials/Multimedia/Multimedia.for.the.Classroom/

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
The 2MASS Sampler http://www.ipac.caltech.edu/2mass/	University of Massachusetts and the Infrared Processing and Analysis Center. Funded by NASA and NSF.	Two Micron All Sky Survey: Decompression software, explanatory supplement, extended source catalog, image gallery of interesting objects. Point source catalog, and compressed sampler atlas FITS format images	Not by design--many files are Mac accessible with some effort.	Folders on CD. Some html-based material. Use of GIF, FITS, and JPEG figure and image formats.	About 575 MB of material	The format of the *readme* file is not recognized by the Mac.
The Sloan Digital Sky Survey Sampler http://www.sdss.org/cdrom1/	SDSS Collaboration, including University of Chicago, Fermi National Accelerator Lab, Institute for Advanced Study, Japan Participation Group, Johns Hopkins, Princeton University, US Naval Observatory, University of Washington	This CD contains a sample of one of the first engineering runs of the SDSS telescope and imaging camera. This represents about 5 minutes of observations from the SDDS (about 1/30,000 of the whole survey). Also contains information and illustrations on telescope design and operation, a tour of the facility, and news of various discoveries.	Windows 95/98/NT, Mac OS, Unix	Html-based Javascript based view of the sky allows user-friendly examination of data. Menu and frames	446 MB of Data 221 MB html programmed material	

TABLE 2. A Sample of Some CD-ROMs in Space and Earth Science (continued)

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
The Dynamic Sun http://sohowww.nascom.nasa.gov/explore/materials.html	NASA Goddard Space Flight Center SOHO Project	Excellent introduction, navigation, and installation instructions. Quick time software and Adobe Acrobat PDF installers are included. A variety of slideshow presentations and many QuickTime movies. Separate guides for middle school and high school teachers. Additional resources include an Frequently asked questions area and Glossary, bonus SOHO image sets, a Storms from the Sun Interactive Poster, and some middle school class activities	Windows, Mac	Easy to use PDF format for slide shows. Glossary and FAQ are in html format. CD-ROM opens up to display folders but *readme* files are easily visible and highly explanatory. High school presentation has more slides than middle school presentation. Includes teachers guides to each presentation. Many interesting movies suitable for project-based research.	127 MB of material, including more than 30 movies and two large slide shows	A very useful product. Html formatted. Now widely distributed. Computer requirements needed were easily found and not excessive. Some simulations/movies require significant amounts of memory.

TABLE 2. A Sample of Some CD-ROMs in Space & Earth Science (continued)

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
Perspectives on an Ocean Planet http://podaac.jpl.nasa.gov/tecd.html	NASA JPL, CNES (French Space Agency)	Starts with outline of over 75 items divided into 8 major areas. Movies, sound accompanying text. Large Outline on various topics from History and Background, Mission Description, spacecraft, mission operations, what has been learned, science data, and outreach.	Mac and PC	Macromedia application. 34 video and many sound narration files accompany each topic area. Hyperlinked text with glossary items. Html version also on CD		

TABLE 2. A Sample of Some CD-ROMs in Space and Earth Science (continued)

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
Winds of Change JPL http://winds.jpl.nasa.gov/education/eduindex.html and http://stargate.jpl.nasa.gov/support/index.html	NASA JPL	CD-ROM devoted to a microwave radar instrument used to measure ocean wind speed and direction from orbit. Contains a Global Climate Curriculum tied to national standards. Includes: Earth Science (Oceanography); Physical Science (Atmosphere); Earth Science (Weather, Climate); Life Science (Living Things). Extensive explanatory and reference material. Extensive assessment, cross-curricular ideas and classroom activity material.	Mac and PC	Strong reliance on movies. Extensive curriculum area tied to themes of the national science framework. There is a web-like interface to find intersections between the content standards and disciplinary themes. By clicking on the bubbles, students and teachers have access to basic questions with background information, concepts, text, activities, images, and movies available.	61 Mb of illustrative images, 408 Mb of movies, 27 Mb of PDF files with explanatory material and classroom activities.	Extensive background information with strong tie in to national standards.

TABLE 2. A Sample of Some CD-ROMs in Space & Earth Science (continued)

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
Geoscience Education Through Interactive Technology (GETIT) http://www.cambriansystems.com/getit.htm	Cambrian Systems and Geological Society of America (NSF-funded)	GETIT is an interactive, multimedia earth science curriculum that focuses on a common threaded theme of energy transfer. Volcanoes, earthquakes, plate tectonics, and hurricanes are attention grabbing contexts for learning. GETIT uses the attractive power of catastrophic events to convey some of the intricacies of scientific inquiry (including appropriate use of mathematics) and the fundamental driving force behind our planet's dynamism.	PC based	GETIT is a very interactive virtual world that allows students to explore real data and conduct research to answer their own questions. Emphasizes an inquiry/discovery approach to learning Is aligned with NSES and AAAS benchmarks for earth science, nature of science, and physical science	GETIT only uses real data. Some of the databases include: North Atlantic Storm Tracks, Earthquakes: Earthquake Information Center, Volcanoes: Smithsonian Institution's Volcanoes of the World, Global population: U.S. Bureau of the Census World Population	Very interactive. Uses music and songs. Is easy to use. Provides multiple levels of help. Focuses on depth not breadth Uses real data and scientifically valid models. Provides an engaging setting for students. Integrates physical science and mathematics

TABLE 2. A Sample of Some CD-ROMs in Space & Earth Science (continued)

Product Name	Developers, Funders, Consultants	Description Of Contents	Cross Platform	Presentation Philosophy	Amount Of Material	Comments
Astronomy Village Investigating the Solar System http://www.cet.edu/products/main.html	NASA Classroom of the Future Center for Educational Technologies Wheeling Jesuit University Pompea & Associates (NSF-funded)	*P*rovides middle school teachers and students with a multimedia instructional package about solar and planetary astronomy. Extensive resources on solar and planetary astronomy. Scientific investigations about the solar system in a rich visualization and modeling environment. Includes investigating the criteria for life in the solar system and inquiry into what the surface of Pluto might be like.	Html-based Mac or PC	-Aligned with National Science Education Standards (NSES) advocated by NASA and the National Research Council -Incorporates current instructional research into effective teaching and learning practices, -Enable students, with the guidance of their teachers, to engage in scientific inquiry-to "do science as done by scientists."	Multiple image sets, QuickTime movies, mini-lectures and articles on many scientific area. Emphasis on planetary probe data, planetary images.	-Provides a rich classroom resource of information about planetary astronomy, and Available Summer 2000