Off-the-shelf authoring tools mentioned most often in museum interviews included HyperCard and MacroMind Director, because both are powerful (though in slightly different ways) and relatively easy to use (see Table 11). HyperCard is currently free with any Macintosh computer purchase, though the features that allow you to create multimedia programs (e.g., special subroutines that allow a HyperCard program to control a videodisc player) require additional spending. MacroMind Director is often used for its animation and sophisticated media integration capabilities (i.e., ability to control external devices such as a videodisc player). On the IBM/compatible side, there was no real consensus of the most popular programs used, but IBM's InfoWindow and AimTech's IconAuthor were among those mentioned.

Putting it all Together

In addition to selecting software and hardware, the museum needs to employ a team of individuals who can put the entire multimedia production together. The talents required to do this are substantial, yet not out of the reach of any museum exhibit staff member who is driven to learn about the technology. In the sample of museums interviewed, all or most of the interactive exhibits were created in-house by the exhibit design staff, with a few museums sub-contracting out for specialized services, such as video production (see Table 12). Those who indicated that they had used independent exhibit designers to create their technology-based exhibits were generally new to using interactive technology, and therefore, could not justify hiring permanent staff with the necessary skills. Four museums mentioned the New England Technology Group (NETG) as a reputable or well known independent design firm, while there was little consensus over any of the other independent firms mentioned. In all cases however, the museum staff worked closely with any outsiders on the design concept and content.

Table 12
Who Created the Interactive Technology-Based Exhibits?

	Totals by museum type					
Who created these interactive exhibits	art	hist	chld	sci	oth	ttl
All/Most done in-house	3	2	4	5		14
Outside contractors (idea & content in-house)		1			2	3
Combination in-house and outside contractors	1	1		1		3
Hope to do in-house				1		1
n/a	1	1	1			3
Percent of responses by category	**21%**	**21%**	**21%**	**29%**	**8%**	24

Understandably, a large part of the exhibit design challenge comes in the media selection process, during which many museums feel the pressure to achieve something new or revolutionary, or to become "computerized" (Cassedy, 1992; Hudson, 1977; Mintz, 1992). Under these circumstances, media choices can become misdirected; what sounds great and what works great as a communication device are not always the same thing. Reiser and Gagne (1983) have done extensive research on the importance of selecting the appropriate media for instruction. These authors point out that although the selection of media is a critical step in the instructional design and development process, research has not yet yielded definitive results that one medium is superior over another in certain circumstances. R.C. Clark (cited in Morrissey & Berge, 1992) supports this by stating that media comparison studies are often flawed because they compare confounded results, (i.e., design approaches for textbooks are often not the same as those for computer-based training), and they do not account for novelty effects of newer media. He goes on to state that "the fact that we learn to prefer certain media or that we attribute varying levels of difficulty, entertainment value, or enjoyment to different media, might influence instructionally relevant outcomes" (p. 179). These beliefs and preferences for certain media can have a particularly strong effect in the informal, self-motivated environment of museums.

A number of educational researchers have developed media selection models that factor in elements of the instructional setting, learner characteristics, learning outcomes, physical attributes of the media, and practical factors regarding costs and resources into the media selection process (Dick & Carey, 1990; Gagne, 1977; Mager, 1988; Reiser & Gagne, 1983). These models tend to involve intricate flow charts and diagrams that help answer questions about the objectives and media, but Mager (1988) describes the process much more simply: "a feature (of any media) only becomes a benefit when it will help you accomplish a purpose...select the most readily available and economic items that will provide the features called for by your objectives" (p.112). While it is unclear whether museums use formal media selection models or not, similar media selection strategies modified to suit the museum environment are recommended by museum experts (Miles et al., 1982). The interviews conducted for this study as well as the literature indicate that there is normally much more leeway and creativity involved in museum exhibit design than there is in traditional educational material design in order to meet the museum's informal educational objectives and resource constraints, and to accommodate the museum audience (Chenoweth, 1990; Dick & Carey, 1990; Gardner, 1991a; Muro, 1992; Ogintz, 1992b; Reiser & Gagne, 1983).

When museum participants were asked to give the main reasons for choosing to use interactive technologies in their exhibits, many responded that they decided to use technology because it *attracts visitors* and/or because the *capabilities of interactive computer systems* allow enjoyable, self-paced and potentially in-depth learning experiences to happen (see Table 13). Art museum participants were the only ones who did not mention the attracting power of computers, focusing instead on the digital storage and interactive multimedia capabilities as reasons to incorporate technology. This makes sense when one considers visitor expectations of art museums versus other types of museums. People who visit art museums tend to come with more aesthetically focused motives and similar expectations, whereas the other museum categories will more likely draw audiences based on opportunities for learning or entertainment. Curators for art museums often consider computers unattractive, and not a drawing factor for their audience. Museums across all categories mentioned the flexibility of multimedia in serving a variety of learning styles, and/or its usefulness as a learning tool.

Table 13
What Do You Consider to be the Main Reasons for Incorporating Interactive Technology in Exhibits?

	Totals by museum type					
Main reasons for incorporating interactive exhibits	art	hist	chld	sci	oth	ttl
They are engaging/fun/have high attracting power		3	1	3	1	8
Topic/complexity requires capabilities of computers	2	1	3		1	7
Learn more by engaging in activities (helps interpret)		2	1	2		5
Multimedia can satisfy/appeal to several/ different learning styles	1	1		3		5
Provides self-paced discovery learning			1	3		4
To supplement traditional exhibits/ provide more information	1	1	1	1		4
Technology provides most flexible/ adaptable learning solution	1		1	1		3
It increases time spent, therefore, learning that occurs		2				2
Interactivity(with & w/o tech.)adds power to communication		1			1	2
n/a				2		2
Percent of responses by category	**12%**	**26%**	**19%**	**36%**	**7%**	**42**

In selecting interactive technology-based exhibits, museums appear to be considering at least three of the media selection criteria advocated by those in education: the informal characteristics of the museum learner, the learning outcomes expected, and the instructional setting. Each of these factors logically leads to use of the self-paced, discovery-based medium of interactive technologies. It is somewhat more difficult to tell from these responses whether the participants considered interactive technologies appropriate to the other media selection criteria, that is, the physical attributes of the media, or the costs associated. The physical attributes of most interactive multimedia systems are that huge amounts of information can take up a very small amount of floor space, and that they can be noisy if a lot of audio is used. Costs vary, but are generally high. While neither of these factors were mentioned as reasons to use technology, both issues were recognized by the participants in other parts of the interview as important considerations in exhibit design.

The museum participants were also asked whether they felt any of the reasons for using technology were a negative reflection on traditional artifact-based museum exhibition, and all responded in the negative. Several felt there was an audience for both types of exhibits, and that if the interactives are properly designed, traditional exhibits could be complemented by a computer program. Others, however, felt strongly that multimedia technologies can more efficiently and effectively expose a wider audience to more information than traditional exhibits are capable of easily or attractively providing. Many also felt that an artifact is not nearly as powerful alone as it can be in conjunction with a multimedia system that can explain the artifact in a number of contexts. Likewise, a multimedia exhibit explaining an artifact is considered to be more powerful if the information in the computer can be made relevant by seeing the actual artifact. The whole is greater than the sum of its parts, in effect.

In terms of a mode of exhibition, incorporating interactivity has proven to be a recurring theme in successful exhibit designs. Yet even the limited number of interactive exhibit examples provided thus far illustrates that interactivity can prove to be an elusive concept. The first companies to introduce the concept of interactivity to a consumer audience were in the computer game business, and they have argued about the concept of interaction for over ten years (Laurel, 1991, p. 20). For them the levels of interactivity are often discussed in terms of the frequency, range, and significance of the human to computer interaction that takes place. Laurel helps to make the theme of interactivity even more fundamental, stating it as a simple yes or no question: "You either feel yourself to be participating in the ongoing action of the representation or you don't" (p. 20). Yes means there is interaction, no means there is not. In this case, frequency, range, and significance are not necessarily the only qualifications for true interactivity, because eventually a creative leap is needed for the design to be a satisfying interactive experience (Laurel, 1991; Interviews: The Austin Children's Museum, 1992; The (Boston) Computer Museum, 1992). The bottom line is that there are several types of interaction and there is no cut and dry formula for designing "good" interactivity.

Bitgood (1991) of the Center for Social Design has defined the concept of interaction in terms of the museum environment. An interactive exhibit is "a device in which the visitor's response to the exhibit produces a change in the exhibit" (p. 4). He limits this definition to physical interaction and excludes mental interaction. Bitgood distinguishes three types of interactivity as a framework and common vocabulary for discussion of interactive exhibits: simple hands-on, participatory, and interactive exhibits.

- **Simple Hands On**: refers to exhibits that prompt the visitor to perform some physical activity, with no real change in the object being affected. Examples of a simple hands-on exhibit would include touching an animal or climbing a sculpture.
- **Participatory**: describes exhibits that involve making comparisons between the visitor's response and some standard. Examples of participation would include comparing surface textures of different rocks or assembling a model and comparing it with a display.
- **Interactive**: refers to exhibits in which there is a cause-and-effect relationship between the visitor response and a change in the exhibit. Examples include lifting a panel to reveal text, pressing buttons to hear sounds or see images, interactive computer simulations, or using microscopes to reveal something previously unseen.

All three levels of interactive exhibits can be used to focus the visitor's attention and increase interest. Bitgood (1991) states that hands-on exhibits are particularly suited for sensory or perceptual learning (e.g., feeling the surface textures of a rock). The Children's Discovery Museum of San Jose has numerous examples of hands-on exhibits, including the opportunities visitors have to grind corn, crawl and climb through mock sewer pipes, navigate a blimp, or build a dam out of sand (Ogintz, 1992b).

Participatory exhibits can be used to teach similarities and differences (e.g., distinguishing different sounds through a headphone) (Bitgood, 1991). The *Etiquette of the Undercaste* exhibit in the Experimental Gallery of the Smithsonian is an example of this type of interaction. Using theatrical staging techniques and simple technology, visitors are put into unfortunate economic and social positions to develop an understanding of these situations. The scenario begins with the visitor laying down in a coffin (i.e., dark drawer) and being told through the headphones they wear that they have been reborn as a homeless person, or a kid addicted to crack cocaine. They then proceed through an audio-visual, highly theatrical interpretation of what a homeless person's or crack baby's life is like. The recorded voice tells them to walk through low doorways, slide down a slide, and to perform other physical movement that takes them through the maze of the exhibit. On their journey, they see alcoholics, beatings, robberies, and listen to explanations of the lure of money in narcotics (Eldridge, 1992; Interview: Experimental Gallery, 1992). Although this exhibit reportedly received a number of negative comments because it made visitors feel so uncomfortable, there is no denying the power of the communication method used. A less controversial participatory exhibit at The Denver Hall of Life features an *Interactive Health Network*, designed by New England Technology Group, that uses magnetic cards to capture information at over 30 stations about the visitors health and physical attributes. Some stations learn things about the visitor - one with an infrared beam checks the person's height, for instance. Others teach the visitor about him or herself, or health issues in general. The computer network includes over 30 stations, and visitors can get printouts of the information they have gathered, or take the magnetic cards home with them and return on up to four visits to compare current and past data (Interview: New England Technology Group, 1992).

Interactive exhibits are appropriate for teaching cause-and-effect relationships or similarities, producing affective changes (in interests or attitudes), providing self-testing, or conceptual orientations (e.g., computerized maps that let the user get more information on areas of interest) (Bitgood, 1991). The Tech Museum of Innovation, for example, has a computer-aided design (CAD) exhibit which allows individuals or groups of visitors to design bicycles (Pollack, 1992; Interview: The Tech Museum of Innovation, 1992). The museum also has a computer interactive program that uses images captured from the Voyager missions to let visitors take a simulated trip over Mars, in which they decide what to explore, the simulation changing depending upon their selections. In another interactive exhibit, visitors can design their own earthquake by selecting vertical and horizontal pressures.

The exhibits in this final category of interactive are often more difficult to produce since they require consideration of more design factors, such as the user-interface and control and feedback mechanisms, but in return they teach higher-level skills (Bitgood, 1991;

Mintz, 1992). Exhibits can also combine the three elements - hands-on exhibits can have participatory components, as can interactive exhibits. According to Bitgood's definitions, a hands-on tortilla making exhibit falls into all three categories at different times of the process: the exhibit is partially hands-on when grinding the corn, it's interactive when making the tortilla, and it's participatory if an example of a finished tortilla is shown for comparison. In any design, the choice of the appropriate exhibit mode should start with the exhibit objectives, and from there the appropriate mode of interaction should logically surface, as well as the best media to use.

Although Bitgood's definitions do not explicitly reference mental interaction, it is important to discuss its significance as it adds another level of meaning to the notion of interactivity. While each type of interaction mentioned above requires mental activity, each also implies that a physical interaction with the object is taking place. Mental interaction, on the other hand, refers to the specific interaction between a person's mind and the object being observed, that is, the thought processes that take place at any time, without physical interaction. It would be naive to think the only interaction that could be found in a museum would be through an interactive computer exhibit, gravity well (a simple mechanical interactive exhibit commonly found in science and children's museums that teaches about gravity by rolling a coin down a funnel-like display), or other physical experience. A person's mind can interact with an art piece on a wall, for instance, and no outside stimulus is necessary to feel that sensation of interaction.

While the former descriptions center around general levels of interactivity that can be found in museum exhibits, there are specific uses of the word interactivity which describe differences in interactive technologies. The interactive technologies used in exhibits, for the most part, are computer-controlled databases of information that are programmed for easy access to any information contained in or controlled by the computer (i.e., stored on the computer's hard drive, a videodisc, CD-ROM etc.). When the information that can be accessed is stored in multiple formats - text, audio/music, video/animation, and graphics - it's called an interactive multimedia system. These exhibits would fall under Bitgood's third category of interactive exhibits which he calls "interactive," since the user's choices lead to a cause and effect relationship. As these technologies have evolved and designers have become more comfortable with communicating and designing with multimedia, variations of computer-based interactivity have also developed.

The first computer programs allowed only basic, sometimes called "meaningless" interaction to users. The only affect that they could have on the program was the selection of when to go to the next screen of information, and in that way it was user-paced. Greater control over computer-based exploratory learning was eventually enabled through increased opportunities for navigation, which allowed self-paced discovery of the information in an otherwise linear program. This type of control was not quite true interaction in which reciprocal actions could lead to any topic in the database, or that could potentially provide unique experiences for each individual. Eventually more sophisticated means of programming were developed to bring the user closer to an almost real life (simulated) interaction - the response from one actor (human or computer) depending on the response of the other. These interactive simulations often employ a question and answer approach, changing the information on the screen in various ways based on the user's responses to questions or situations described in the computer program. An application example would be a computer program that revealed easy, moderate, or difficult math problems based on whether the correct answer was given to the first question, and possibly, on how quickly it was answered.

Three levels of programmed interaction have been defined by Lucas (1992) from the Educational Technology Center at Lehigh University, as reactive, interactive, and proactive models for interactive technology. The reactive model pertains to the meaningless interaction or simple button pushing mentioned above, and is an outgrowth of stimulus and response behavioristic approaches. Lucas provides the example of pressing a space bar to turn the page on the screen, and states that the reactive model has been the most widely used model in instructional technology (p.8). The proactive model is derived from a cognitive approach to allow the user to construct his or her own path through the program. These hypertext (or hypermedia) programs allow the user to navigate their way through the information database, branching from one topic of interest to another, and putting the user in complete control over the learning environment. The final type of interaction suggested above is in line with Lucas' interactive model, which she describes as "an environment in which the learner branches through a program based on responses made to questions given by the computer" (Lucas, 1992). This two-way communication and feedback allows not only the branching mentioned in the proactive model, but also customization of the information presented dependent upon what the program determines are the users interests, motives, etc.. Note that none of these descriptions of interactivity represent that which is found in person-to-person communication or interaction which is spontaneous and unpredictable, and impossible to achieve without using some form of human or artificial intelligence. In each of the types of programs mentioned, the pathways that the user can potentially follow may be numerous, but they are not unlimited since the branches had to be defined/programmed by the designer at an earlier point in time.

Each of the three types of interactive technology described by Lucas (1992) would fall under Bitgood's (1991) third category of interactive exhibits, which he calls "interactive". The possible confusion in the naming of this final category may be lessened if one further specifies whether the interaction is with mechanical media (pulling levers, moving puppets, or conducting science experiments) or electronic media (e.g., watching videotapes, exploring videodiscs or computer programs) (see Exhibit 4). Generally, following Bitgood's categories, hands-on exhibits are mechanical, as are participatory, though the latter can include electronic media in the environment. Interactives use a mix of both electronic and mechanical media. As with Bitgood's recommendations about the appropriateness of using hands-on, participatory, or interactive exhibit modes, Lucas' models are also appropriate for different learning situations. Complete control (proactive model of instruction) is more appropriate for expert learners of the knowledge area. Novice learners would benefit from the programmed guidance found in tutorials and similar programs (interactive model of instruction). In learning basic skills, such as math, the reactive model of instruction would be most appropriate to provide the drill and practice necessary to attain these skills (Lucas, 1992). Given these descriptions, the interactive model of instruction in technology-based exhibits would be the most appropriate for the informal, presumably non-expert museum visitor, though proactive modes would be helpful to researchers, scholarly visitors, and museum staff.

By capitalizing on engaging and stimulating educational techniques, with or without computers, museums not only help individuals understand significant and relevant information, they help them assume responsibility for their own learning. The *What If?* gallery that recently opened at the Indianapolis Children's Museum has interactive multimedia exhibits as well as simple hands-on activities. The learning strategy is to prompt visitors to learn by asking them "what if?" questions, and then allowing them to explore various simulated environments that contain answers to the questions. One exhibit asks "What if you could discover a dinosaur?" and then lets children play archaeologist and dig for bones. Another exhibit asks about communication in Ancient Egyptian exhibit and then teaches kids how to decipher hieroglyphics. (Ogintz, 1992a; Interview: Indianapolis Children's Museum). No matter what medium of information presentation is employed, it is the interaction with the information that leads to learning.

Exhibit 4
Levels of Interactivity

Type of Interaction	Level of Control Over Learning	Electronic/Mechanical Interaction
Hands-on	low	mechanical
Participatory	low to medium	mechanical & electronic
Interactive	low, to medium,to high	mechanical & electronic
Reactive	low	electronic
Interactive	medium	electronic
Proactive	high	electronic

Note: These are generalized interpretations made by the author of this study based on the types of interactivity described by Bitgood (1991) and Lucas (1992).

Interactive Multimedia in Museums

Museum participants in this study have had varying lengths of experience with computer interactives and interactivity in general. Of the museums interviewed, most of the science museum participants stated that they have had all types of computer-based interactives since they were opened, and many of the children's and science museums reported "always" having had some form of interactivity (mechanical or electronic) in their exhibits (see Table 14a). Several of the children's museums who have had substantial experience with interactive technology-based exhibits state that their primary focus is on mechanical interactives. One children's museum stated the importance of interactivity in this way: *our audience (lar-*