Instructional Design Theory and the Development of Multimedia Programs[1]

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Introduction

There is no one model or approach for designing and developing programs for learning and performance support with interactive multimedia. But modern interactive multimedia technology offers unique environments for developing programs and it has distinct design requirements. This uniqueness does not obviate the need to know more traditional instructional design theories and models. Indeed, multimedia technology makes knowledge of design theory more important than ever because without such guidance, there is a tendency to employ the technology superficially, exercising its bells and whistles to create programs loaded with pyrotechnics but of little educational value. Multimedia effects are used in ways that make little, if any, contribution to learning or, worse, in ways that actually intrude on the learning process. Instructional design theories provide strategies for ensuring multimedia can be utilized to achieve learning outcomes. Developers need to know how these strategies can be applied in multimedia

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environments. They also need to be aware of some additional design and development issues that arise when the technology is utilized.

This chapter begins with a definition of multimedia and a brief description of multimedia trends to establish a context for understanding its remaining sections. This background information is followed by a discussion of how the use of multimedia affects the entire instructional development process and a discussion about how instructional design theories relate to the application of multimedia technology. Additional multimedia design and development issues are then delineated – issues relating specifically to the unique features of the technology.

Multimedia Technology and Technology Trends

Multimedia programs employ two or more of the following types of information: text, graphics, pictures, animation, audio, and video. Interactive programs are non-linear and alter the content presented and/or the order it is displayed on the basis of user input. The foremost interactive multimedia device currently is the computer and when people talk about interactive multimedia programs today, they usually are referring to programs that are computer-based (Ambron, 1988). In addition, when distance learning or performance support is involved, there usually is some presumption that the programs are provided via networks. Hypermedia is a closely related term referring to multimedia content that is composed of interlinked units of information that users can browse and explore (Shneiderman & Kearsley, 1989). The preeminent example of networked multimedia and hypermedia is the Internet's World Wide Web. Early multimedia programs were not as integrated as they are today, in part, because computers lacked sufficient power. Multimedia content was recorded as analog television and presented via special peripheral devices that the computers controlled. Students would interact with text on computers that would direct the devices to display still images or motion episodes on separate television monitors.

Four major trends have contributed to making the computer a multimedia appliance. The first is conversion. Conversion does not just mean being able to convert analog content to digital. It means that devices that were previously analog are becoming digital. Compact audio discs, digital still and video cameras, and digital telephones are, perhaps, the most prevalent examples, but digital radio and television broadcasts also are possible. The conversion to digital has help fuel a second trend, convergence, or the coming together of here-to-fore separate technologies. It is now possible to view digital movies or place phone calls with computers because computing, telephony, and television are coming together. Convergence not only applies to hardware but to software. At one time desktop publishing and word processing software were very different. Eventually, the layout, graphic, and WYSIWYG (what you see is what you get) features of the former became integrated with the font, spell check, and grammatical features of the latter so that functionally the two types of software tools are almost indistinguishable. Many of the applications built with software tools are converging also. Authoring tools that formerly created computer-based instruction for delivery on standalone computers or CD-ROM can now generate instruction for delivery on the

Internet's World Wide Web. While some of the programs generated provide electronic performance support systems (EPSS) and others provide more formal instruction, many programs incorporate both and, in these cases, it is sometimes difficult to determine just where the online support ends and training begins, since users can move seamlessly from the support system to more directed instruction. The third trend driving multimedia computing concerns capacity and costs. The former keeps going up, while the latter keeps declining. New capabilities engender new demand and economies of scale lower production costs. Cost and capacity factors have contributed to the forth trend – commonness. It used to be that computers were the exclusive domain of a privileged, knowledgeable few. Now, computers are ubiquitous, in the work place and at home, and, as computers have become more common, they have become easier to use and readily available as a means of providing multimedia instruction.

Multimedia in Instructional Development

Every instructional development model addresses the issue of media selection or choosing a mechanism for delivering training and/or performance support. The use of multimedia and computers is usually confronted when media selection decisions are made. Simply deciding to use multimedia computing is insufficient. Additional decisions still have to be made about the type of computer to use and its various features. It may need a certain amount of memory and storage to accommodate the large multimedia files, and it may need to accommodate external storage media such as CD-

ROM or digital videodisc. It also may need to be networked, and the network may have to have certain transmission speeds and other quality of service requirements. Multimedia developers face a unique challenge. Since technology changes rapidly, there is always an excuse not to use it because something better and cheaper is on the horizon. But such reasoning can lead to postponing adoption decisions forever. If the potential benefits of technology are to be used to advantage, adoption decisions will have to be made and the timing of these decisions becomes paramount. Adopt too early and the technology may be too expensive, unstable, non-standardized, or non-interoperable with other technologies. Adopt too late and the older technology may prove be more expensive and cumbersome than newer technology or, worse, no longer supported (Locatis & Al-Nuaim, 1999).

Technology's role in instructional development extends beyond the choice of delivery platforms and affects the development process itself. Most development models have an initial analysis phase, where performance problems are appraised to determine whether they would be most appropriately resolved through training, performance support, or some other intervention. Often, the learner population and the context in which training and/or performance support may be provided is assessed. There is also a design phase where the goals and objectives of the intervention are established and strategies are planned for achieving them. A delivery mechanism may be identified at this time and storyboards, scripts, and screen layouts devised. These strategies are often refined and realized in the form of a training and/or performance improvement product in a development phase. Finally, most models have an evaluation phase where the interventions developed are tried out and their effectiveness is determined. Multimedia affects the development process in at least three ways.

The first way multimedia affects the development process is that it makes it possible to contract the development stages. Much of the up front analysis, planning, and design in instructional development is done on the computer and, when multimedia programs are to be created, it may unnecessary to create screen layouts, tests, and other instructional assets on paper that later will be programmed. Instead, easy to use authoring tools and markup languages can be employed to generate approximations of the final product immediately. Such rapid prototyping allows early review of the content and design alternatives and speeds development. The prototypes are concrete objects, not theoretical plans, having specific features that developers and their clients can discuss. Moreover, these mockups can be tested with small numbers of users and the feedback used to develop more refined, working prototypes.

In addition to using rapid prototyping, the use of multimedia usually accentuates the importance of pilot testing in development projects, especially when the development projects are large and the investments in deploying technology widely are substantial. Pilot testing one or few completed, working prototypes can help determine whether these program components are effective enough to justify further development and whether the technologies employed will prove cost-effective if deployed on a wider scale. Such pilot testing varies from traditional assessments in instructional development, because it is done using program components, not the entire program. For example, if an instructional program is to consist of ten multimedia modules, the pilot test may involve one or two of the first prototypes. If an EPSS is to support in a dozen different areas, one or two areas might be rapidly prototyped, further developed until they are functionally complete, and pilot tested. After pilot testing, additional instructional modules may be developed or further functionality might be added to the EPSS.

The third way multimedia affects instructional development is that it adds a requirement to do some technology assessment in the early up front analysis stage. If multimedia are likely to be part of the solution to a training or performance problem, then some of the up front analyses of these problems should include an appraisal of technology options as well. It is useful to determine what technologies are being used currently in the workplace and how comfortable people feel about them. It also may be useful to determine how receptive the organization and the various groups within it are to new technology. Sometimes, no additional technology investment may be required when existing infrastructure is leveraged. Other times, modest technology upgrades, such as the sound cards or higher resolution displays for existing desktop computers, may be needed. One the other hand, major upgrades in faster computers or higher speed networks might be necessary or older technology must be replaced completely. Even when appropriate technology is in place or management is willing to invest in new technology, the attitudes and readiness of employees may augur against it -- at least not without some additional traditional classroom instruction or personal mentoring. Much depends on previous experiences with technology and the confidence with which people use it.

Instructional Theory and Multimedia Development

One of the greatest threats to the integrity of multimedia projects is for developers to become so enamored with the capabilities of the technology that they attempt to use them all, even if they add expense and have marginal utility. Instructional theory provides guidance for designing multimedia programs that will achieve a range of learning outcomes. The key is to determine what outcomes one wants to achieve and then to identify the appropriate instructional theories for attaining them. Is the objective to obtain certain knowledge or skill, to solve problems, to apply procedures, or learn on one's own? Is it to motivate, to foster reflection, or to encourage individuals to learn together? Since most multimedia programs have multiple goals and objectives, several theories may be relevant. While the theories sometimes seem contradictory, they usually are not. Instead, each theory tends to emphasize particular aspects of the learning process. The theories that figure more prominently for one given set of learning outcomes may be totally irrelevant or only tangentially applicable in achieving different goals.

There are three reasons why instructional theories have relevance to the design of multimedia programs for learning and performance support. First, they have stood the test of time. Indeed, some are based on teaching traditions dating back to ancient Greece.

Second, they have empirical support. While some of this support is based on experience people have had in applying a theory, most of the theories are supported by substantial scientific research. Finally, each theory offers precise guidelines for bringing about different educational outcomes. When a theory is relevant to given instructional goals, it usually offers a blueprint for constructing learning experiences that will facilitate their attainment. In sum, the theories are authoritative sources for making informed design decisions. They provide rational frameworks for thinking about and discussing design options that can be more productive and have greater payoff than exchanges between developers and clients about their personal preferences and predilections. Although it is not possible to describe how each individual theory can be applied in designing multimedia programs in single chapter, they can be discussed categorically, depending on whether they have a behavioral, cognitive, or humanistic/social/affective orientation.

Behavioral Theories and Multimedia Design

Behavioral theories tend to emphasize the responses learners make during instruction. The responses are made to some stimulus, but other than acknowledging that some cueing or prompting may be necessary to evoke responses, the theories have little to say about how knowledge or information should be presented and portrayed externally, not to mention the thinking that transpires internally inside the learner's head. The theories do, however, have something to say about sequencing instruction and how learners should progress.

The primary tenet of behavioral theories is that responses that are appropriate to attaining learning and performance outcomes should be reinforced and those that are inappropriate should not. The implication for interactive multimedia design is that learners should be actively responding to the program content, not passively viewing it. Moreover, when a program provides opportunities for interaction, they should contribute directly to attaining a program's goals. A multimedia program that teaches reading, for example, may have a game in which students have match words beginning with the same letter. The task is one of pattern matching, not reading. More appropriate games would have students match words starting with the same sounds or match the names of objects with their pictures. Another implication is that learners need immediate knowledge of results after they respond and, possibly, remediation. Feedback might be provided in games, for example, by having a counter score each response. The games might have text or sounds encouraging students to try again when their responses are incorrect and that route students to remedial learning events when they fail to attain a certain performance threshold.

Behavioral theories also hold that certain skills are prerequisite to others and that learning should progress in small steps. Adding and subtracting single digits, for example, is preparatory to adding and subtracting multiple digits where carrying and borrowing may be involved. Consequently, behaviorists also prescribe mastery of earlier skills before allowing students to progress to later ones. The approach has intuitive appeal and is very a plausible in cases where prerequisites can be identified. The problem is that is not always clear that there are prerequisites for certain skills or what constitutes mastery. Swimmers, for example, do not have to master dog paddling before progressing to the crawl stroke and when physicians do medical diagnosis they do not have complete history taking before ordering laboratory tests. Even when there are prerequisite tasks and an obvious order of precedence in their performance, there may be a range of sequencing options. In addition or subtraction, for example, it is possible to teach the steps from first to last or to teach the last step first, then the next to the last step, and so on.

Prerequisites and mastery learning raise questions about learner control of instruction and generally augur against it. Most multimedia developers, however, are loath to handcuff their users electronically and usually provide a range of tools for exploring their programs. Research on aptitudes, however, indicates that students with well-developed self learning skills can thrive in open environments (Snow & Lohman, 1984). Older students or students who already have substantial knowledge of the subject matter are more likely to have these skills than novice learners. Two design options are popular when learners are novices. One is to provide them with advice about to proceed through a program, based on their previous performance. Another is to provide programs having mechanisms for activating or deactivating learner control (cf., Shin et. al., 1994). Some may allow teachers to set the learner control function, while others may allow students freedom at first, but impose more direction when performance is low.

The behavioral theory dictate that instruction should proceed in small steps has largely been discredited. Small steps are not only boring, they lead to instruction that is inefficient. Most multimedia developers break instruction down into logical steps that reflect the subject matter and the tasks that are performed in the real world, rather than divide content into arbitrary sub-skills. If there is any question about size of step, they are prone to opt for large steps initially, dividing instruction into smaller steps only if tryouts indicate learners are having difficulty. While this approach insures development of lean programs, there are concerns that the programs provide insufficient instruction when used in conjunction with learner control (Schnackenberg & Sullivan, 2000). Some developers also opt for creating adaptive programs that dynamically adjust the size of step and difficulty of the information presented based on previous performance. These programs are more sophisticated than those imposing more direction when performance is low because the programs have algorithms that constantly compute estimates of each learner's knowledge level during the course of interaction (Tennyson et. al., 1984).

Cognitive Theories and Multimedia Design

Cognitive theories fall into two camps: those that endorse expository teaching and those favoring approaches enabling students to discover and construct knowledge on their own. While constructionist argue that all learning is constructed because students must "make sense" out of the information presented, clearly, there are programs encouraging greater hypothesis generation and independent study. Most cognitive theories focus on the stimulus and on how knowledge is represented as well as the thinking that goes on inside a learner's head. Where the two cognitive camps diverge is on how much guidance should be provided. Those advocating expository approaches are similar to behaviorists in favoring program control. Unlike the behaviorists, these theorists are more tolerant of allowing learners to progress without mastering prerequisites. Students may only partially apprehend component concepts and skills initially, and it is only when they have been exposed to all components that the pieces "fall into place" and understanding occurs.

The most pervasive influence of cognitive theories on multimedia development is, perhaps, the area of knowledge representation. Both camps want to insure knowledge is appropriately portrayed and that conceptual relationships and problem solving strategies become internalized appropriately by students. Expository theories particularly stress content organization though tables of contents, concept maps, graphical displays and other mechanisms that make explicit subject relationships. Information visualization strategies from screen layout to the use of color in multimedia programs are of special concern (cf., Lynch & Horton, 1999; Shneiderman, 1998; Tufte, 1990). One popular multimedia design strategy is to employ metaphors to depict content. A program teaching accounting may use a spreadsheet metaphor, while one teaching research skills might situate the instruction in a virtual library setting. Another strategy is to use analogies. While metaphors establish more global context for representing knowledge, analogies provide more specific ones. A heart, for example, may by likened to a pump; a brain to a computer. Metaphors and analogies are often employed in non-instructional multimedia applications. An airline's web site, for example, may use a ticket counter metaphor that users can interact with to obtain information about fares, destinations, and schedules. When metaphors and analogies work, they are spectacular, but when they fail results can be abysmal, so they should be chosen carefully.

Cognitive theories have also influenced multimedia design in the development of intelligent tutoring programs, expert systems, and user interfaces. While adaptive instructional programs dynamically adjust instruction, the adjustments are based on statistical probabilities calculated from previous performance in the program. Intelligent tutoring programs can be much more sophisticated, presenting problems intentionally designed to detect reasoning errors and repair them. Some compare student performance to an underlying expert model and intervene when a student's performance begins to diverge. Others have underlying knowledge bases of rules experts employ to solve problems that they explicitly teach, and they may have the capability to solve the problems they present to students themselves because they are integrated with expert systems (Wenger, 1987). There are also expert systems that exist independently of tutoring programs that are not used so much to detect reasoning errors as to prevent them. The systems can be viewed as a special type of electronic performance support system that renders advice based on information users provide. The systems are intended to reduce the amount of information people need to keep in their heads and to suggest problem solutions that might be overlooked (cf. Shortliffe, 1990). In medicine, for example, it is impossible to keep track of all drug interactions and some interactions produce side effects mimicking diseases and syndromes. Expert systems can inform physicians of interactions in the medications they may consider prescribing or, if a patient presents with certain symptoms that can be ascribed to drug interactions or a disease, they may suggest drug interaction as a possible cause to help guard against possible misdiagnosis. Cognitive theory's influence on interface design has been to encourage development of simpler interfaces and to reduce the amount of cognitive overhead students need to interact with programs (Norman, 1993). Anyone who has starred at a computer screen understands the notion of metaphor extends beyond multimedia applications and to the computer's operating system. Users no longer need to know commands but interact with a "desktop" and they use programs with graphical user interfaces enabling them to place "files" into "folders" or to "bookmark" their favorite web sites.

Constructionist cognitive theories have added a dimension of openness to multimedia development (Hannafin, et. al., 1997). Of special importance is the development of case studies and simulations to discover underlying concepts and problem solving strategies. Sometimes the cases and simulations have fidelity with the real world and sometimes they do not. A multimedia chemistry program may offer a virtual laboratory with devices and substances that user manipulate to conduct experiments much as they would in a real lab. A program teaching map reading and computational skills, one the other hand, might place learners in a completely hypothetical situation, such as being in a mythical land, and require them to use maps, compasses, and other devices to locate treasure. Constructionist theories support the use of databases and online information sources to solve problems. The Internet and World

Wide Web constitute a vast information space for addressing research questions or for browsing and exploration that can be employed to teach the metacognitive skills of learning how to learn on one's own.

Humanistic/Social/Affective Theories and Multimedia Design

Humanistic, social, and affective theories address cultural factors in learning, educational outcomes related to learning how to work in groups, and the development of attitudes. They also are concerned with motivation. Although they are diverse, they have impacted multimedia design. Cultural factors are an important factor in multimedia development. Care is taken to avoid stereotypes. If programs require characters, then they usually are representative of the target population for which programs are intended. A number of motivational strategies such as employing cues to gain and direct attention, offering encouragement, and providing problems that are challenging but still doable to instill confidence and feelings of accomplishment are used routinely in multimedia programs.

Of all the theories, those in the humanistic, social, and affective realm probably have more to say about how multimedia programs are utilized rather than how they are designed, however. The ways multimedia programs are utilized, can dramatically affect learning outcomes in ways developers might not have anticipated. For example, skilled teachers can use the most culturally pugnacious and biased web sites of extremists groups as springboards for learning about fear and hate and for encouraging critical thinking. Most multimedia programs are intended for individual use, but research shows additional benefits accrue by having students use them in groups (cf. Hooper, 1992). Peer discussion fosters further elaboration of the content and allows more advance learners to help their cohorts. Cooperative learning approaches identify specific strategies for fostering such outcomes while discouraging competition and ensuring all students contribute. While most group learning with computers has occurred in classroom settings, online communication tools are enabling students to learn collaboratively at a distance (Hiltz, 1994). While some tools, such as email and discussion groups, allow for asynchronous communication, others, such as chat, videoconferencing and streaming video applications allow for one to one, one to many, and many to many communication (Locatis & Weisberg, 1997). A challenge for multimedia developers will be create environments where multimedia resources and online collaboration tools are integrated to allow knowledge sharing and advancement (Scardamalia et. al., 1992).

Multimedia Development Issues

All the design and development decisions that need to be addressed in traditional instruction and performance improvement development projects should be addressed when multimedia is involved as well. The training and performance problems need to be identified, the characteristics of the population having the problems need to be described, and the context and environment (organizational and cultural) were interventions to improve performance might be made need to be appraised. Addressing these issues becomes even more important when multimedia are used because significant start up and development costs may be involved. But the prospect of using multimedia often raises additional concerns, many of which are not specifically addressed in development models or instructional design theories.

Asset Use and Allocation

It is one thing to have the capability to present content in a range of modalities and another to actually do so. First, every modality employed adds to development costs and some modalities are more expensive than others. A program having video, animation, and graphics will generally be more expensive to create than one having just graphics and text. Moreover, use of some multimedia boost system requirements. Audio and video may require more powerful computers with CD-ROM or DVD drives and sound cards or, if delivered via the Internet, a certain level of network performance and capacity. Second, use of some modalities or too many modalities may be counter-productive. For example, while it may seem clever to have continuously running animations on a text page, they distract from reading, and it would be better to allow users to activate and control them on their own. But if the animations are gratuitous and do not add substantive content, they will have little benefit, even when interaction is added. Novice developers often use varied backgrounds and colors, moving text, and other gimmicks that usually only contribute to eye strain. Ironically, abuses such as these are more likely because authoring tools have made it easier to create so many varied multimedia assets.

Content Granularity

Many multimedia programs are excessively long and linear. Most users work with computers interactively and exercise a high degree of control over the work that they perform with them. Long audio and video sequences or reams of text can turn an active technology into a passive one. Appropriate granularity of multimedia content is a difficult problem. Old adages such as "limit information to what can be displayed on a single screen" are not very useful. Not everyone has the same size screen and most users can adjust its resolution anyway. As computer use has increased, more users know that they can scroll down displays and that there may be more information than what fills a single screen. Moreover, when text is involved, many users may print it for use offline. They may prefer to print the entire resource or sections of it rather than individual pages. Finally, convergence has made it possible to broadcast audio and video as streams over the Internet. These programs may be archived and offered on demand or live, but are usually just as passive as regular radio and television programs. The granularity problem depends on how the multimedia information is to be used and what users may expect. Users may tune into a live video broadcast of a symposium on the Internet expecting to see it in its entirety. Users accessing an archive of the conference, however, may prefer the option of choosing among different presentations that were made during the symposium instead of the whole program.

Meaningful Interaction

Learning and performance improves when users can interact with content meaningfully. There are many levels and types of interaction, the simplest of which is paging forward and backward through successive displays. If the program is an EPSS, such page turning may suffice, since most users simply may be looking up information, but when learning is involved, higher levels of interaction are warranted. One higher level is providing students with problems and selectable options for solving them. The choices may be simple links to other parts of the program providing feedback or learners may be routed to different parts of a program. Another type of interaction is a constructed response, where users must compose their answers and feedback and routing students through the program are based on this input. Other interactions may involve monitoring the time students take to respond and scoring their performance. Complex computer simulations of time sensitive performance, such as solving trauma cases in emergency rooms, are examples. The computer may alter the condition of the simulated patient automatically, introducing new complications, if certain interventions fail to be made, and each option students choose may be used to calculate problem solving performance. There is a trade off between level of interactivity and development cost. It is much more difficult to evaluate any input students compose themselves, than to assess their selections from a list of options. Adding time as a variable and/or scoring algorithms often requires formidable programming.

Human Interaction

One type of interaction that often is overlooked in multimedia program development and use is interaction among students or between students and teachers. The presumption that students should use programs individually, has a long history in multimedia development. As more tools evolve allowing students to collaborate online, multimedia developers need to define ways of incorporating them into their programs, since student to student and student to teacher interactions are by nature much more open and free wheeling than any that can be realized with computers alone. While the use of asynchronous communication tools such as email predominate today, synchronous tools such as videoconferencing are becoming more feasible at the desktop. Human interaction also can be designed into applications involving live streaming audio and video broadcast of lectures, seminars, and other events over the World Wide Web. In addition to providing a link on a web page to the broadcast, links also can be provided allowing users to send email or chat messages to the program presenters. If planned appropriately, audience participation can be encouraged and the broadcasts may assume some of the character of radio and television talk shows.

User Interfaces

Human factors and human-computer interaction are important considerations in multimedia program development. Computer displays do not have the density of print and care must be taken to insure fonts and images are legible and displays are clear and uncluttered. An overarching goal is to make the interface transparent, so that users can concentrate on learning the content form an instructional program or obtaining support of an EPSS without be preoccupied with the computer an intervening tool. One way this is accomplished is by devising "affordances" or creating interactive multimedia objects with functionalities that are intuitive and obvious. Forward and backward arrows for paging and printer icons for printing are popular examples. Another way this is accomplished is by making parts of the interface similar with the computer operating system or other application tools users are likely to understand already. For example, if the computer operating system and most other applications for the computer use drop down menus, then this method of making menu selections should be considered. One benefit of offering resources on the web is that browsers provide a standard interface for accessing content. Finally, the overall design should be consistent. Screen layouts should follow a standard format and navigation tools should be uniformly placed so users know exactly what to expect as they interact with the program.

User Navigation

While navigation is part of the interface, it is important enough for special consideration. When linear media like video are employed, users are guided through the program. While books are non-linear, their size and organization are usually apparent at a glance. Not so with computer programs, and disorientation is common. While care should be exercised to provide navigation features that are consistent with program or learner control strategies developers choose to adopt, it is often advisable to provide tools allowing users to exit the program, go to the start of the program, or access "landing pads" in the program (such as indexes and tables of contents) that let them jump to other parts. In addition, users should not have to traverse more than three menu layers to access content. Search features also may be important, especially if users are expected to look up information, as in an EPSS. When multimedia is designed for the web, links outside the program to other resources and web site need careful consideration. While linking to existing databases and other related online resources is a unique advantage, enabling developers to leverage resources and not have to develop them themselves, placement is crucial. The overall goal is to encourage users to stick with the program and the web site, so users should not be encouraged to leave. If users select a link is to an outside resource that they expect is internal, they may become perplexed. It is better, therefore, to have external links grouped in one section of the program, appropriately labeled, rather than riddled throughout. Since external resources are beyond developer control and may be moved or deleted by those in charge of these sites so as to make the links inoperative, this strategy also has the advantage of making the links easier to maintain.

Asset Management

One of the most labor intensive efforts in multimedia development is the identification, creation, and/or capturing of resources. When existing photographs, artwork, or other resources are identified for inclusion in programs, permissions, clearances, or copyrights may have to be obtained. Many graphics, sound, and video resources also may have to be developed from scratch. While these resources may already be in digital format, they often are not. Photos may have to be scanned and audio and digital recordings digitized. The higher the resolution of a digitized image or the fidelity of a digitized audio source, the larger its file size. More storage space will be consumed when it is stored on a CD-ROM and more bandwidth will be consumed if the file is delivered over the Internet. Consequently, many developers may create or capture them in lowest resolution acceptable. A better strategy, however, is "capture large; deliver small". Since so much effort is involved, digitize resources at the highest resolution, archive them, and then export them at a lower, acceptable quality. The reason is that technology improves rapidly. As the resolution of computer displays improves and bandwidth increases, standards of acceptable quality will rise also. When programs are updated, it will be easier to re-export the hi-resolution resources at the new standard of acceptability than to have to recapture them. Even if a program is not updated, many of the multimedia resources in it might be re-used in future projects and it may be worthwhile to catalog individual assets and place them in a database so they can be retrieved and re-purposed.

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