Title

A SYSTEMATIC APPROACH FOR DESIGNING HYPERMEDIA ENVIRONMENTS FOR TEACHING AND LEARNING

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Abstract

This paper will present a systematic approach for designing hypermedia environments for online learning. First, I will discuss distance education, online courses, and general considerations for designing online learning environments. Second, I will present the history and definition of hypermedia, its attributes, and theoretical background. Third, I will present and discuss a systems approach to developing hypermedia to be used as part of courses and learning environments delivered on the World Wide Web. Issues relating to structuring of the information, branching and interactivity, user interface, and navigation will be discussed in detail.

Technology and distance education

Recent advances in telecommunications and microcomputers are changing the way we interact with each other, communicate, and access information. The world is becoming a global network within which the use of telecommunication technologies is a major component. There is a rapid increase in the proportion of schools that are connected to the Internet. In 1994 35 percent of US schools were online, compared to 95 percent in 1999 (U.S. Department of Education, 2000). In 1998 51percent of instructional rooms in US schools were connected to the Internet (U.S. Department of Education, 1999). Computer networks provide educators with more tools and strategies for facilitating learning and reaching more students (McIsaac & Gunawardena, 1996). While access to the Internet by schools is increasing, students, educators, and scientists from around the world are able to collaborate and create new learning communities, which foster new approaches to teaching and learning. The Internet provides new opportunities for interaction and it has become an important delivery medium of distance education.

One of the most frequent uses of advanced telecommunication technologies in higher education is for the delivery of online courses and degree programs. Educational institutions are encouraging, and at times requiring, teachers and faculty to develop online courses. However, online universities have often being called “digital diploma mills” and have been accused as not been as effective as traditional universities (Noble, 1999). As institutions battle for dominance in the area of online education, few would contest that online education is here to stay.

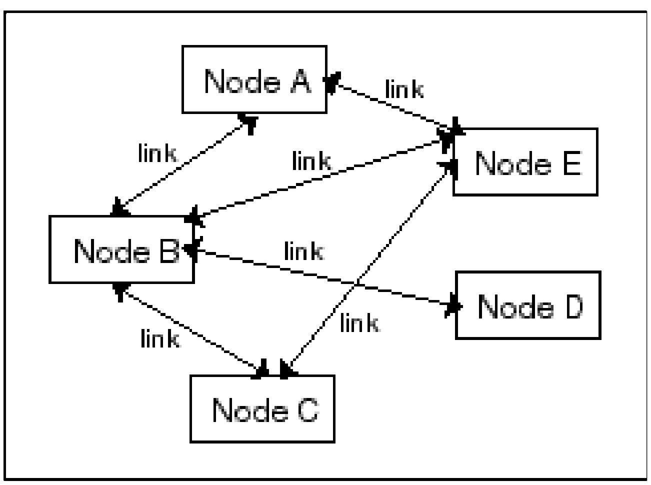
One of the major tasks that instructional designers involved with initiatives to deliver online instruction face is the designing of online learning environments in hypermedia format. Designing online learning environments is not something exclusively practiced by distance educators. The line between distance and traditional education is becoming more blurred. Most university courses in the U.S. make some use of the Internet to provide an online syllabus, online readings, establish a discussion list, and the like.

Designing the online course

Designing an online course can be a real challenge for educators and instructional designers. The important factors in any instructional environment are the strategies employed, and the overall design of instruction. In order for an online course to be effective, it has to be as well designed as any other traditional course. Vrasidas and McIsaac (1999) found that the structure of an online course is crucial in promoting interaction and the feeling of social presence. Furthermore, there are some extra considerations relating to the delivery medium of online instruction.

Eastmond and Ziegahn (1995) emphasized the importance of careful design for online courses and discussed several considerations relating to the effectiveness of the course. Online courses need to follow an instructional design model that is grounded on theory and research (Price, 1996). Although Eastmond and Ziegahn (1995) support a more open, flexible design of instruction, the process I will describe later on is based on a more structured model. Some of the considerations discussed by Eastmond and Ziegahn (1995) are the selection of online and off-line activities, decisions with regards to how much of the content will be online and when the learner will be referred to other resources (readings, videos, CD-ROMs, other WWW sites, etc.), issues with regards to promoting participation and interaction in the course, designing the syllabus, and facilitating online discussions. One of the components of online courses that use the Web is the designing of hypermedia environments that will be used to deliver or support instruction.

Figure 1. Nodes and links in a hypermedia system.



Hypertext and hypermedia

In its regular form, text is mainly linear. The reader follows a linear paging sequence when reading text from a book or an article from a journal. On the contrary to regular text, hypertext is nonlinear. In the words of Theodore Nelson (1987), who is regarded as the father of the term, hypertext means "non-sequential writing" (p. 29). The major components of any hypertext document are the nodes and links. Nodes are the primary elements of information and the links tie the nodes together (see Figure 1). The size of the nodes can range from a word, a sentence, or a paragraph of text, to a combination of images, sound, video, and to a larger amount of information. Links associate the nodes with regards to their semantic relationships. The link between node A and another node B will be a result of the semantic relationship of the two nodes, or a result of the hierarchical structure of the information in the hypertext system. The difference between a hypertext and hypermedia system is that in hypertext the nodes consist of text, whereas in hypermedia the nodes might consist of multiple media such as text, images, sounds, animations, and movies.

Nelson coined the term hypertext in 1965 but the idea goes back to 1945 when Vanevar Bush was director of the U.S. government's Scientific Research and Development office. In his classic article "As we may think", Bush (1945) described his ideas about organizing information to facilitate storage and retrieval with the help of the machine called the *memex.* According to Bush (1945),

> A memex is a device in which an individual stores all his books, records, and communications and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

Augment, the first usable hypertext system, was developed by Douglas Engelbart in 1962 at the Stanford Research Institute. It was designed to augment human intelligence (Barker, 1993).

Hypermedia attributes, memory, and learning

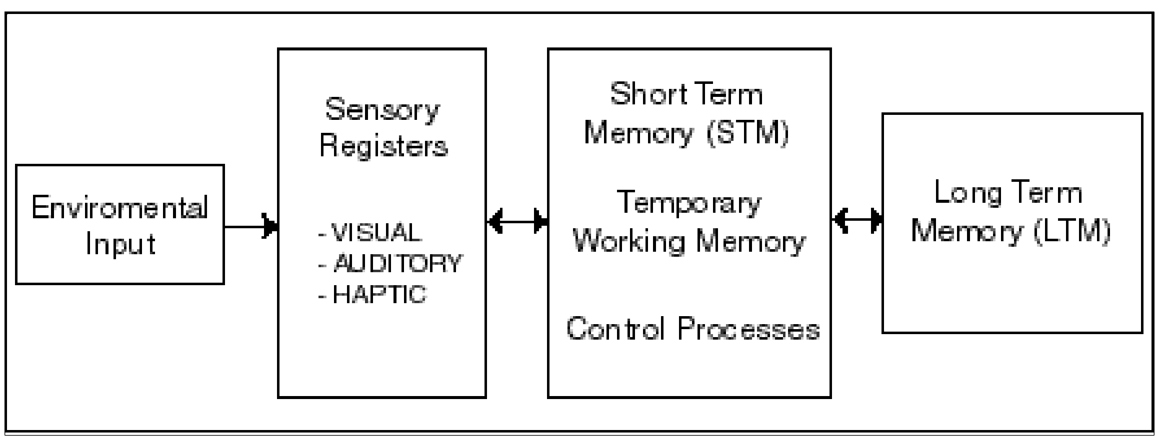
Hypermedia systems are usually used for either informational or instructional purposes (Romiszowski, 1990). Accessing of information at a nonlinear manner is one of the biggest advantages of hypermedia envisioned by pioneers in the field (Bush, 1945; Nelson, 1987). When used as informational, hypermedia systems are similar to huge databases that store information and the user is allowed to browse, search, and retrieve information. Jonassen (1989) asserted that the difference between a database and a hypermedia system is that in a database information is represented in a "... two-dimensional (rows x columns)..." way whereas hypermedia systems "...can represent information multi-dimensionally..." (p. 17). When used as instructional, hypermedia systems are designed so that they carry the whole burden of instruction. They present the instructional objectives and the material to the learners, guide them through activities, test their performance, and provide them with feedback.

Allowing for high learner control is another advantage associated with hypermedia systems (Barker, 1993; Conklin, 1987; Jonassen & Grabinger, 1990; Romiszowski, 1990). Learners can browse, search, and navigate through a rich hypermedia system and look for specific information that will enable them to accomplish certain tasks at their own pace. The level of learner control is usually defined by the degree of interactivity built in the system. According to Jonassen (1989) "the premise is that increased interactivity will produce greater attention to and comprehension of the information" (p. 14). Allowing learners to select material, paths, and strategies, might not be very effective because often times learners do not have the knowledge, and experience to select the right path. However, studies have shown that careful design can enable learners to make the right choices (Romiszowski, 1990).

Silva (1992) conducted a study to examine the influence of interactivity on learning in a hypermedia system. The results indicated that the highest scores were achieved by learners that were allowed to freely browse the material with an interactive plan available to them. Furthermore, it was found that the students of lower academic status learned more when their interaction with the system was limited to a sequential presentation of the information. One of the implications from this study is that students with different academic abilities will benefit in different ways from hypermedia systems.

Another attribute of hypermedia is that it parallels the way that the human brain and memory work. Atkinson and Shiffrin (1971) proposed a multistore model of the human memory system which is divided into three components: the sensory registers, the short term store or short term memory (STM), and the long term store or long term memory (LTM). The incoming information is recorded in the sensory registers, which can be visual, auditory, or haptic (see Figure 2). The STM lasts only for a very brief time and here is where the control processes of rehearsal, coding, retrieval, decisions, and strategies take place. The control processes are performed to facilitate the flow of information from STM to LTM. The information in the sensory registers stays there only for a very short time and it then decays. If it is matched with information structures already existing in LTM called "schemata" then it is transferred to STM from the sensory registers.

Figure 2. Short and Long Term Memory. From R. C. Atkinson and R. M. Shiffrin, The control of Short Term Memory, Scientific American, 225, pp. 82-90, 1971.



Schemata are the basic cognitive units. Neiser (1976) described schemata as "the entire perceptual cycle" (p.54). Piaget proposed the terms assimilation and accommodation. Assimilation is the process during which humans, after perceiving their environment, assimilate new information using preexisting schemata. Accommodation is the process during which preexisting cognitive structures or schemata are modified to accommodate new information (Piaget & Inhelder, 1969). Information stored in the LTM determines up to a great extent how incoming information is processed. It determines what we can learn and store in the LTM (Winn, 1993). Assimilation of new information depends upon preexisting schemata.

Building on schema theory Jonassen (1989) postulated that there are a lot of similarities between memory and hypermedia. He argued that "Schema are to memory as nodes are to hypertext. They are the building blocks of memory and hypertext. Hypertext resembles memory" (p. 23). When learners use a hypermedia system they can access information in a nonlinear fashion and in a way that it best fits their own schemata. Hypertext, according to Jonassen (1989), can facilitate the acquisition of new knowledge. For learning to occur, incoming information should be matched with preexisting structures. Information in a hypertext system is usually structured according to the model of the expert's structure of knowledge. Hypertext systems can mirror an experts knowledge structure. Therefore, "a useful knowledge structure may be mapped more directly onto the learner's cognitive structure" (p. 86).

Another advantage of hypermedia systems is their multi-modal nature (Barker, 1993). Information is stored in more than one mode. Visual, verbal, and auditory information can be incorporated in such systems. Representation of information in multiple modes can improve learning and retention, only when there is an overlap between the different modalities (Hannafin & Hooper, 1993). If for example, text and sound are representing the same piece of information, then the likelihood of that information to be learned is increased. This is supported by Paivio's (1986) dual code theory according to which information can be stored in the LTM in a verbal-like mode (propositional or digital), an image-like mode (iconic), or in a combination of the two. Representing information in both image and verbal-like forms has the advantage of being more easily retrieved and remembered (Pressley & Miller, 1987).

A systems approach to hypermedia development

Before discussing the systematic process of designing and integrating hypermedia in teaching and learning, it is necessary to briefly discuss the systems approach to Instructional Design (ID). ID deals with the methodology of designing instruction. One of the approaches employed in ID is based on general systems theory (Bertalanffy, 1968; Gustafson & Tillman 1991), according to which all the major components that have an impact on curriculum and instruction are part of a system and they all work towards the same goal, which is learning (Dick & Carey, 1996). Models of ID are systems of linked events that guide the instructional development process. The main components of most models of ID are the statement of objectives, the selection of the appropriate instructional strategies, and the evaluation component.

During the last eight years the author was involved in the development and production of several hypermedia projects, many of which were recorded on CD-ROMs and/or delivered on the WWW. For the development of these projects a process was developed, which guided the development of the project from conceptualization to final production and implementation (see Table 1). This process was based on several theoretical instructional design models (Dick & Carey, 1996; Gagne, Briggs, & Wager, 1989; Smith & Ragan, 1993) and other factors involved in hypermedia development. Such factors include the design of the user interface, branching and interactivity, information structure, and navigation tools (Barker, 1993; Jonassen, 1989; Park & Hannafin, 1993; Schwier & Misanchuk, 1993). This process can be applied for the development of other multimedia projects including online databases, commercial websites, and interactive kiosks.

The process discussed below is based on a number of questions and issues that are addressed at every step of hypermedia development. However, this is not a rigid process. Steps often overlap and their sequence might change depending on context. Like in instructional development, in hypermedia development there are no prescriptions. Every project is unique depending on its goal, audience, content, and budget. The emphasis of the following discussion will be on the design component of the process.

Table 1. A systems approach to hypermedia development.

Phase 1	Phase 2	Phase 3
· Goal development · Audience & learner analysis · Needs assessment · Limitations · Content analysis · Task analysis · Identifying objectives	· Develop evaluation component · Strategies and interactivity · Design (flowchart, storyboard) · User interface · Collect material · Production of prototype	· Revisions · Implementation · Summative evaluation
Formative Evaluation		

Phase 1

Goal development

What is the goal driving development of the project? Why is this system developed instead of a different instructional module? Is it developed as an informational resource or as an instructional system? Why is hypermedia appropriate for this purpose? Why is technology-based learning suitable for this project? The goals of the project should be in alignment with the overall goals of the institution which will use the project.

Audience and learner analysis

Which is the target audience? What are the learner characteristics? How experienced are the learners in using hypermedia and navigating the Web? Are they familiar with microcomputers? What do the learners already know about the subject of the project? What are their attitudes towards the subject and the delivery medium?

Needs assessment

What are the specific skills, knowledge, and concepts that need to be taught? Detailed surveys and pilot studies can provide the development team with valuable insights on what is needed by teachers and schools. What are the skills that the learners lack? What gap is it to be bridged with this system?

Limitations

Do all the learners have access to the Internet, computers with CD players, and related technologies? What is the budget for developing the project? How much of that budget will be applied for software, hardware, hiring professionals, etc. If the project will be delivered online, then the limited bandwidth available will determine its general look (limited use of video, sounds, animations, and images). Such a project will require much more time for planning and development. Another factor is the skills that the development team has for creating multimedia Web documents.

Content analysis

One of the major components of hypermedia development is the structuring of information. Content analysis is very important for modularizing the content into small chunks. This step is crucial in determining the nodes and links of the system, branching and navigation, options provided to the user, and interface design.

Task analysis

What are the tasks that the learner will be expected to perform during and at the end of instruction? Are there any prerequisites that the learners must posses before entering this unit? What is the hierarchy of the tasks expected to be performed? These tasks are operationalized in the next step.

Identifying objectives

If this is going to be an instructional system, then the objectives will specify what learners are expected to know at the end of instruction. How are they going to demonstrate their knowledge? If the system is going to be an informational resource, then certain guiding criteria need to be specified which will derive from the content analysis.

Phase 2

Develop evaluation component

If the project is going to be used as an instructional system, then there needs to be a way to measure its effectiveness. Did the learners actually learn what they were supposed to learn? How are they going to demonstrate their knowledge? The evaluation component will derive from the task analysis and the specification of objectives.

Strategies and interactivity

What are the instructional strategies that will be employed in order to meet the instructional objectives? How will the information be presented? What kinds of examples will be used? Will there be any simulations, demonstrations, and tutorials on how to use the system? Will the system be highly interactive all the way through? Will the user have to respond, get feedback, and proceed to the next level? What kinds of practice sessions will be provided?

Design

This stage is probably the most crucial in hypermedia development and it will be discussed in detail. Some of the practical issues that are associated with the design stage are the selection of the authoring tool, delivery medium (online or CD-ROM), storage, and distribution. Because of limited bandwidth, there are instances that, some of the materials are easier to distribute on a CD-ROM (Technology Based Learning and Research, 1994).

Jonassen (1989) argued that the two major components of designing hypermedia are the structuring of the information (content) and the designing of navigation tools (user interface and options provided). An effective project should include a flowchart that illustrates the structure of the system and the semantic relationships between the subtopics. Very often the user can get lost in the hypermedia system, which can result in frustration (Conklin, 1987). Concept maps can be used and be accessible to the user throughout the system. Such maps allow users to identify where they are at any point in the system (Barker, 1993). The use of focus questions can also eliminate the possibility of the user to get lost (Romiszowski, 1990). If the user has a specific piece of information to look for or a certain task to complete, then it is more likely that he will not be wandering from section to section.

The degree of interactivity in a program depends on the tasks users have to carry out and the number of options that are provided to them (Jones, Farquhar, & Surry, 1995). The interactivity of a program is illustrated in the flowchart and the user interface. The flowcharting and storyboarding derive from the information mapping and the content analysis from Phase 1. The building of the navigation structure and the design of the user interface, many times overlap and can be a circular process. While designing the navigation and the structure of the information, multimedia developers should always have in mind the interface and begin making decisions about the arrangement of information and navigation options on the computer display.

Some additional guidelines for the design of educational hypermedia systems are the following: (a) Allow users to access information in any order they want. This can be achieved by providing multiple ways of accessing information such as indexes, menus, search engines, and bookmarks. (b) Layer the information in a meaningful way. Allow users to go as deep as they wish depending on what they are looking for, how much they are interested in the topic, and what their prior knowledge is. (c) Keep learners informed on how much progress they are making, and where they are located at every moment. (d) Allow users to backtrack and return to any section of the system they want. (e) Provide cues that indicate a choice they made was entered in the program. For example, when they use a search engine, give them some feedback that the information was accepted and it is been processed. (f) Use concept maps and advance organizers to facilitate the conceptualization of the structure of the information. (g) Organize information in small manageable pieces and present information from multiple perspectives. (h) Situate information in authentic realistic contexts. (i) Provide a well structured help section to reduce problems of getting lost in the system (Jones, Farquhar, & Surry, 1995; Park & Hannafin, 1993; Schwier & Misanchuk, 1993).

User interface

The interface is the communication medium between computer and user. Unless the interface is clear and easily understood, communication between computer and user can result in a negative experience. The physical aspect of the interface is defined by the arrangement of the information and the navigation tools on the computer display. The functionality of the interface is crucial for the success of any interactive environment (Wright, 1990). The major factor that will determine the design of the interface is the learning task that users have to perform.

Using metaphors in designing the interface can increase transferability of knowledge (Barker, 1993; Jones, Farquhar, & Surry, 1995). The idea of transferability is defined by Barker (1993) as the ability of the learner "to carry across knowledge and skills relevant to one (well-known or familiar) domain and use them in another less familiar area" (p. 106). Four types of metaphors proposed by Barker (1993) were the book, the guide, the museum, and the story metaphors. For example, in the book metaphor different chapters can be used to represent different topics, whereas the table of contents can serve as the main menu.

Some additional guidelines for the interface design are the following: (a) Keep it clean, readable, simple, user-friendly, and provide ample white space. (b) Place the information on the screen in a consistent manner. For example, present special instructions always in the same place on the screen. (c) Navigation tools should be consistent with regards to their location on the screen. Use color coding or other means to group together buttons and navigation tools. (d) Have in mind that due to limited bandwidth, high-resolution images, sounds, and videos take a long time to load and play on the Web. Try to use low-resolution graphics, and use small sound and movie files. (e) Use colors and graphics that do not distract from the content. (f) Provide cues that mark the places the user has already visited.

Collection of material and production of prototype

During this stage developers collect the content and organize it in categories. Text, images, sounds, movies, and animations are all gathered. All materials needed for the project are identified during the storyboarding process. Then, a prototype is developed and goes through testing and evaluation.

Phase 3

Formative evaluation

Dick and Carey (1991) argued that one of evaluation's major aims is to collect data that guide the decision making process. Formative evaluation takes place during the instructional development process and it constantly provides the developer with feedback about the project. The hypermedia system is constantly tested and revised in order to maintain alignment between the three main phases of instructional development. The best way to test instructional materials is to have learners try them during the development process and get feedback from them. Before the final production, instructional designers, multimedia developers, graphic artists, and content experts need to evaluate the prototype and provide feedback to the producers. Feedback collected throughout the development process will be incorporated in the project and revisions will be made as needed.

Implementation.

After the final product is fine-tuned and completed, it is implemented in the context for which it was designed. One important aspect of the implementation phase is the training of teachers on how to incorporate the product in their classrooms. Developers should include a detailed manual and a "how to" guide that prospect users can refer to when they need help. In addition, workshops and seminars delivered to educators can also be valuable.

Summative evaluation

At the end of the process, summative evaluation takes place. Summative evaluation refers to the evaluation conducted to determine whether an already developed and applied program meets its goals successfully. Summative evaluation will provide evidence about the overall effect of an instructional system. The results will be analyzed to determine the overall effectiveness of the system and whether it should be continued. Evidence that results from this phase can be used to determine whether the hypermedia project was effective in delivering instruction and meeting its goals.

Conclusion

Hypermedia systems are valuable educational tools because they provide easy and nonlinear access to large amounts of information, they allow greater learner control, and present information in more than one mode. The systematic process that was briefly described in this paper approaches hypermedia development and integration as a system of interrelated events. The important stages during this process are the structuring of the information, design of navigation, and design of the user interface.

Applications of electronic networks for teaching and learning are expanding, as the global community begins to acknowledge the benefits that they have to offer. New advances in technology, such as Java technology, and streaming of digital media, enable more elaborated instructional modules to be delivered on the Web. Regardless of the medium and the technology employed, a systematic approach to designing and integrating hypermedia in teaching and learning can improve the effectiveness and efficiency of instruction.

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