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ABSTRACT

A classification scheme for multimedia interaction is described based on the degree of control and type of cognitive engagement experienced by learners in prescriptive, democratic, and cybernetic independent learning environments. Reactive, proactive, and mutual levels of interaction and their associated functions and transactions are discussed. Principles for designing interactive multimedia instruction emerging from this classification are discussed, along with current research on learner control. The classification is temporal and developmental. As levels of interaction are ascended by the instructional designer and reflected in the design of interaction, the amount of control abdicated to the learner changes. As instructional design theory advances, the categories offered will probably evolve. Four figures illustrate the discussion. (Contains 42 references.) (SLD)

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Abstract

This paper describes a classification scheme for multimedia interaction based on the degree of control and type of cognitive engagement experienced by learners in prescriptive, democratic and cybernetic independent learning environments. Reactive, proactive and mutual levels of interaction. and their associated funtions and transactions are discussed. The paper also explores principles for designing interactive multimedia instruction which emerge from this classification and current research on learner control.

Genesis of a Taxonomy of Interaction

The need for a taxonomy of interaction for emerging technologies grew out of the interactive videodisc literature, which used the term *levels* to describe hardware-dependent ways learners could operate equipment and software. Commonly accepted labels for levels of interactivity were, and remain, Level I, II, III, and sometimes IV, depending on your reference (Iuppa, 1984; Katz and Keet, 1990; Katz, 1992; Schwartz, 1987; Schwier, 1987). Level I videodiscs were controlled by the learner with a remote control unit to access frames or segments on the discs. Level II interactivity featured control programs recorded on videodiscs which could only be accessed by compatible players. Level III interactivity occurred when the control programs for a videodisc were provided by an external computer connected to a player. Level IV usually introduced sophisticated interfaces, such as touch screens, into the system.

These levels say little about the quality of interaction engaged by the learner (see Figure 1). What is the relative quality of cognitive engagement experienced by a learner who presses buttons on an RCU (Level I) versus a learner who touches the screen (Level IV)? Many would argue that there is little difference, if any, in the level of thought required in the actions, yet they are categorized as dramatically different levels of interaction. However convenient this designation may have been or continues to be for interactive video, for environments created by emerging technologies it is more productive to characterize interaction according to the sophistication and quality of interaction available to a learner in a particular program.

Figure 1. Interactive features of level I, II and III videodiscs.

	Program Control	Program Structure	System Costs	Flexibility
Level I	remote control unit	linear or user-defined	least expensive option	free access to segments of videodisc
Level II	embedded program	strictly defined by program on disc—may be overridden	higher videodisc production and hardware costs	response to programmed options typically limited to single keypress
Level III	external computer program	defined by program on external computer	added cost of computer in the system	dependent upon program or programming skills of user

A Taxonomy of Interaction for Emerging Technologies

Multimedia-based independent learning happens in several contexts, depending upon the nature of the learning task, the abilities and preferences of the learner, and the external requirements of the learning context. Learning may occur in prescriptive, democratic or cybernetic environments, each of which may be appropriate or inappropriate to accomplish defined learning tasks (Romiszowski, 1986).

Instructional designers acknowledge the role played by prescriptive types of instruction; indeed, prescriptive instruction has dominated the attention of instructional design for decades. Some types of learning, say performing double-ledger accounting, may be appropriately addressed in a confined, externally defined and structured, highly proceduralized fashion. An instructional designer can develop effective, reliable instructional materials to address this problem.

But emerging technologies require us to look at independent learning systems in a new way—as environments which promote the learner's role in regulating learning. Emerging technologies focus on an ability to manage, deliver and control a wide range of educational activities (Hannafin, 1992). Instructional designers must look beyond the attributes and differences of individual media components, and instead extend attributes across developing technologies. To fully exploit the capabilities of more powerful instructional technologies, designers must also reexamine the assumptions, models and strategies we employ in instructional design (Cognition and Technology Group at Vanderbilt, 1992; Jonassen, 1991; Osman and Hannafin, 1992; Rieber, 1992; Schott, 1992; Spector, Muraida and Marlino, 1992; Tennyson, Elmore and Snyder, 1992).

Emerging technologies offer an expanding range of interactive possibilities which are remarkably consistent, regardless of the platform used to deliver the instruction. Because a computer acts as the heart of a multimedia learning system, and because most multimedia computer systems have similar devices for communicating (e.g., keyboard, mouse, touch screen, voice synthesis), the quality of interaction is more the product of the way instruction is designed, and less the result of the system on which it is delivered. In order to describe a taxonomy of interaction for multimedia instruction, this paper describes three learning environments within which interactive multimedia function, suggests three levels of interaction commensurate with these environments, examines functions played by interaction within these levels and enumerates several types of overt transactions available at each functional level of interaction (Figure 2).

Figure 2. A taxonomy of interaction for multimedia instruction.

Multimedia Learning Environments	Levels of Interaction	Functions of Interaction	Transactions Performed to Interact
Prescriptive	Reactive	Confirmation	Space Bar/Return
Democratic	Proactive	Pacing	Touch Target
Cybernetic	Mutual	Navigation	Move Target
		Inquiry	Barcode
		Elaboration	Keyboard
			Voice Input
			Virtual Reality

Multimedia Learning Environments

Instruction is shaped by the instructional designer's knowledge of the learning task, learner and context. It is also influenced by assumptions about the learner and learning—assumptions which reveal the orientation of the learning materials. These factors, among others, conspire to define a multimedia environment. Romizowski (1986) used the terms prescriptive, democratic and cybernetic to describe a schemata of systems for individualizing instruction; systems which may also be considered *environments* in multimedia instruction.

Prescriptive instruction specifies what the learner is to learn. Instruction is based on specific objectives and the instructional system is used as a primary delivery medium. In many, if not most, cases the instructional content and boundaries of learning are decided by the instructional designer, and the learner's role is to receive and master the given content. A popular breakdown of prescriptive instructional designs for computer-based instruction includes drill and practice, tutorials, games and simulations (e.g. Alessi and Trollip, 1985; Hannafin and Peck, 1988; Heinich, Molenda, and Russell, 1989; Romiszowski, 1986). Recently, instructional design theory has offered models for dealing with higher-order learning and more complex cognitive skills with prescriptive design models based on cognitive theory (e.g., Merrienboer, Jeisma, & Paas, 1992;Tennyson, Elmore, & Snyder, 1992). Although such models do not offer a complete theory of instructional design based on cognitive theory, they offer potentially powerful solutions to specific design challenges (Schott, 1992).

Democratic environments turn over control of instruction to the user. Unlike prescriptive environments, democratic environments do not impose highly structured learning strategies on the learner. Rather, democratic environments emphasize the learner's role in defining what is learned, how it is learned, and the sequence in which it is learned. The most apparent difference between democratic and prescriptive environments is the level of learner control, and they do not always operate in isolation from one another. Democratic environments may be used to support prescriptive instruction, acting as a supplementary resource to the primary instruction. For example, a learner following a self-instructional program on a comparison of British and American forms of government (prescriptive) might choose to explore a learning resource on the Canadian House of Commons to elaborate information for an assignment (democratic). For other democratically oriented learning, resources stand alone, without reference to prescribed instruction, and the learner makes virtually every decision about how the materials are used. These types of learning resources emphasize navigation, motivation and access, and they downplay objectives and evaluation.

Cybernetic environments emphasize a complete, multi-faceted system in which the learner can operate naturally, albeit synthetically. Intelligent interactive multimedia, based on expert systems, heuristic designs, and virtual reality can provide rich, dynamic and realistic artificial environments for learning. In cybernetic environments, the learner maintains primary control of the learning, but the system continually adapts to learner activity, and may even adapt in novel ways based on heuristic interpretations of learner actions. The learning environment may either adapt actively, or passively by advising the learner about the patterns and consequences of actions taken. The instructional environment, unlike instruction provided at proactive and reactive levels, actually expands beyond the initial design decisions made during its development.

Jonassen (1991) might use the term *objective* (encompassing both behavioural and cognitive orientations) to describe prescriptive environments as they are based on assumptions of a single, externally defined reality, wherein the goal of instruction is to bring the learner into line with these externally defined goals. Democratic and Cybernetic environments might emphasize a more *constructivist* orientation—one in which multiple realities are recognized as legitimate, and therefore, learners may be empowered to express an array of appropriate directions, processes and outcomes for learning. Fundamental to the movement toward more constructivist orientations in instructional design, is a respect for the learner's ability to understand and select from a number of personally satisfying strategies for learning. For example, Osman and Hannafin (1992) challenge designers to go beyond content acquisition in designs, and cultivate metacognitive capabilities and strategies of learners. This, in turn, requires that instructional designers include procedures and tools learners can use for the specific content to be learned and generalize to other settings, rather than focus solely on specific content and skills to be learned.

Levels of Interaction

The different multimedia environments will emphasize different levels of interaction. Such interaction can be characterized as reactive, proactive or mutual depending upon the level of engagement experienced by the learner.

In a reactive interaction a learner responds to stimuli presented to the learner by the program, for example by making a selection from a menu (Lucas, 1992; Thompson and Jorgensen, 1989). Such approaches are typified by tutorial designs wherein the learner and computer are engaged in a preordained discussion which is initiated by the program, not the learner.

By contrast, proactive interaction requires the learner to initiate action or dialog with the program. Proactive interaction promotes generative activity; that is, the learner goes beyond selecting or responding to existing structures and begins to generate unique approaches and constructions other than those provided in instructional materials. An example of this is when a learner uses key word searching of a hypermedia database, organizes resultant information to address a self-generated question.

The highest level of interaction, mutual interaction, is characterized by artificial intelligence or virtual reality designs. In such programs, the learner and system are mutually adaptive. Sometimes, this is referred to as recursive interaction. Recursion is based on the mathematical notion of indefinite repetition, and in multimedia, it suggests a conversation which can continue indefinitely. This is a useful distinction, but it falls short of the potential capabilities of multimedia systems in the future. Because multimedia systems may ultimately be capable of cybernetic conversation--actually learning from and adapting to conversation with a learner--the term *mutual* interaction is used here. At a less sophisticated level, mutual interaction can be used to describe the appearance or trappings of meaningful conversation. Mutual interactivity is still in its infancy, but the area is attracting a great deal of research and development interest.

The three categories of interaction do not exist as "pure" categories in most instructional software—interactive multimedia programs often incorporate a combination of reactive and proactive approaches (although very few are sophisticated enough to incorporate mutual approaches). But the levels are hierarchical, in that one subsumes the other. In other words, mutual interactions contain proactive elements, and proactive interactions contain reactive elements. For example, when learners generate new questions and approaches (proactive) they can, in turn, be used by the system to formulate new conversation (mutual). Similarly, when learners generate their own strategies (proactive) they are responding to existing stimuli at a sophisticated level (reactive).

Functions of Interaction

Hannafin (1989) identified five functions interaction can serve in independent learning materials: confirmation, pacing, inquiry, navigation and elaboration. Confirmation verifies whether intended learning has occurred (e.g., learners responding to questions during instruction can measure performance). Pacing gives control of the timing of instruction to the learner (e.g., the learners selecting an abbreviated or elaborated version of instructional content). Navigation determines the amount of freedom and ease of access learners have to instructional components (e.g. learners choosing segments from a menu). Inquiry allows learners to ask questions or construct individual pathways through instruction (e.g. learners searching supplementary material). Elaboration allows learners to move from known to unknown information or expand what is already known.

Each function is expressed differently during instruction, depending upon the level of interaction. For example, reactive navigation is typified by menus or prescribed branching options presented to learners. Proactive navigation, by contrast, would permit the learner to initiate searches or participate in open-architecture movement throughout material. Mutual navigation might happen when a program anticipates navigation routes of the learner based on previous movement, and advises the learner about the nature of choices made. In mutual navigation, the learner could could follow or ignore the advice, and also advise the system about about the nature of navigation opportunities desired. Figure 3 gives one example of interaction obtained at each functional level of the taxonomy.

Transactions During Interaction

Transactions are what learners do during interaction; they are the mechanics of how interaction is accomplished. For example, learners type, click a mouse, touch a screen or scan a virtual environment. Learners can also engage in many productive types of covert transactions, mentally engaging themselves in the construction of metaphors, questioning the validity of content, constructing acronyms to remember material and the like. This discussion will focus on overt transactions, but the reader should realize that covert transactions can be employed whenever overt transactions are unavailable to the learner. Also, the use of one does not preclude the use of another.

The level of interaction can be influenced by the type of interaction permitted by hardware configurations and instructional designs, and therefore the transactions. Several transactions cannot be easily adapted to higher levels of interaction. For example, the range of possible interactions is confined if a spacebar is the only means of interacting with a program. Devices such as the mouse and instructional design strategies such as touch screen menus do not permit the learner to construct inquiries, thereby eliminating the possibility of adopting a proactive or mutual orientation. For example, a learner can use a touch screen or use a single keyboard entry to make menu selections or answer questions (reactive interaction). Touch screens and single keyboard entries are too restrictive, however, to be used for generative interactions such as on-line note taking (proactive interaction).

Conversely, transactional methods serving proactive or mutual interactions can also be used in reactive interactions. For example, a keyboard synthesizer can be used by a learner to compose a new song (proactive interaction), while the same keyboard synthesizer can be used to have learners mimic a score played by a program (reactive interaction). In this way, transactions conform to the hierarchy of this taxonomy. Transactional events available for higher levels of interaction can be adapted to lower levels of interaction, but the relationship is not reciprocal.

Figure 4 lists several transactional events which can be employed at reactive, proactive and mutual levels of interaction. The list of transactions is not exhaustive, but it illustrates some interactive strategies employed in interactive multimedia programs. The figures illustrate the notion that as interaction reaches for higher levels of engagement with learners, generative transactions are required.

Figure 3.Example of an interactive event each functional level of interaction.

	Confirmation	**Pacing**	**Navigation**	**Inquiry**	**Elaboration**
Reactive	Learner matches answer given by system	Learner turns page when prompted	Learner selects choice from a menu	Learner uses "help" menu	Learner reviews a concept map
Proactive	Learner requests test when offered	Learner requests an abbreviated version of instruction	Learner defines unique path through instruction	Learner searches text using keywords	Learner generates a concept map of the instruction
Mutual	System adapts to progress of learner and learner may challenge assessment.	System adapts speed of presentation to the speed of the learner	System advises learner about patterns of choices being made during instruction	System suggests productive questions for the learner to ask, given previous choices	System constructs an example based on learner input, and revises it as learner adds information

Figure 4. Some examples of transactions available to serve different functions and levels of interaction.[2]

	Reactive	Proactive**	Mutual***
Confirmation	Touch Target Drag Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Pacing	Space Bar/Return Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Navigation	Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Inquiry	Touch Target Barcode Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality
Elaboration	*	Keyboard Voice Virtual Reality	Keyboard Voice Virtual Reality

* **Note:** At a reactive level of interaction, elaboration would be restricted to covert responses to stimuli (e.g., "think about this image").

****Note:** Because the learner must generate original input to be truly proactive, only overt transactions which permit generation of complex information were identified.

*****Note:** Mutuality implies sharing complex information between user and system, therefore requiring complex dialogue.

[2] Figures 3 and 4 are adapted from material originally published in Schwier and Misanchuk (1993).

Implications of the Taxonomy for Instructional Design

The taxonomy carries implications for instructional design, primarily concerning questions of learner control. An instructional developer constantly weighs the need to be prescriptive versus the need for learners to explore. How does learner control converge with the proposed taxonomy? *Learner control* may refer to a number of things. Learners may be granted or may require control over:

- Content of instruction.
- Context for learning.
- Presentation method of the content.
- Provision of optional content.
- Sequence of material to be learned.
- Amount of practice.
- Level of difficulty.
- Level of advisement.

The taxonomy is meant to be descriptive, not prescriptive, yet each of these points of control represents a decision point for an instructional designer. As levels of interaction are ascended by the instructional designer, and reflected in the design of interaction, the amount of control abdicated to the learner changes. At a reactive level of interaction, the instructional developer retains almost complete control over the content, its presentation, sequence and level of practice. A proactive level of interaction relinquishes much of the developer's control over instruction, as the learner determines what content to encounter, the sequence and how much time to devote to any particular element, and whether additional content will be explored or ignored. In proactive designs, the learner holds a high degree of control over all elements of instruction, and this may not always be beneficial to the learner. The learner is still at the mercy of the content selected by the designer/producer of instructional material and the navigational tools provided to the learner, but within these confinements, the learner exercises complete control. At a mutual level, the highest level of interaction, the system and the learner negotiate control of instruction. The learner engages the instruction and makes decisions, but as instruction proceeds, the system adopts the role of wise advisor (or tyrant) and attempts to structure the instruction for the learner, based on needs revealed by the learner. Thus, the amount of learner control is shared at a mutual level of interaction.

One problem for an instructional developer is to decide when to assert and when to relinquish control. This decision will, in turn, influence which level of interaction may be appropriate to employ in the design of instruction. The issue has moral and ethical overtones. Certainly, it would be inappropriate to set unprepared learners adrift in a sea of learning resources without the skills necessary to navigate their craft, and then expect them to operate efficiently. Learners need to be sufficiently mature, and have access to the necessary problem solving and attack skills to perform successfully in less-structured learning environments. Osman and Hannafin (1992) point out that significant variables in the acquisition and use of metacognitive strategies are the age of learners, previous experience and their belief in their abilities. Programs need to emphasize not only knowledge about strategies, but also knowledge about maintaining and transferring strategies to other settings. Cybernetic systems may be able to "tune" themselves to the metacognitive strategies employed by learners, adjust to them, and advise learners of trends which emerge. Systems can, by advising the learner in an organized fashion about decisions made, promote the development of personal metacognitive strategies.

Decisions about control form part of the art of instructional design. One should not assume that proactive and mutual forms of interaction do not impose external elements of learner control. On the contrary, considerable control of the learner can be exercised by the instructional designer in subtle and passive forms, such as the design of the access structure available to the learner. For example, confusing or obscure icons may discourage learners from exploring associated material in a learning resource. If control is to be given to learners, attention must be paid by instructional designers to the covert elements of a design with may frustrate learners from exercising that control. In other words, control must not only be *given* to learners, it must be *taken* by learners, and design factors may inhibit or encourage their decision to take control.

Although prescriptions regarding learner control in independent learning designs would be premature, tentative advice is available.

General Conclusions About Control

- Control is often used to refer to the selection of content and sequence, but may also include the full range of learner preferences, strategies and processes used by the learner.
- Relinquishing control of the instruction and giving the learner control may increase motivation to learn (Santiago and Okey, 1990; Steinberg, 1977).
- When control of the learning is given over to the learner, so also is the external definition of efficiency. Learner control does not necessarily increase achievement and may increase time spent learning (Santiago and Okey, 1990).
- Learner control may permit students to make poor decisions about how much practice they require, which are reflected in decremented performance (Ross, 1984). On the other hand, metacognitive strategies can be acquired by the learner which will help the learner make more productive dec .ons (Osman and Hannafin, 1992).

Control Issues Related to Learner Characteristics

- Learners who are generally high achievers or who are knowledgeable about an area of study can benefit from a high degree of learner control (Borsook, 1991; Gay, 1986; Hannafin and Colamaio, 1987).
- Naive or uninformed learners require structure, interaction, and feedback to perform optimally (Borsook, 1991; Carrier and Jonassen, 1988; Higginbotham-Wheat, 1988, 1990; Kinzie, Sullivan, and Berdel, 1990; Schloss, Wisniewski, and Cartwright, 1988).
- The effectiveness of learner control is mitigated by such learner characteristics as ability, previous knowledge of the subject matter, and locus of control (Santiago and Okey, 1990).

Control Issues Related to Program Variables

- Learner control with advisement seems to be superior to unstructured learner control for enhancing achievement and curiosity, promoting time-on-task, and stimulating self-challenge (Arnone and Grabowski, 1991; Hannafin, 1984; Mattoon, Klein, and Thurman, 1991; Milheim and Azbell, 1988; Ross, 1984; Santiago and Okey, 1990).
- Learner control of presentations has been shown to be beneficial with respect to text density (Ross, Morrison, and O'Dell, 1988) and context conditions (Ross, Morrison, and O'Dell, 1990).
- Courseware should be adaptive. It should be able to alter instruction dynamically, based on learner idiosyncracies (Borsook, 1991; Carrier and Jonassen, 1988).
- One opinion holds that learners should be given control over contextual variables such as text density, fonts, and backgrounds, but not over content support variables such as pacing, sequence, and examples (Higginbotham-Wheat 1988; 1990).

Control Issues Related to Practice

- Give learners opportunities to practice using higher-order cognitive strategies, such as metacognitive procedures and mental modelling to promote complex learning and transfer (Osman & Hannafin, 1992; Jih & Reeves, 1992).

- Cooperative learning strategies can be applied to computer-based instruction, but learners may need to learn and practice using collaborative skills for collaborative strategies to be successful (Hooper, 1992).
- Practice should include practice with strategies for learning, not just practice with specific content or skills. Learners can benefit from memory and organizational strategies to make information more meaningful. Metacognitive strategies can promote learning and can be generalized across learning situations, but they must be learned and practiced (Osman & Hannafin, 1992).
- Practice should be available to the learner at any time, and in several forms to satisfy self-determined needs. In prescriptive environments, practice will be imposed often during early stages of learning and less often as time with a particular topic progresses (Salisbury, Richards, & Klein, 1985).
- Practice during instruction should be varied.
- As facility and familiarity with the learning task increase, so should the difficulty of practice. In prescriptive environments, the difficulty level would be managed externally by the instructional designer. In democratic and cybernetic environments the learner may be advised about difficulty levels and productive choices, but the decision will be left in the hands of the learner.
- Practice events should require learners to use information and discover and derive new relationships in information.

These suggestions, however inviting, should be approached with caution. Not only are they tentative, they are also contradictory in some cases. For example, the advice offered by Higginbotham-Wheat (1988; 1990) can be interpreted to mean that learners should influence only variables which have little instructional significance, and be denied control of significant instructional variables. Certainly this contradicts the intentions and findings of many of the other studies cited, as some argue that we need to go beyond objective and prescriptive designs, and embrace generative and constructivist approaches (Jonassen, 1991; Hannafin, 1992). Inherent in these arguments is the concept of control, an issue which will occupy a central position in multimedia research during this decade.

Summary

The classification of interaction for multimedia instruction offered in this paper is temporal and developmental. As instructional design theory advances, and as the development of instructional technologies continues to bluster, the categories offered herein will likely evolve. Certainly our understanding of productive avenues for instructional design and practice will also grow. Increasing attention is being given to democratic and cybernetic environments for learning, and this is, in turn, requiring instructional designers to reconsider the roles played by interaction during instruction.

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