Learning Environments and Interaction for Emerging Technologies: Implications for Learner Control and Practice[1]

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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 functions and transactions are discussed. The paper also explores principles for designing interactive multimedia instruction which emerge from this classification and from current research on learner control and practice.

Resume: Get article decrlt un precede de classification d'Interactions multimedia! base sut le degre de controle et sur le type d'engagement cognltlf utilise par les etudlants evoluant dans des envlronnements favorables a l'apprentlssage Independent, normatlf, democratlque et cybernetique. On y discute egalement les nlveaux d'interactions reclproques, reactlfs et proacflfs alnsi que les fonctions et les transactions connexes, On y explore egalement les prlncipes soustendants la conception des programmes d'apprentissage multimedlas interactlfs qui emergent decette classifteatlon et des courantsderecherchesur les contrdles des etudiants et leurs pratiques.

Multimedia-based instruction is shaped by the instructional designer's knowledge of the learning task, learner and context—knowledge which can be gleaned from elaborate front-end analyses. But instruction is also influenced by an instructional designer's assumptions about the learner and learning—assumptions which are not publicly analyzed, yet are revealed in design features of the learning materials. One such feature is how prescriptive the instruction is. Is the entire learning experience structured for the learner, or is the learner invited and empowered to construct a personal learning experience from the materials?

This paper extends an earlier paper entitled *A Taxonomy of Interaction for Instructional Multimedia,* by Richard Schwier presented at the annual meeting of the Association for Media and Technology in Education in Canada, Vancouver, British Columbia, June, 1992.

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Instructional designers acknowledge the important role played by prescriptive learning environments; indeed, prescriptive instruction dominated the attention of instructional design for decades and continues to be expressed in significant instructional products today. Some types of learning, say performing double-ledger accounting or studying for university entrance examinations, may be appropriately addressed in a confined, externally defined and structured, highly procedural fashion. An instructional designer can develop effective, reliable — and prescriptive — instructional materials to address these types of problems.

But emerging technologies coax us to look at multimedia learning systems in a new way — as environments which promote the learner's role in regulating learning. An emerging technology is not hardware; rather, it is a systematic and highly integrated architecture for learning. Emerging technologies are those which focus on an ability to manage, deliver and control a wide range of educational activities (Hannafin, 1992). To take full advantage of emerging technologies, instructional designers must look beyond the attributes and differences of individual media components, and extend their individual attributes across developing technologies. Given that interactive multimedia instruction by its very nature combines the attributes of several media, it is an important platform for developing emerging technologies. But having an appropriate platform is not sufficient. To fully exploit the capabilities of more powerful instructional technologies, designers must also reexamine the assumptions and expand the strategies we employ in instructional design (cf. 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).

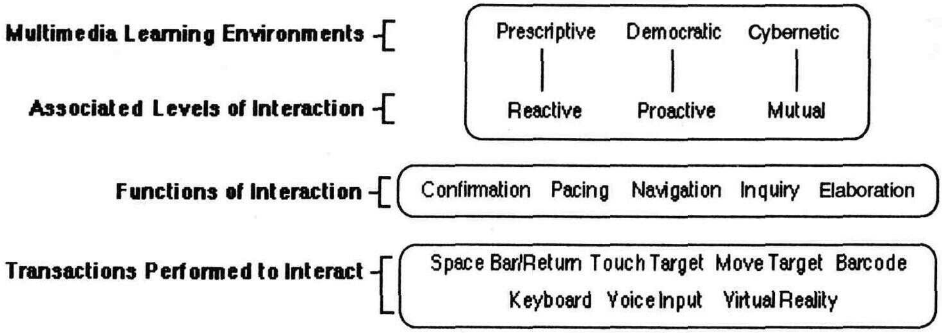
Multimedia-based technologies offer an expanding range of interactive possibilities which are remarkably consistent, regardless of the platform used to deliver the instruction. Because a computer acts as the heart of a multimedia learning system, and because most multimedia computer systems have similar 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 functions, suggests three levels of interaction associated 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 1).

Multimedia Learning Environments

Romiszowski (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

Figure 1.
Components of a Taxonomy of Interaction for Multimedia Instruction.



delivery medium. In many, if not most, cases the instructional content and boundaries of learning are decided by the instructional design team, 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, 1993; Romiszowski, 1986).

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 down-play objectives and evaluation.

Cybernetic environments emphasize a complete, multi-faceted system in which the learner can operate fluidly, 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 adapt either actively or passively by advising the learner about the patterns and consequences of actions taken. The cybernetic instructional environment, unlike instruction provided in prescriptive and democratic environments, actually expands beyond the initial design decisions made during its development. This expansion marks its difference from being merely a sophisticated prescriptive environment; the very substance of the learning landscape is changed by the nature of interactions during instruction, not just the path followed by an individual through existing material (whether prescribed or democratic). This is certainly more evident in predictions for the 21st century than in practice , as few products to date offer a truly cybernetic environment.

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. For example, given a CD-ROM disc of clips from classic films, one learner might gather examples of racism and sexism from the classics for comparison with contemporary films; another learner might look at the impact of colorization on the visual impact of black-and-white classic films. 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 generalize to other settings, rather than focus solely on specific content to be learned.

The three learning environments described above each allow interaction, but the nature of the interaction is fundamentally different in each environment. A prescriptive environment will largely present interactive events to which learners can react, such as embedded questions. In democratic and cybernetic environments, all interactivity will not be pre-ordained. The learner will have a hand in shaping the interaction. The next section will examine the type of interaction associated with each of the three environments.

Levels of Interaction

The different multimedia environments will emphasize different types 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. The learner organizes, shapes and in a sense creates a personal expression of learning. An example of this is when a learner uses key word searching of a hypermedia database, and organizes resultant information to address a self-generated question. The question is the learner's, the collection of data is unique to the learner, and the boundaries of the search and the personal level of satisfaction with the completed product are the learner's.

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 discrete 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 ofInteraction

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 knowr.

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 2 gives one example of interaction obtained at each functional level of the taxonomy.

Figure 2.

Example of an Interactive Event at 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

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 transaction permitted by hardware configurations and instructional designs. 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 transacting 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 activities 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.

IMPLICATIONS OF THE TAXONOMY OF INTERACTION FOR LEARNER CONTROL AND PRACTICE

The taxonomy of interaction carries implications for designing interactive multimedia-based instruction, primarily concerning questions of learner control and practice. Control and practice events in multimedia-based instruction are expressed in the nature of interaction provided learners. How do learner control and practice converge with the proposed taxonomy?

This taxonomy is meant to be descriptive, not prescriptive, yet each point of interaction in an instructional treatment represents a decision point for an instructional designer. An instructional developer constantly weighs the need to be prescriptive versus the need for learners to explore. As levels of interaction are ascended by the instructional designer, and reflected in the design of interaction and practice, 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, how much practice with any particular content is required, and whether additional content will be explored or ignored. An instructional designer must struggle with whether the learners have the necessary skills and motivation to work successfully in a democratic environment, and therefore whether proactive interaction strategies will be beneficial to the learner. At a mutual level 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 an instructional developer faces is 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 successfully. Learners need to be sufficiently mature, and have access to the necessary problem solving and attack skills, such as metacognitive practice strategies, 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, a designer might unintentionally use confusing or obscure icons and thereby 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 which 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.

A significant amount of research about practice and control has been conducted over the past several years. Although prescriptions regarding the use of learner control and practice in multimedia-based learning designs would be premature, tentative advice is available. The following conclusions have implications for the design of interactive multimedia instruction, and especially illuminate when it might be appropriate to move from prescriptive environments to democratic environments. Generally speaking, the decision to relinquish control of instruction to the learner carries with it the assumption that the learner will be empowered by that decision. Most of these conclusions speak to when learners might be empowered by being given more control over instruction and conversely when learners might be hampered by having such control. As a general observation, it is worth noting that most of these studies emphasized a logicalpositive orientation—one in which the measures of learning and performance are externally defined. Terms such as "efficiency," "perform optimally," "effectiveness" betray a positivist orientation. It is possible, from a constructivist point of view, to suggest that learners construct multiple—and equally valuable—realities from their unique interactions with multimedia, thereby challenging external definitions of "effective" performance. Some of the more recent studies have begun to focus on generative and collaborative approaches. Some of the conclusions, most notably those concerning practice strategies, adopt a more constructivist posture.

General Conclusions About Practice

- Practice should be available to the learner at any time, and in several forms to satisfy self-determined needs in democratic and cybernetic environments. In prescriptive environments, practice should 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.
- 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).

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 & Okey, 1990; Steinberg, 1Q771

- 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 & Okey, 1990).
- Learner control may permit students to make poor decisions about how much practice they require, which are reflected in decremented performance (Boss;, 1984). On the other hand, metacognitive strategies can be acquired by the learner which will help the learner make more productive decisions (Osman & 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 & Colamaio, 1987).
- Naive or uninformed learners require structure, interaction, and feedback to perform optimally (Borsook, 1991; Carrier & Jonassen, 1988; Higginbotham-Wheat, 1988, 1990; Kinzie, Sullivan, & Berdel, 1990; Schloss, Wisniewski, & Cartwright, 1988).
- The effectiveness of giving control to the learner is positively correlated with learner ability, previous knowledge of the subject matter, and locus of control (Santiago & 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 & Grabowski, 1991; Hannafin, 1984; Mattoon, Klein, & Thurman, 1991; Milheim & Azbell, 1988; Ross, 1984; Santiago & Okey, 1990).
- Learner control of presentations has been shown to be beneficial with respect to text density (Ross, Morrison, & OT)ell, 1988) and context conditions (Ross, Morrison, & O'Dell, 1990).
- Courseware should be adaptive. It should be able to alter instruction dynamically, based on learner idiosyncrasies (Borsook, 1991; Carrier & 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).

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 import, 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 empowering learners, 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 descriptive, temporal and developmental. The purpose of the taxonomy is to help us understand how we can and should express interaction within different learning environments. As instructional design 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, in turn, requires instructional designers to reconsider the roles played by interaction during instruction.

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