Promoting Cognition in Multimedia Interactivity Research

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This article suggests that researchers need to reconfigure their conception of multimedia based interactivity. By integrating and extending earlier conceptions of the construct, it is argued that the cognitive processes of users should be central rather than peripheral to interactivity research. A model is presented in which interactivity is described as a continuous dynamic interplay between instructional events, students’ actions (functional interactivity) and their cognition (cognitive interactivity). The relationships between these components of the model are discussed, as are two potential benefits of interactivity – increased intrinsic motivation and more favourable learning outcomes. The way in which the model can be used to frame and structure further research on interactivity is discussed and emphasises the need to simultaneously assess functional and cognitive interactivity for specific instructional events.

Common Conceptions of Interactivity

One of the most often stated reasons for employing multimedia for teaching and learning is that it provides students with an interactive learning experience. Yet despite the promise and ubiquity of the term, interactivity has been an elusive construct for educational multimedia researchers to define. A scan of the literature quickly reveals a degree of variability in how interactivity is conceived. Schwier and Misanchuk’s (1993) taxonomy defined it as a series of levels, functions, and transactions, Sims (1997) by the elements of the interface, Plowman (1996a, 1996b) in terms of narrative,

1 This article focuses primarily on students’ interactions with stand-alone educational multimedia. Many of the issues covered in this article will also apply to attributes of online learning environments (such as “interactive” tasks viewed through a browser). However, the facility for person to person interaction in online learning environments (such as discussion groups or online tutorials) makes them qualitatively different from educational multimedia and thus precludes them from this analysis.
and Borg & Hinbotham-Wheat (1991) in reference to communication. Reflecting on this variation, Aldrich, Rogers, and Scaife (1998) suggested the most common conceptions of interactivity are based on either a reactive-proactive continuum (the “instructional” approach) or design classifications of users’ actions and activities (the “functional” approach).

The instructional approach is exemplified by Thompson and Jorgensen’s (1989) three instructional models. Each model in this framework exists on a continuum and describes the nature of the relationship between the user and the instructional source (whether a person or a computer). More particularly, it describes the role of the learner and the technology in an instructional event. At the “reactive” end of the continuum the learner is a relatively passive receiver of information and knowledge. Conversely at the “proactive” end of the continuum the learner is an active participant in the construction of his or her own knowledge. These two opposing views have a clear correspondence with the polarised instructivist and constructivist philosophies of teaching and learning. However, Thompson and Jorgensen (1989) introduced a third category and placed it between the reactive and proactive poles. Labelled the “interactive” model this type of instruction draws on the two previous conceptions and suggests an interplay between “information transmission and simpler levels of learner manipulations of the material and activities that are grounded in the learner’s own evolving understanding of the experience” (p. 25) [italics in original].

The second common classification of interactivity focuses much more on the functional affordances of the interface. Interactivity is defined by the physical actions of the user and the purposes of these actions (Sims, 1997, see also Schwier & Misanchuk’s (1993) functions and transactions). Sims’ hierarchical developers’ classification of interactivity outlined 11 “interactive concepts,” which describe what happens when a student uses elements of the interface. For example, “linear interactivity” refers to the functionality of the interface that allows the user to move forward and back in the program. “Update interactivity” describes the process whereby users respond to predetermined problems (questions or tasks), which the system subsequently provides feedback on while “construct interactivity” requires users to manipulate elements of the interface to achieve specific goals.

While these two conceptions of interactivity emphasise distinct components of the construct, a degree of communality exists between them. Both define interactivity as a dynamic relationship between two entities. From the instructional perspective the two entities are the user and the instructional source, while the functional perspective is more specific, describing the dynamic as a relationship between the user and elements of the interface. While seemingly obvious, this is an important point as interactivity is often described as an attribute of educational multimedia programs. But an educational multimedia program cannot be interactive; it only has the potential to be so. A user is required to release this dynamic relationship. In addition to being conceptions of interactivity recognise that the tasks – their content and instructional design – promote deeper processing (Craik & Lockhart, 1972) in a way that superficial processing does not (Craik & Lockhart, 1972). Moreover, viewing interactivity as an interaction between the user and the technology allows researchers to focus on the potential benefits of interactive learning designs for cognitive processing of the user, these processes peripheral to researchers’ conception of the cognitive processes are the result of the user and the interface, they reside in the potential benefits of interactive learning design cognitive processes of the user, these processes peripheral to researchers’ conception of the cognitive processes are the result of the user and the interface, they reside in the

Cognitive Conceptions of Interactivity

One of the first models of interactivity to grow in popularity was Jonassen’s (1985) three-dimension model of design. Within the “levels of interactivity” categories of “task analysis,” “level of process,” and “design of problem.” These three categories emphasise an instructional task and, more generally, the drill and practice, problem solving, etc. allows the process content material. However, while considering students’ cognitive processing, Jonas much further than suggesting that drill and practice shallow processing while problem and similar promote deeper processing (Craik & Lockhart, 1988). In a later chapter on the design of ed (1988) dealt more extensively with cognitive knowledge is mediated through student thought; instructional design should focus on being activity” (p. 155). Jonas learning is underpinned by students’ use of cognitive processes for deep processing (Craik & Lockhart, 1988).
inbotham-Wheat (1991) in reference to communicative variation, Aldrich, Rogers, and Scaife (1998) suggest conceptions of interactivity are based on either a linear (“instructional” approach) or design class of activities (the “functional” approach). Proach is exemplified by Thompson and Jorgensen’s models. Each model in this framework exists on a scale of expertise. The nature of the relationship between the user and system (whether a person or a computer). More particular is the learner and the technology in an instructional context. The linear model is a relatively passive and knowledge. Conversely at the “proactive” end learner is an active participant in the construction of knowledge. These two opposing views have a clear core relationship: in the model, this type of instruction directly on the manipulation of instructional design and suggests an interplay between “information” levels of learner manipulations of the material and the learners own evolving understanding of the content.

Classification of interactivity focuses much more on the process of the interface. Interactivity is defined by the user and the purposes of these actions (Sims, 1997; Sanchez’s 1993 functions and transactions). Sims’ classification of interactivity outlined 11 “interaction processes” which happen when a student uses elements. “Linear interactivity” refers to the functional level where the user can move forward and back in the activity. “Construct interactivity” requires users to the interface to achieve specific goals. Interactions of interactivity emphasise distinct components of communality exists between them. Both dynamic relationship between two entities. From the two entities are the user and the instruction. Interactivity is more specific, describing the interaction between the user and elements of the interface. As this is an important point as interactivity is often confused as educational multimedia programs. An educational program cannot be interactive; it only has the potential to be so. A user is required to release this potential, thus establishing the dynamic relationship. In addition to being conceived as a dynamic, both conceptions of interactivity recognise that the design of instructional events of tasks – their content and instructional design – is an important factor in students’ learning. Increasing a program’s potential for interactivity through the careful design of instructional events is almost universally seen as a benefit to students’ learning processes and outcomes (for dissenting voices see Plowman, 1996a, 1996b; Rose, 1999).

Yet, despite offering these insights both conceptions of interactivity have a fundamental shortcoming: they fail to adequately consider the internal cognitive processes of users (Sims, 2000; Aldrich et al., 1998; Draper, 1996). Aldrich et al. argued that neither conception adequately addresses users’ “engagement” with the learning material or learners’ “internal” processes. These internal processes are seen by many authors as the critical component of interactivity (Aldrich et al.; Draper; Spector, 1995; Hannafin, 1989). The value and merit of interactive learning designs should, therefore, be determined by the degree to which they encourage beneficial cognitive processes and strategies in students. While these cognitive processes are the result of a dynamic interplay between the user and the interface, they reside in the user, not the interface. Given the benefit of interactive learning designs are ultimately reflected in the cognitive processes of the user, these processes should be central rather than peripheral to researchers’ conception of the construct.

**Cognitive Conceptions of Interactivity**

One of the first models of interactivity to explicitly address students’ cognition was Jonassen’s (1985) three-dimensional Taxonomy of Interactive Learning Design. Within the “levels of interactivity” axis Jonassen introduced the categories of “task analysis,” “level of processing,” and “type of interactive program.” These three categories emphasise that the structure and content of an instructional task and, more generally, the type of interactive program (drill and practice, problem solving, etc.) affect the depth with which students process content material. However, while recognising the importance of considering students’ cognitive processing, Jonassen’s (1985) analysis did not go much further than suggesting that drill and practice learning designs promote shallow processing while problem- and simulation-based learning designs promote deeper processing (Craik & Lockhart, 1972).

In a later chapter on the design of educational technology Jonassen (1988) dealt more extensively with cognition. He argued that “Because knowledge is mediated through student thought processes and not the medium itself, instructional design should focus on the thought processes activated by learning activities” (p. 155). Jonassen suggested that generative learning is undermined by students’ use of cognitive strategies which can be promoted by incorporating “learning strategies” into the instructional design...
of courseware (where learning strategies are defined as the cognitive activities that support learning). Students may be explicitly instructed to use a particular learning strategy (labelled “detached”) or, alternatively, learning strategies may be embedded into the structure of tasks students are required to complete. For example, a problem solving exercise might be designed in such a way that students must relate new content material to their prior knowledge in order to solve the problem.

A second author to call for a more cognitive perspective on interactivity was Hannafin (1989). He argued that designers should be “less concerned with the physical evidence of interaction than with the cognitive activities that the lesson is designed to engender” (p. 172). In a similar way to Jonassen (1988), Hannafin (1989) suggested that functional interactivity mediates the relationship between instructional information and students’ cognitive processes. At the conclusion of his paper, Hannafin suggested five functions or purposes of interactivity and aligned them with students’ cognitive processes. Furthermore, and again like Jonassen, Hannafin proposed learning or instructional tasks that promote specific interactions and, as a result, support specific cognitive processes.

More recently, a third research team has focussed explicitly on cognition and interactivity (Aldrich et al., 1998; Rogers & Scaife, 1999). Aldrich et al. aimed to develop an explanation of interactivity which focused “explicitly on the kind of cognitive activities...that take place through the physical activities afforded by the interface” (p. 324). In their framework of cognitive interactivity, Rogers and Scaife suggested that interactivity refers to the interaction between internal and external representations of conceptual information while users engage in a given learning task. Internal representations refer to the learners’ cognitive structures and processes given the content of an activity, while external representations refer to how this content is presented, often in multiple forms, on the interface. While not entirely clear, external representations appear to refer to both program- and user-generated representations of the content. Regardless, Rogers and Scaife clearly suggested that researchers’ understanding of interactivity would benefit from investigating users’ cognitive processes given the way in which screen-based material is presented and structured.

Rogers and Scaife’s (1999) primary concern was to determine the most effective way to design and display multiple representations of concepts on the interface and to support users’ interactions with them. To this end they identified four “cognitive properties” of external representations, which make them harder or easier to interact with. “Interact” in this context refers to the “perceptual and cognitive processes that occur when external representations are used, adapted or constructed by the user in a given activity” (p. 4). The importance of Rogers and Scaife’s research to the current discussion is that interactivity is defined in terms of cognition and is seen as an interplay between representations, which occur inside (cognitive) and outside the computer. Scaife suggested, “it doesn’t make sense to talk about internal processes that occur when using e-learning tools; we need to explain how they interact with the user.”

The work of Jonassen (1985, 1988) and specific nature of instructional events and with, them, will greatly influence the type of interaction design that can be used by designers. An analysis of interactivity at the level of instructional activities is often preceded by an analysis of instructional events, focusing on the interactional processes of knowledge. This interactivity between the internal processes of users and the external representations of the problem is crucial to an understanding of learning.

While these three separate areas of research are connected to the need for interactivity, they are not necessarily sufficient. A model for multimedia interactivity is needed.

A Model for Multimedia Interactivity

The review to this point has suggested the complexity of the interactivity, and the need for a more comprehensive design. Second, it has a fun-structured model of instructional events. Third, it has a fun-structured model of instructional events. The model that describes the cognitive processes of engaging in an instructional event. An ad hoc model needs to provide an analysis of each event, the relationship between the interaction model and the instructional events, and the relationship between the interaction model and the instructional events.

Instructional Events

Instructional events provide the foundation for multimedia programs. The model, as ultimately these are the basis for general multimedia programs or
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A Model for Multimedia Interactivity Research

The review of this point has suggested three fundamental components of interactivity. First, interactivity is grounded in the design of computer-based instructional events. Second, it has a functional component that describes users' behavioural interactions or more simply, what students actually do when faced with an instructional event. Third, it has a cognitive component that describes the cognitive processes and strategies students use when engaging in an instructional event. An adequate research model of interactivity needs to provide an analysis of each of these components and, more importantly, the relationship between them. Figure 1 presents a Cognitive Interaction Model that incorporates these elements and may be used to frame research investigations into computer-based interactivity.

Instructional Events

Instructional events provide the foundation for the Cognitive Interaction Model, as ultimately these are the basis for interactivity. Instructional events refer to general multimedia programs or specific tasks within a program,
which are presented to or completed by students for the purpose of learning. The defining feature of an instructional event is its implicit or explicit learning goal. Designers of educational multimedia usually construct instructional events with learning goals in mind for students. These can refer to both how students complete learning tasks and what they are supposed to learn from them. As such, the learning goals of an instructional event describe both the behavioural and cognitive learning processes and the learning outcomes implied in the task's content and instructional design.

While instructional events are typically designed with these implicit or explicit learning goals in mind, it cannot be assumed that students will use instructional events in the way designers expect. Indeed, it is probable that students will use tasks which give them a degree of control in multiple ways. For this reason, designers or educators cannot assume that the learning design of an instructional event will necessarily promote the expected

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**Figure 1.** A cognitive interaction model of multimedia interactivity

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behaviour or cognitive processing. To use Thon terms, a reactive learning design will not necessarily promote beneficial ones.

This notwithstanding, an assumption of interactive multimedia applications have beneficial learning processes and outcomes than Jonassen's (1988) notion that instructional e-adaptive learning strategies. Jonassen's per thoughtful design of interactive instructional that require students to process materials in p. Research on interactivity, therefore, needs to under which the content and design of specific the kinds of behavioural and cognitive process Figure 1 these processes are referred to as activity respectively and are expanded upon next.

**Functional and Cognitive Interactivity**

The Cognitive Interaction Model proposes between instructional events and the behaviour relationship is referred to as functional internal functional conception of interactivity previ (1997) taxonomy, behavioural processes can behaviours such as moving forward or back answer a multiple choice question, or more so manipulating variables in a simulation, navigate a concept map. The relationship between instructional processes is bidirectional because it induces a behavioural response from students. The relationship between instructional activities determines what instructional designs that are more adaptive, these behavi determine subsequent instructional sequence components of future instructional events. Provisional hypotheses, or concept maps created in a program as part of an instructional event.

The second type of interactivity in the model proposes that the relationship between students' cognitive processes is mediated by their attempts to capture the continual interplay three defining components of interactivity by back loop between events, behaviour and cognitive processes students use in learning environments that students engage in an
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are typically designed with these implicit or d, it cannot be assumed that students will use as designers expect. Indeed it is probable that give them a degree of control in multiple ways. Educators cannot assume that the learning vent will necessarily promote the expected behaviour or cognitive processing. To use Thompson and Jorgensen’s (1989) terms, a reactive learning design will not necessarily prevent beneficial cognitive processes just as a proactive or interactive design will not automatically promote beneficial ones.

This notwithstanding, an assumption of interactive learning design is that some interactive multimedia applications have a better chance of promoting beneficial learning processes and outcomes than others. This is typified by Jonassen’s (1988) notion that instructional events can be embedded with adaptive learning strategies. Jonassen’s perspective suggested that the thoughtful design of interactive instructional events results in interactions that require students to process materials in particular and beneficial ways. Research on interactivity, therefore, needs to unravel the circumstances under which the content and design of specific instructional events promotes the kinds of behavioural and cognitive processes thought to be beneficial. In Figure 1 these processes are referred to as functional and cognitive interactivity respectively and are expanded upon next.

Functional and Cognitive Interactivity

The Cognitive Interaction Model proposes a bidirectional relationship between instructional events and the behavioural processes of users. This relationship is referred to as functional interactivity and is aligned with the functional conception of interactivity previously described. Like Sims’ (1997) taxonomy, behavioural processes can represent relatively simple behaviours such as moving forward or back and clicking on a button to answer a multiple choice question, or more sophisticated behaviours such as manipulating variables in a simulation, navigating a microworld or creating a concept map. The relationship between instructional events and behavioural processes is bidirectional because just as the instructional event induces a behavioural response from students, the result of students’ behavioural activities determines what instructional events occur. In learning designs that are more adaptive, these behavioural processes can not only determine subsequent instructional sequences but can also constitute core components of future instructional events. For example, electronic notes, provisional hypotheses, or concept maps created by students may be revisited in a program as part of an instructional event.

The second type of interactivity in the model, labelled cognitive interactivity, proposes that the relationship between instructional events and students’ cognitive processes is mediated by their behavioural processes. Figure 1 attempts to capture the continual interplay and dependency between the three defining components of interactivity by depicting a continuous feedback loop between events, behaviour and cognition. Research on the cognitive processes students use in learning environments has focussed on both the study behaviours that students engage in and the cognitive strategies sup-
ported by these behaviours (see Weinstein & Mayer, 1986; Weinstein, 1978; Rigney, 1978; Jonassen, 1988; Pintrich, Smith, Garcia, & McKeachie, 1991). In the Cognitive Interaction Model, behavioural and cognitive processes are distinguished from each other and cognitive processes refer only to students’ use of cognitive and metacognitive strategies. Cognitive strategies are the internal mental processes, operations and procedures that students engage in to acquire, integrate, organise, and retain new information. Metacognitive strategies are the specific processes by which students evaluate or monitor their own thinking and knowledge structures (Weinstein & Mayer; Rigney).

A number of researchers have developed taxonomies to describe and distinguish between cognitive and metacognitive strategies. One of the most well known and often cited is Weinstein and Mayer’s (1986) eight-fold classification, which includes rehearsal (basic and complex), elaboration (basic and complex), organisation (basic and complex), comprehension monitoring, and affective and motivational strategies. Pintrich et al. (1991), who drew on Weinstein and Mayer (1986), defined elaboration as a cognitive strategy that helps students “store information into long-term memory by building internal connections between items to be learned” (p. 20). Organisation is a strategy that helps students “select appropriate information and also construct connections among the information to be learned” (p. 21). In Pintrich et al.’s classification, metacognitive or self-regulatory strategies refer to students’ awareness, knowledge, and control of cognition and involves three general processes: (a) planning; (b) monitoring, and (c) regulating. A number of other cognitive processes and strategies could also be included in this taxonomy such as processes associated with problem-solving and critical thinking.

In some circumstances the correspondence between behavioural and cognitive processes may seem quite clear. If a student constructs a meaningful concept map (a behavioural process) one may assume this will be accompanied by the use of “organisation,” as this cognitive strategy is inherent in the activity. However, just because students are presented with an instructional event does not necessarily mean they will engage in the task. Moreover, as previously mentioned, even if students do engage in the task there is no guarantee all of them will use it in the same way or will necessarily employ the cognitive strategies imbued in the task’s design (Jonassen, 1988). This is why there is a need for researchers investigating interactivity to simultaneously assess both behavioural and cognitive processes given a specific instructional event. The dynamic interplay and dependency between these aspects of the model makes it clear that interactivity cannot be determined by assessing the functional interactivity of the interface, nor can it be assumed through an a priori classification of the relationship between the learner and the instructional source. Just as Rogers and Scaife (1999) suggested researchers need to know how internal and external representations of knowledge are used together to solve problems, interactive learning knowing how functional and cognitive interactivity as interactivity has been defined as comprising (instructional events, behavioural processes, and no line directly linking instructional events and /). While the relationship between an instruction cognitive strategies would usually be mediated by (as shown in Figure 1), a direct relationship between students’ use of cognitive strategies could exist. ‘I have no behavioural input or control over an inst the automatic presentation of an animation or a control (play, stop, pause etc) is an instructional al interaction on the part of users. But the mere will almost certainly induce some form of cog argued that entering the screen represents a be with the animation (it effectively starts it). Howtive processing of the animation is independent. The functional interactivity of clicking to enter a al purpose rather than an educational purpose as For these reasons a direct relationship between interative processing is not represented in the Cognitive

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Benefits of Interactivity

The final part of the model proposes two po ity. The first, promoting intrinsic motivation, is viding students with interactive multimedia f “involvement” in learning. In his discussion afforded by instructional technologies, Hannaf are concerned with the manner in which ii engagement” (p. 170). Similarly, Spector (1995 t of learning effectiveness) is more likely the or involvement with the subject material” (p. 5:

The notion of “engagement” in interactivity parallels with educational research on intrinsic tion in educational situations is characterised by
Model, behavioural and cognitive processes are referred to as metacognitive strategies. Cognitive strategies are the mental processes used by students to engage in learning and retain new information. Metacognitive processes by which students evaluate or monitor their own knowledge structures (Weinstein & Mayer; Rigon). have developed taxonomies to describe and distinguish metacognitive strategies. One of the most widely used is Weinstein and Mayer's (1986) eight-fold classification (basic and complex), elaboration (basic and complex), comprehension monitoring, and strategies. Pintrich et al. (1991), however, defined elaboration as a cognitive strategy that involves taking what is presented and transforming it into a more meaningful representation. In addition, metacognitive or self-regulatory strategies such as planning, monitoring, and controlling processes and strategies could also be added to this list. These processes are associated with problem-solving and can be thought of as processes that are used to help students solve problems. According to Mayer (1989), interactive learning can only be understood by knowing how functional and cognitive strategies work together.

As interactivity has been defined as comprising three essential components (instructional events, behavioural processes, and cognitive processes), there is no direct link between these components. Instead, the relationship between an instructional event and students' use of cognitive strategies would usually be mediated by their behavioural strategies (as shown in Figure 1), a direct relationship between an instructional event and students' use of cognitive strategies could exist. This would occur when a user has no behavioural input or control over an instructional event. For example, the automatic presentation of an animation or video with no mechanism of control (play, stop, pause etc) is an instructional event requiring no behavioural interaction on the part of users. But the mere presence of the animation will almost certainly induce some form of cognitive processing. It may be argued that entering the screen represents a behavioural activity associated with the animation (it effectively starts it). However, in real terms any cognitive processing of the animation is independent of this behavioural response. The functional interactivity of clicking to enter a new screen has a navigational purpose rather than an educational purpose associated with the animation. For these reasons a direct relationship between instructional events and cognitive processing is not represented in the Cognitive Interaction Model.

While most models and discussions of interactivity have paid particular attention to the relationship between instructional events, few models have considered the cognitive component. The Cognitive Interaction Model extends previous conceptions of interactivity by going beyond functional concepts of the task and by making users' cognitive processes central to it. Cognitive rather than functional interactivity is the primary focus of the model. While functional interactivity is an important component of the model, it is effectively subsumed by cognitive interactivity.

Benefits of Interactivity

The final part of the model proposes two potential benefits of interactivity. The first, promoting intrinsic motivation, is based on the view that providing students with interactive multimedia promotes "engagement" or "involvement" in learning. In his discussion of the types of interactions afforded by instructional technologies, Hannafin (1989) said, "in effect we are concerned with the manner in which instruction fosters cognitive engagement" (p. 170). Similarly, Spector (1995) suggested "the critical factor (of learning effectiveness) is more likely the learner's mental engagement or involvement with the subject material" (p. 531).

The notion of "engagement" in interactivity research has clear conceptual parallels with educational research on intrinsic motivation. Intrinsic motivation in educational situations is characterised by students being absorbed in
learning for its own sake, involvement, enjoyment, timelessness, immersion, curiosity, and persistence (Ames 1992, Cordova & Lepper, 1996; Csikszentmihalyi, 1982, 1985; Hanekiewicz, Barron, & Elliot, 1998; Hidi & Harackiewicz, 2000). Educational researchers have found that intrinsic motivation can be fostered by altering the design of classroom tasks and activities. Providing students with tasks that involve variety and diversity, are relevant and appropriately challenging, permit students to show competence or skill and give them a degree of control or self-determination have been found to increase intrinsic motivation (Ames; Becker & Dwyer, 1994; Chan & Ahern, 1999; Cordova & Lepper; Harackiewicz et al.; Newby & Alter, 1989; Lepper & Cordova, 1992; Rezabek, 1995). This research suggested, therefore, that the characteristics of intrinsically motivating learning environments are often similar to the characteristics of interactive learning designs. That is, some of the features of interactive multimedia — providing students with control or allowing them to test their knowledge and skill — are also features of educational environments that have been found to be intrinsically motivating.

But how exactly does interactivity promote intrinsic motivation? Hidi and Harackiewicz (2000) provided a possible explanation. They argued that some learning environments foster situational interest. This type of interest is sparked by conditions in the learning environment and is seen in contrast to “individual” interest, which is more personally based and topic specific. Hidi and Harackiewicz suggested that after situational interest is triggered (by, for example, an exciting lecture or a captivating animation), a student’s interest is maintained by engaging them in meaningful cognitive processing. If situational interest is maintained in this way it increases students’ intrinsic motivation for learning.

This explanation is consistent with the Cognitive Interaction Model of interactivity. The implication for interactivity researchers is that while the “bells and whistles” of multimedia may trigger situational interest, the ability of instructional events to promote meaningful cognitive processes (cognitive interactivity) is vital in determining whether a student’s interest is maintained. If interest is maintained by challenging students to engage in meaningful cognitive processing, not only will students become “involved” and “immersed” in their learning but they will also enjoy it more. Thus, only if educational multimedia is interactive at a cognitive rather than a functional level will it promote intrinsic motivation.

The second potential benefit of interactivity proposed in the model relates to students’ learning outcomes. Many of the learning benefits of interactivity espoused by researchers have their genesis in either Craik and Lockhart’s (1972) or Marton and Säljö’s (1976a) work on levels of processing. While these seminal articles use the same term, “levels of processing,” they refer to different phenomena. In their analysis of information processing and memory, Craik and Lockhart proposed that stimuli are more memorable if they are processed at a “deeper level.” Deep processing refers to semantic
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promote intrinsic motivation? Hidi and Stipek linked intrinsic motivation to interesting curriculum and individualized learning experiences. They argued that students' interest is sparked when the learning environment is meaningful and challenging. Engaged students experience deep-level thinking and knowledge growth, which are necessary for meaningful learning. Efforts to promote intrinsic motivation in educational settings should focus on creating meaningful and engaging learning experiences.

The implications of the Cognitive Interaction Model for Interactivity Research

Analysing Instructional Events

The Cognitive Interaction Model provides a framework for conducting interactivity research, the first stage of which would involve an analysis of
instructional events. This analysis may be directed at the overall design and structure of an educational multimedia program or at the level of specific tasks within a program with the goal of identifying potential functional and cognitive interactivity at each level. For example, educational programs adopting a situated model (Herrington & Oliver, 1995, 1997) may support types of interactivity that are distinct from more conventional page turning applications. Likewise, discrete interactive tasks (simulation tasks, formative assessment tasks, searching, prediction and construction tasks, annotating, and concept mapping, etc.) may also encourage different types of functional and cognitive interactivity.

Analysing instructional events is not a simple task. In particular, it may be difficult to specify cognitive strategies for some instructional events and, as mentioned, some instructional events are likely to promote more than one strategy (e.g., note-taking could be elaborative, self-regulatory, and organisational). Thus, researchers should not be disheartened if they are unable to create a definitive analysis of instructional events in their programs; indeed, it is not possible to do so. But such an analysis should help researchers develop preliminary expectations about the types of processes available to students for instructional events and the cognitive processes that these might support. This type of analysis is important as it will initially direct researchers to the general characteristics and specific elements of an educational multimedia program which offer the greatest potential for cognitive interactivity.

The classifications of Jonassen (1988) and Hannafin (1989) provided a useful heuristic for an analysis of instructional events. For example, Jonassen suggested a number of instructional tasks associated with the cognitive strategy of organisation. These include asking students to identify or classify concepts and constructing a concept map. While some of Hannafin's suggestions were quite broad (e.g., using menus is said to be associated with metacognitive skills), his framework does provide a number of indicators of how specific instructional events could be related to students' cognitive processing. He suggested that the strategy of elaboration can be promoted by introducing students to new concepts using familiar subject matter and examples, and by asking them to think of other areas where these concepts apply.

Methodological Implications

The critical methodological implication of the Cognitive Interaction Model is the simultaneous measurement of behavioural and cognitive processes. The measurement of behavioural processes could be carried out through the use of audit trails or observation. The measurement of students' cognitive processes is inherently difficult as they are hidden from the researcher. This notwithstanding, cognitive processes and strategies have been assessed using a variety of methods in the past. These valuable tools for interactivity researchers include self-report protocols, and video-stimulated recall. The more cognitive processes is discussed next.

Audit trails are electronic records of users' technology environments, neatly referred to when by Williams and Dodge (1993). By employing multimedia programs, researchers can study interactivity. While identifying single use of instructional events it may be more profitable to study interactions and document patterns in similar situations. For example, if students are faced with a drag-and-drop sequence rather than individual drops may be recorded at the sequence and time of students' activities will be documented. If a program contains a theorem section, it may be useful to gauge the thinking processes before moving on to the next section. We can look at similar functional interactivity (such as grouped using ordination techniques such as dimensional scaling). These groups may be used related to students' cognitive processing and/or

Another method for assessing interactivity involves in-person or using video equipment. This would be costly, but it is similar to auditing the documentation of students in their educational data collection is certainly less convenient, more reliable means of recording the precise movements. Nonetheless, when used together with a report on their general cognitive strategy use through self-report by Hanley, & Houmell's, (1979) approaches to (1987) Study Process Questionnaire, and Pinto Strategies for Learning Questionnaire. In his report on their general cognitive strategy use at or unit rather than the cognitive processes associat (or computer-based) tasks. In a discussion of his (1976a) approaches to investigating students (1993) noted the distinction between measures and use more specific, on-line strategy use...

Whereas Marton and Säljö were tapping while doing a task, the constructs derived from
analysis may be directed at the overall design and multimedia program or at the level of specific the goal of identifying potential functional and rules. For example, educational programs (Herrington & Oliver, 1995, 1997) may support a distinction from more conventional page turning to interactive tasks (simulation tasks, formative prediction and construction tasks, annotating, may also encourage different types of functions).

Events is not a simple task. In particular, it may be strategies for some instructional events and, oral events are likely to promote more than one thing could be elaborative, self-regulatory, and others should not be disheartened if they are an analysis of instructional events in their probable to do so. But such an analysis should help any expectations about the types of behavioral for instructional events and the cognitive support. This type of analysis is important as it is to the general characteristics and specific multimedia program which offer the greatest potential.

Jonassen (1988) and Hannafin (1989) provided a set of instructional events. For example, Jonassen instructional tasks associated with the cognitive strategies asking students to identify or classify concept map. While some of Hannafin's suggestions menus is said to be associated with metacogni- tions provide a number of indicators of how speed be related to students' cognitive processing. tions of elaboration can be promoted by introducing familiar subject matter and examples, and by areas where these concepts apply.

Theoretical implication of the Cognitive Interaction measurement of behavioural and cognitive of behavioural processes could be carried out or observation. The measurement of students' already difficult as these are hidden from the data, cognitive processes and strategies have of methods in the past. These valuable tools for interactivity researchers include self-report questionnaires, think aloud protocols, and video-stimulated recall. The measurement of behavioural and cognitive processes is discussed next.

Audit trails are electronic records of users' activities within educational technology environments, newly referred to as users' "what, where and when" by Williams and Dodge (1993). By embedding audit trails into educational multimedia programs, researchers can easily document users' functional interactivity. While identifying single use functions is useful, for many instructional events it may be more profitable to look across a series of functional interactions and document patterns in students' behavioural processes. For example, if students are faced with a drag-and-drop construction task, the sequence rather than individual drops may be of interest. At a broader level, the sequence and time of students' activities within sections of a program may be documented. If a program contains a theoretical and a practical (applied) section, it may be useful to gauge whether students begin by experimenting with practical tasks before moving on to the theory or vice versa. Students who exhibit similar functional interactivity (patterns of behaviour) may be grouped using ordination techniques such as cluster analysis and multidimensional scaling. These groups may be used in subsequent analyses and related to students' cognitive processing and/or learning outcomes.

Another method for assessing functional interactivity is observation, either in person or using video equipment. This would generate data about students' behavioural processes, which are similar to audit trails and have the advantage of documenting students in their educational context. However, this form of data collection is certainly less convenient, more obtrusive, and probably a less reliable means of recording the precise movements of students and their intentions. Nonetheless, when used together with audit trails, in situ observation would provide a powerful measure of functional interactivity.

Educational and psychological researchers interested in students' approaches to learning and achievement motivation have assessed students' cognitive strategy use through self-report questionnaires (see Entwistle, Hanley, & Hounsell's, (1979) Approaches to Studying Inventory; Biggs' (1987) Study Process Questionnaire, and Pintrich et al.'s (1991) Motivated Strategies for Learning Questionnaire). In these questionnaires students report on their general cognitive strategy use and study patterns for a course or unit rather than the cognitive processes associated with specific classroom (or computer-based) tasks. In a discussion of his own and Marton and Säljö's (1976b) approaches to investigating students' learning processes, Biggs (1993) noted the distinction between measuring general cognitive strategy use and more specific, on-line strategy use...
ically asked what they usually did, or what they were predisposed to do, which is one step removed from what they actually do when engaging in a given task in a particular context. The questions asked are different, and serve different purposes, but the nature of the constructs addressed is closely related. (p. 5)

Thus, to measure the cognitive and metacognitive strategies students use while interacting with a piece of courseware, most established learning strategy questionnaires would need to be modified to reflect the specificity of computer-based learning tasks.

Alternative methods of assessing students’ cognitive processing are think aloud protocols and video stimulated recall. In the former technique students are asked to articulate what they are thinking as they interact with courseware. A difficulty with this technique is that when students interact with particularly demanding or engaging material their verbalisation will often be suspended. Ironically the instructional events of most interest to interactivity researchers – those requiring sustained cognitive effort – are also the events for which students find it difficult to articulate their thoughts. Video stimulated recall is similar to think aloud protocols, but with this method students retrospectively report their thought processes triggered by a video of them working with courseware. Qualitative analysis of students’ responses in both these procedures can give researchers an indication of the types of cognitive processes that occur when students are using educational multimedia.1

Potential Research Designs

Research on interactive multimedia needs to be guided by theories of learning (Reeves, 1993). The central role of cognitive and metacognitive strategy use in the Cognitive Interaction Model aligns any resultant research with both information processing (e.g., dual-processing or cognitive load theory) and socio-cognitive approaches to learning research (e.g., theories of achievement motivation or student approaches to learning). There is no shortage of potential theoretical approaches to choose from (see the list of theories supplied by Kearsley, 2002) and a discussion of these alternatives is beyond the scope of this article. It may be more useful to consider two potential research designs that also exemplify viable theoretical approaches to interactivity research.

The Cognitive Interaction Model suggests that multimedia interactivity research needs to focus on how students interact with courseware. One possible research design is to provide different groups of students with edu-

1 Conversation analysis has also been used extensively to document students’ cognitive processing. It has not been included here as it typically documents the verbal interaction between students at a computer rather than the cognitive strategies of a single student while using a computer-based courseware.
multimedia needs to be guided by theories of the central role of cognitive and metacognitive strategies. Students use of courseware is most established learning strategies to be modified to reflect the specificity of assessing students' cognitive processing are think-aloud protocols. In the former technique students are thinking as they interact with software, they are verbalising their thought processes triggered by a video of them. A qualitative analysis of students' responses in both techniques can indicate the type of cognitive strategies students are using educational multimedia.

Model suggests that multimedia interactivity as students interact with courseware. One possible difference between students with educational multimedia containing similar content but different instructional designs. For example, drawing on cognitive load theory, Mayer and Chandler (2001) argued that user-controlled (interactive) animations are associated with less cognitive load for students compared to uncontrolled, continuous animations. They proposed that reducing the cognitive load associated with animations would enable students to process material more deeply using cognitive strategies such as elaboration and organisation. When two groups of students were presented with an animation on the formation of lightning (one user-controlled, one continuous), they found that students with the user-controlled animation performed better on transfer tasks. While Mayer and Chandler (2001) did not directly assess cognitive processing, they assumed it given these learning outcomes. This type of research design is also exemplified by the studies of Cordova and Lepper (1996) and Rezabek (1995) who based their research on theories of intrinsic motivation and flow respectively.

These theories could be equally well applied to an alternative research design in which students' movements and activities within a single educational multimedia program are tracked. Presuming the courseware was designed to give users a degree of control, it would be possible to investigate the relationship between students' use of the multimedia (their functional interactivity) and their cognitive strategy use (cognitive interactivity). Audit trails could be used to determine how students differentially navigate the program or to look more specifically at how they complete various interactive tasks within a program. The patterns of students' behaviour at either or both these levels of analysis could be related to their use of cognitive strategies measured through questionnaires and/or think aloud protocols. Antecedent variables (e.g., students' goals, self-efficacy or other background characteristics of learners) as well as outcome variables (e.g., retention, conceptual understanding, positive affect, or intrinsic motivation) could also be included in such a design.

While the focus of this article has primarily been on how interactive multimedia programs can promote students' cognitive processes, it is important to acknowledge that a range of other elements exist in learning environments, aside from the computer, which can also affect the cognitive strategies students use. As eluded to, individual factors such as students' goals and self-efficacy and contextual factors such as students' interactions with peers and tutors may all contribute to their use of cognitive strategies. Moreover, students may complete learning activities alongside educational multimedia – most obviously note-taking – which would also contribute to the types of cognitive processing that occurs. Recognising these additional factors highlights the complexity of learning environments but does not diminish the need to focus on the characteristics of educational multimedia. The investment institutions and educators have made in interactive multimedia and a
belief in its benefits warrant detailed and rigorous investigation. Theoretically based interactivity research needs to acknowledge the potential contribution of these additional elements to student learning processes and outcomes, while at the same time maintaining a commitment to investigating whether interactive educational multimedia programs and tasks are associated with specific behavioural and cognitive processes.

Conclusion

Previous discussions and models of interactivity have been overly preoccupied with the types of behavioural interactions that multimedia affords. While some researchers have recognised the need to consider what students were thinking, to date this has not been adequately incorporated in a general research model of the construct. It is time, therefore, for interactivity researchers to actively focus on students’ cognitive processes. The Cognitive Interaction Model proposed in this article highlights three fundamental components of multimedia interactivity: (a) the content and design of instructional events, (b) the behaviours and actions of students, and (c) their cognitive processes and strategies. While two types of interactivity are proposed in the model – functional and cognitive interactivity – researchers should focus their attention on the latter. Cognitive interactivity describes a continuous, dynamic relationship between instructional events and students’ cognitive processes that is mediated by their behavioural processes. The critical methodological implication of this research model is the simultaneous assessment of students’ behavioural and cognitive processes so that the relationship between these can be established for specific instructional events.

In a piercing deconstruction of interactivity, Rose (1999) suggested that “the very quality which is said to make computers unique and to justify their instructional use continues to defy definition” (p. 48). In order to counter such critiques, interactivity researchers need to engage in theoretically based research. Such research demands that the beneficial learning processes and outcomes associated with multimedia’s “interactive” nature are clearly articulated. The research models of interactivity that emerge from this review must then be used to structure theory driven research on computer-based, interactive learning. This article offers one possible model and some initial research suggestions for this long-term, but long overdue process.

References


detailed and rigorous investigation. Theoretical research needs to acknowledge the potential contributions to student learning processes and outside maintaining a commitment to investigating all multimedia programs and tasks are associated and cognitive processes.

Models of interactivity have been overly pre-organised interactions that multimedia affords. Recognised the need to consider what students are not been adequately incorporated in a general construct. It is time, therefore, for interactivity in students’ cognitive processes. The Cognitive this article highlights three fundamental continuity: (a) the content and design of instructions and actions of students, and (c) their cognition. While two types of interactivity are proposed a cognitive interactivity – researchers should need to be aware that cognitive interactivity describes a continuous interaction between instructional events and students’ cognition by their behavioural processes. The critical of this research model is the simultaneous ioural and cognitive processes so that the relation established for specific instructional events. m of interactivity, Rose (1999) suggested that I to make computers unique and to justify their defying definition” (p. 48). In order to counter searchers need to engage in theoretically based and that the beneficial learning processes and time media’s “interactivity” nature are clearly articulate of interactivity that emerge from this review re. theory driven research on computer-based. It offers one possible model and some initial long-term, but long overdue process.


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