THE INTERACTIVE CONUNDRUM I: INTERACTIVE CONSTRUCTS AND LEARNING THEORY

Sims, R.

School of Multimedia and Information Technology
Southern Cross University

Email: rsims@scu.edu.au
http://multimedia.scu.edu.au

Abstract

The role and function of interactivity within computer-enhanced learning is undergoing increased scrutiny. Through a reappraisal of learning theories in terms of their implications for interactivity and identifying the major interactive constructs, this paper provides a context for better understanding interactivity and achieving its potential for enhancing the learning process.

Keywords

Interactivity; learning theory

Interactivity in conflict

In a world of interactive gadgetry, the following opinions succinctly demonstrate the conflicting attitudes toward interactivity and the conundrum that confronts the implementation of computer-enhanced learning (CEL) environments.

Computer-based instruction provides greater potential for truly interactive instruction than any mediated teaching device to date, excluding in many instances, the human tutor. (Jonassen, 1988:97)

In denying the possibility of difference and in elucidating *différance,* deconstruction essentially reveals interactivity to be not a conceptual unity, defined in terms of clear distinctions between antithetical terms, but as a fragmented, inconsistent, and rather messy notion encompassing both privileged and marginalised binaries, and the range of meanings in between. (Rose, 1999:48)

But who is right? Is interactivity an intrinsic component of CEL, enabling effective and engaging learning experiences, or is it a misnomer, masking processes too complex to measured by overt response-feedback mechanisms?

I argue that the conundrum exists because the perceived advantage of interactivity in CEL is based on its equivalence to real-life teacher-learner communication. But can (or should) computer-based applications attempt to replicate this level of communication? The evolution of educational technology has been reinforced by rhetoric (from both manufacturers and developers) that computers are inherently interactive and therefore beneficial, especially to learning. In reality however, the interactivity demonstrated is frequently little more than mouse-clicks and generalised, repetitive, non-adaptive feedback.

Given the current interest in interactive constructs (Sims, 1997; Aldrich, Rogers & Scaife, 1998) contrasted by the argument that *interactive* and *interactivity* lack “denotive value” (Rose, 1999), it is therefore important to reassess not only the notion of interactivity but its role in enhancing the learning process in its various forms. In order to better understand this role, this paper revisits the relationships between interactive constructs and learning theories, proposing a classification that

substantiates interactivity as a viable mechanism to support learning. Using this framework, the discussion reassess how these interactive constructs might be applied to current forms of CEL applications, including on-line initiatives, and provides a research framework for an in-depth investigation of interactivity. In developing this argument, much of the research is based on stand-alone CEL environments (i.e. human:computer interactions); however, the conclusions drawn are equally relevant to computer-mediated (on-line) human:human interactions.

From learning theory to interactivity

Interactive prescriptions

The relationship between how we learn and the interactions which support that learning can be traced as far back into history as we might wish to pursue. However, if we focus specifically on the current century, there are numerous, varied and evolving approaches to learning which can be assessed in terms of their implications for CEL environments and the associated interactive constructs. For the purposes of this section, the term *interactivity* refers to those functions and/or operations made available to the learner to enable them to work with content material presented in a computer-based environment. The later discussion will expand on this definition.

Texts based generally on learning theories separate the work of behavioural, cognitive and contemporary theorists (e.g. Bower & Hilgard, 1981), while those more focused on the educational technology field offer a more specialised analysis. For example, Romiszowski (1986) acknowledges that one's particular philosophical position will influence the structure of learning activities, differentiating the Humanist (with an emphasis on useful content), Behaviourist (emphasising outcomes), Cognitivist and Developmental (emphasising the process) and Cybernetic (emphasising the system) approaches. More recently, Kearsley (1999) compiled the *Theory into Practice* database, documenting an extensive range of learning theories, concepts and domains. From my synthesis of these theories, a process which identified the major **focus** of the theoretical position, the means by which it might be **implemented** in a learning environment and the likely interactive constructs which would be **manifested** in a CEL environment, I have derived four dimensions linking the prescriptions of interactivity from those theoretical positions.

In presenting these dimensions, it is argued that learning should not be linked to any single strategy or intervention, but viewed as a complex interaction between circumstances, conditions, environment, motivation and culture. While no one theory or paradigm can explain learning completely, this analysis does provide a framework and foundation for considering the constructs of interactivity in the context of CEL.

Deriving interactive constructs

The following dimensions are by no means meant to assign an interactive element to any one theoretical position but rather to demonstrate how an assessment of learning theory can reinforce the potential for implementing appropriate interactive strategies. In summary, the four major dimensions identified can be characterised by:

Learners - the *who* of the learning process
Content - the *what* of the learning process
Pedagogy - the *how* of the learning process
Context - the *when* and *where* of the learning process

Within this framework, a set of focus points in relation to interactivity are also identified to further differentiate their relation to the specific learning activity. While beyond the scope of this paper, Reeves (1999) points to an additional dimension - whether the CEL environment is one which learners will learn *from* (instructivist) or one they will learn *with* (constructivist).

Interactivity and learners

The details provided in Tables 1 to 4 following (using the descriptions of Kearsley, 1999) propose that certain learning theories have a particular focus on the learner, and that by examining this focus particular interactive constructs can be derived. By considering the *Learner* dimension, developers may be able to create applications more adaptive to the specific characteristics of the target population. For example, providing certain orienting sequences or ensuring the learner is clear of their role in the educational process.

Table 1: Interactive constructs for learners

Focus	**Interactive Constructs**	**Related Theories**
Goal Navigation; Exploration	• Select navigational paths • Retrieve appropriate content • Move within a simulated environment • Explore conditions of rule operation • Compare results	Sign Learning (Tolman, 1932); Constructivist (Bruner, 1966); Information Pick-Up (Gibson, 1966); Structural Learning (Scandura, 1973); Androgogy (Knowles, 1984); Adult Learning (Cross, 1981); Soar (Newell, 1990)
Making Selections	• Access manageable pieces of material • Modify content structure	Information Processing (Miller, 1956)
Tools	• Access help or support tools	Cognitive Dissonance (Festinger, 1957)
Control: to Construct or Deconstruct	• Construct or modify properties of and/or relationships between learning objects • Create personal narratives	Gestalt (Wertheimer, 1959); Lateral Thinking (de Bono, 1967); Experiential (Rogers, 1969); Dual Coding (Paivio, 1986); Levels of Processing (Craik & Lockhart, 1972); Script (Schank, 1982); Component Display (Merrill, 1983); Cognitive Flexibility (Spiro, Feltovich, Jacobson & Coulson, 1992)
Prompt for engagement	• Generate original responses	Originality (Maltzman, 1960); Constructivist (Bruner, 1960);
Scaffolding; Modelling	• Assemble or disassemble support tools as required • Adapt dynamic scaffolding according to individual schema • Access exemplars to support knowledge acquisition	Constructivist (Bruner, 1966); Social Learning (Bandura, 1971); Script (Schank, 1982)

Interactivity and content

The content or subject matter presented to users is the second dimension to be assessed carefully. While the structuring of the content sequences is closely associated with the pedagogical dimension, the level and depth of content and the underlying information and presentation design is critical to the overall interactive experience. It is predicted that more detailed emphasis on the way in which the content elements, and the media used to represent them, are linked to the underlying rationale for the application will result in more effective interactions and consequent learning. A tangential element of this dimension is the importance of including learner representatives in the design process, as they are the group who can verify the effectiveness of the interactive experience in terms of participation, engagement and learning outcomes.

Table 2: Interactive Constructs for Content

Focus	Interactive Constructs	Related Theories
The more the better	• Present questions frequently	Connectionism (Thorndike, 1913)
Essential	• Ensure interactions implemented	Contiguity (Guthrie, 1930); Drive Reduction (Hull, 1943)
Engagement	• Integrate meaningful engagement through access to different content representations • Enable the means to control displayed media elements	Dual Coding (Paivio, 1986), Levels of Processing (Craik & Lockhart, 1972)
Content Dependent	• Vary structural presentation as a function of content domain • Enable learner elaboration of epitomes	Algo-Heuristic (Landa, 1974); Component Display (Merrill, 1983); Elaboration (Reigeluth, 1992)
Multimedia	• Enable the means to select media used to display content structures • Enabling access to and manipulation of content	Symbol Systems (Salomon, 1979); Dual Coding (Paivio, 1986); Cognitive Flexibility (Spiro et al, 1992)
Minimalist	• Include only necessary content	GOMS (Card, Moran & Newell, 1983); Minimalist (Carroll, 1990)

Interactivity and pedagogy

As detailed in Table 3, the pedagogical structures associated with a CEL application also suggest certain interactive constructs. This dimension too is critical, as it will determine the extent to which the learner is able to move (navigate), test (explore) and manoeuvre (self-pace) through the product. It will also focus on what measures will represent completion; if based on a teaching (instructivist) model, then some form of assessment might be required. If based on a learner (constructivist) model, then completion of the task might be the measure of success. The implications are that the instructional design process must be extended to adapt for interactivity to maximise engagement - as the learner may be operating in an independent environment without access to teacher support.

Interactivity and context

The fourth dimension by which learning theories and interactivity may be examined relates to the context in which learning is undertaken. In the classroom, learning can range from the abstract to the laboratory and simulated conditions, which can be replicated on a computer if appropriate. However, attempting to provide a context for learning demands not only the integration of knowledge and information into a specific situation but also enabling the learner to position themselves in that context to understand the situation and purpose of that information. For example, while a group

of army specialists may be taken to a bombing range to practice disarming explosives, recreating the same scenario on a computer is complex because time and space constraints exist. One of the challenges therefore, if attempting to develop a CEL environment incorporating a contextual metaphor, is to provide learners with adequate visual cues and support tools to establish a realistic and meaningful learning experience.

Table 3: Interactive Constructs and Pedagogy

Focus	Interactive Constructs	Related Theories
Vary according to learner	• Vary as a function of developmental stage • Vary according to individual skills • Integrate contextual and socio-cultural elements	Genetic Epistemology (Piaget, 1929); Conditions of Learning (Gagne, 1985); Subsumption (Ausubel, 1963); General Problem Solver (Newell & Simon, 1972); Androgogy (Knowles, 1984); Adult Learning (Cross, 1981); ACT (Anderson, 1976); ATI (Cronbach & Snow, 1977); Triarchic (Sternberg, 1977);
Question-Answer-Feedback	• Adopt a cyclic question (stimulus), answer (response) and feedback loop	Operant Conditioning (Skinner, 1950)
Self-pacing	• Enable learner control • Enable self-testing of achievement (mastery)	Mathematical (Atkinson, 1972); Criterion-Referenced (Mager, 1988)
Problem Based	• Enable assessment of individual success • Enable testing and problem-solving of currently held beliefs or concepts • Provide tools to solve problems	Experiential (Rogers, 1969); General Problem Solver (Newell & Simon, 1972); Double-Loop (Argyris & Schon, 1974); Repair (Brown & Van Lehn, 1980); Mathematical Problem Solving (Schonfield, 1985

Table 4: Interactive Constructs for Context

Focus	Interactive Exemplars	Related Theories
Contextual, Situated	• Enable access to people (real or simulated) to provide assistance • Focus on action-consequence model • Relate contextual controls (tools) to support facilities • Enable social operations r	Functional Literacy (Sticht, 1976); Social Development (Vygotsky, 1962); Symbol Systems (Salomon, 1979); Phenomenography (Marton, Hounsell & Entwistle, 1984); Cognitive Flexibility (Spiro et al, 1982); Situated (Lave & Wenger, 1990)
Learning Styles	• Enable learner and program adaptation strategies	Modes of Learning (Rumelhart & Norman, 1978); Multiple Intelligences (Gardner, 1993)

Attempting to provide a context for learning demands not only the integration of knowledge and information into a specific situation but also enabling the learner to position themselves in that context to understand the situation operation of that information. While a group of army specialists may be taken to a bombing range to practice disarming explosives, recreating the same scenario on a computer is complex because time and space constraints exist. Therefore one of the challenges, if attempting to develop a CEL environment incorporating a contextual metaphor, is to provide learners with adequate visual cues and support tools to establish a realistic learning experience.

A case for reason

These four dimensions of interactive learning, derived from a set of learning theories, suggest that interactivity constructs can be viewed as outcomes from educational research rather than a manifestation of a technological imperative. Therefore it is important not to assume that 'old technology is bad, new technology is good' in the way that Kearsley & Shneiderman (1999) promote an engagement theory model to supersede the attempts of the last three decades to achieve success with CEL applications. Instead there is a case for reason, a case to remind ourselves that it is the theoretical frameworks, which provide a guide for interactivity, that will enable us to achieve success in our teaching and learning endeavours.

Given this, the following discussion reviews the classifications of interactivity and sets out to demonstrate that a better understanding of the interactive process is required in order to maximise engagement within CEL environments. Although many products have been demonstrated as representing effective applications by the development teams or through competitive awards, the real effectiveness of any application will only be achieved when representatives of the target group praise its worth. How we might achieve this is the purpose for attempting to better understand the interactive conundrum.

Constructs of interactivity

Revisiting the concept

In challenging the way educational technology has applied the term *interactive* to its outputs, it has been suggested that if we cannot define the term, how can we promote it as a determinant of learning …

In recent years, the concept of interactivity has become so firmly entrenched within the discourse of educational computing that it is a truism to say that instructional software is interactive and that interactivity promotes learning, and a kind of heresy to dispute it. (Rose, 1999: 43)

Nevertheless, analyses of interactivity have provided useful perspectives for assessing interactivity through to taxonomies (Schwier & Misanchuck, 1993); levels (Sims, 1997) and dimensions (Aldrich et al, 1998), as expanded in Table 5.

Table 5: Interactive constructs

Taxonomy of Interactivity (Schwier & Misanchuk, 1993)	**Levels of Interactivity** Sims(1997)	**Dimensions of Interactivity** (Aldrich et al, 1998)
Levels Reactive Proactive Mutual Functions Confirmation Pacing Navigation Inquiry Elaboration Transactions Keyboard, Touch Panel Pointing Device Voice	Levels Object Linear Hierarchical Support Update Construct Reflective Simulation Hyperlinked Non-Immersive Contextual Immersive Virtual	Visibility and Accessibility Visualise content in different ways Access content in different Manipulatability and Annotatability Construct content Make notes Creativity and Combinability Create new content by combining media Experimentation and Testing Run a simulation Build a model

Even so, it is acknowledged that further research is required to better understand what is often an ill-defined concept, with the aim of "moving the emphasis away from the level of physical interactivity at the interface (ie. button presses and mouse clicks) to a

consideration of cognitive interactivity (ie. learning activities which are supported when interacting with the software" (Aldrich et al, 1998:331).

An alternative perspective focusing on narrative and play as a model for interactive endeavours (Plowman, 1996, Sims, 1999) focuses on the strategies which might be implemented to enable the user (learner) to become an integral part of the narrative or story being promoted by the developer. Not only will the learner be offered activities for participation and engagement, but the underlying structure (scaffolding) will ensure they have a clear orientation and sense of purpose for moving within the application, regardless of its explicit structure. In offering this as a potential success factor for interactivity, it augments those issues that must be considered by the development team to include strategies to enable the learner to be integrated into the interactive world as the lead character.

So despite the criticism levelled by Rose (1999), for those actively developing CEL applications, a resurgence of interest in the value of interactivity can only help to ensure the quality of the products are ensured. As advocated by Reeves (1999), the promise of effective interactivity will be achieved by focusing on the ways in which we can make the applications work better rather than relying on empirical research or technological developments to prescribe the solutions.

Conclusions

The application of the term interactivity to CEL applications has assumed to imply an implicit level of effectiveness and learning guarantee. However, despite attempts to provide a context for interactivity through taxonomies, levels and dimensions, there remains a level of mystery about its function and purpose. By revisiting the foundations for educational practice - the theories of learning - a wide range of potential interactive constructs can be derived which should enhance the learning process, whether by simple physical interaction or through more complex and implicit cognitive engagement.

In many ways it appears that too little research has been undertaken to actually determine what is happening during the interactive experience. Much of the praise for this has come from the popular press which has adopted the term as one of the positive indicators of a productive digital future. Similarly, it is not simply a case that we need to move ahead with the technology as promoted by Kearsley & Shneiderman (1999).

It is not the technology which is at fault but the implementation of the interactivity demanded by users. Indeed, interactivity is not a promise unfulfilled, but rather a promise not yet realised.

References

Aldrich, F., Rogers, Y. & Scaife, M. (1998). Getting to grips with "interactivity": helping teachers assess the educational value of CD-ROMs. *British Journal of Educational Technology*, *29*(4), 321-332.

Anderson, J. (1976). *Language, Memory and Thought*. Hillsdale, NJ: Erlbaum Associates.

Argyris, C. & Schon, D. (1974). *Theory in Practice*. San Francisco: Jossey-Bass.

Atkinson, R. C. (1972). Ingredients for a theory of instruction. *American Psychologist*, *27*, 921-931.

Ausubel, D. (1963). *The Psychology of Meaningful Verbal Learning*. New York: Grune & Stratton.

Bandura, A. (1971). *Social Learning Theory*. New York: General Learning Press

Bower, G.H. & Hilgard, E.R. (1981). *Theories of Learning*. (5th Edition). New York: Prentice Hall.

Brown, J.S. & Van Lehn, K. (1980). Repair theory: A generative theory of bugs in procedural skills. *Cognitive Science, 4*, 379-426.

Bruner, J. (1966). *Toward a Theory of Instruction*. Cambridge, MA: Harvard University Press.

Card, S., Moran, T. & Newell, A. (1983). *The Psychology of Human-Computer Interaction*. Hillsdale, NJ: Erlbaum.

Carroll, J.M. (1990). *The Nurnberg Funnel*. Cambridge, MA: MIT Press.

Craik, F. & Lockhart, R. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning & Verbal Behavior, 11*, 671-684.

Cronbach, L. & Snow, R. (1977). *Aptitudes and Instuctional Methods: A Handbook for Research on Interactions*. New York: Irvington.

Cross, K.P. (1981). *Adults as Learners*. San Francisco: Jossey-Bass.

DeBono, E. (1967). *New Think: The Use of Lateral Thinking in the Generation of New Ideas*. New York: Basic Books.

Festinger, L. (1957). *A Theory of Cognitive Dissonance*. Stanford, CA: Stanford UniversityPress.

Gagné, R. (1985). *The Conditions of Learning*. 4th Edition. New York: Holt, Rinehart & Winston.

Gardner, H. (1993). *Multiple Intelligences: The Theory in Practice*. NY: Basic Books.

Gibson, J.J. (1966). *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin.

Guthrie, E.R. (1930). Conditioning as a principle of learning. *Psychological Review, 37*, 412-428.

Hull, C. (1943). *Principles of Behavior*. New York: Appleton-Century-Crofts.

Jonassen, D. (1988). *Instructional Designs for Microcomputer Courseware*. Hillsdale, NJ: Lawrence Erlbaum.

Kearsley, G. (1999). *Explorations in Learning & Instruction: The Theory Into Practice Database*. [Online]. Available: http://www.gwu.edu/~tip/ [10th August 1999].

Kearsley, G. & Shneiderman, B. (1999). Engagement Theory: A framework for technology-based teaching and learning. [Online]. Available: http://www.gwu.edu/engage.htm [10th August 1999].

Knowles, M. (1984). *Andragogy in Action*. San Francisco: Jossey-Bass

Landa, L. (1974). *Algorithmization in Learning and Instruction*. Englewood Cliffs, NJ: Educational Technology Publications.

Lave, J., & Wenger, E. (1990). *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press.

Mager, R. (1988). *Making Instruction Work*. Belmont, CA: Lake Publishing Co.

Maltzman, I. (1960). On the training of originality. *Psychological Review*, *67*(4), 229-242.

Marton, F., Hounsell, D. & Entwistle, N. (1984). *The Experience of Learning*. Edinburgh: Scottish Academic Press.

Merrill, M.D. (1983). Component Display Theory. In C. Reigeluth (ed.), *Instructional DesignTheories and Models*. Hillsdale, NJ: Erlbaum Associates.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*, 81-97.

Newell, A. (1990). *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press.

Newell, A. & Simon, H. (1972). *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall.

Paivio, A. (1986). *Mental Representations*. New York: Oxford University Press.

Piaget, J. (1929). *The Child's Conception of the World*. NY: Harcourt, Brace Jovanovich.

Plowman, L. (1996a). Narrative, linearity and interactivity: making sense of interactive multimedia. *British Journal of Educational Technology, 27*(2), 92-105.

Reeves, T.C. (1999). A research agenda for interactive learning in the new millenium, in B. Collis & R. Oliver (Eds) *Proceedings of EdMedia 1999*. Charlottesville, VA: Association for the Advancement of Computing in Education.

Reigeluth, C. (1992). Elaborating the elaboration theory. *Educational Technology Research & Development, 40*(3), 80-86

Rogers, C.R. (1969). *Freedom to Learn*. Columbus, OH: Merrill.

Romiszowski, A.J. (1986). *Developing Auto-Instructional Materials*. London: Kogan Page.

Rose, E. (1999). Deconstructing interactivity in educational computing. *Educational Technology, 39*(1), 43-49.

Rumelhart, D. & Norman, D. (1978). Accretion, tuning and restructuring: Three modes of learning, in. J.W. Cotton & R. Klatzky (Eds), *Semantic Factors in Cognition*. Hillsdale, NJ: Erlbaum.

Salomon, G. (1979). *Interaction of Media, Cognition, and Learning*. San Francisco: Jossey-Bass.

Scandura, J.M. (1973). *Structural Learning I: Theory and Research*. London: Gordon & Breach.

Schoenfeld, A. (1985). *Mathematical Problem Solving*. New York: Academic Press.

Schank, R.C. (1982). *Dynamic Memory: A Theory of Reminding and Learning in Computers and People*. Cambridge University Press.

Schwier, R. & Misanchuk, E. (1993). *Interactive Multimedia Instruction*. Englewood Cliffs, NJ: Educational Technology Publications.

Sims, R. (1997). Interactivity: A Forgotten Art? *Computers in Human Behavior*, *13*(2), 157-180.

Sims, R. (1999). Interactivity and narrative: Strategies for effective learning, in B. Collis & R. Oliver (Eds) *Proceedings of*

EdMedia 1999. Charlottesville, VA: Association for the Advancement of Computing in Education.

Skinner, B.F. (1950). Are theories of learning necessary? *Psychological Review*, *57*(4), 193-216.

Spiro, R.J., Feltovich, P.J., Jacobson, M.J., & Coulson, R.L. (1992). Cognitive flexibility, constructivism and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. In T. Duffy & D. Jonassen (Eds.) *Constructivism and the Technology of Instruction*. Hillsdale, NJ:Erlbaum.

Sternberg, R.J. (1977). *Intelligence, Information Processing, and Analogical Reasoning*. Hillsdale, NJ: Erlbaum.

Sticht, T.G. (1976). Comprehending reading at work, in M. Just & P. Carpenter (Eds), *Cognitive Processes in Comprehension*. Hillsdale, NJ: Erlbaum.

Thorndike, E. (1913). *Educational Psychology: The Psychology of Learning*. New York: Teachers College Press.

Tolman, E.C. (1932). *Purposive Behavior in Animals and Men*. New York: Appleton-Century-Crofts.

Vygotsky, L.S. (1962). *Thought and Language*. Cambridge, MA: MIT Press.

Wertheimer, M. (1959). *Productive Thinking* (Enlarged Edition). New York: Harper & Row.