DOCUMENT RESUME

ED 466 185 IR 021 256

AUTHOR	Kennedy, David; McNaught, Carmel
TITLE	Computer-Based Cognitive Tools: Description and Design.
PUB DATE	2001-00-00
NOTE	7p.; In: ED-Media 2001 World Conference on Educational Multimedia, Hypermedia & Telecommunications. Proceedings (13th, Tampere, Finland, June 25-30, 2001); see IR 021 194.
AVAILABLE FROM	Association for the Advancement of Computing in Education (AACE), P.O. Box 2966, Charlottesville, VA 22902 ($40, AACE members; $50, nonmembers). Tel: 804-973-3987; Fax: 804-978-7449; Web site: http://www.aace.org.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Computer Assisted Instruction; Computer Graphics; Computer Oriented Programs; *Computer Software; Educational Resources; *Educational Technology; Foreign Countries; Graphs; Higher Education; *Instructional Materials
IDENTIFIERS	Australia

ABSTRACT

With computers, tangible tools are represented by the hardware (e.g., the central processing unit, scanners, and video display unit), while intangible tools are represented by the software. There is a special category of computer-based software tools (CBSTs) that have the potential to mediate cognitive processes--computer-based cognitive tools (CBCTs). Only a limited number of CBSTs have been designed specifically for educational purposes. It is the design of the educational environment, specifically the educational intent, that transforms student interactions with a CBST to that of a CBCT. Two examples of CBCTs are described. The Interactive Graphic Tool (IGT) facilitates on-screen sketching of graphs. Students receive qualitative feedback, may revise their articulation of graphical knowledge any number of times, and ultimately have access to expert answers for comparison and self-evaluation. The Text Analysis Object (TAO) also facilitates an iterative approach to knowledge construction. The TAO allows a student to type extended answers to questions, receive qualitative and limited summative feedback, and access to both expert and "good student answers" for comparison and self-evaluation. (Contains 15 references.) (Author/AEF)

Computer-based cognitive tools: Description and design

David Kennedy
Centre for Learning and Teaching Support
Monash University, Australia
david.kennedy@CeLTS.monash.edu.au

Carmel McNaught
Learning Technology Services
RMIT University, Australia
carmel.mcnaught@rmit.edu.au

Abstract: With computers, tangible tools are represented by the hardware (e.g., the central processing unit, scanners, and video display unit), while intangible tools are represented by software. There is a special category of computer-based software tools (CBSTs) that have the potential to mediate cognitive processes—computer-based cognitive tools (CBCTs). Only a limited number of CBSTs have been designed specifically for educational purposes. It is the design of the educational environment, specifically the educational intent, that transforms student interactions with a CBST to that of a CBCT. Two examples of CBCTs are described. The Interactive Graphing Tool (IGT) facilitates on-screen sketching of graphs. Students receive qualitative feedback, may revise their articulation of graphical knowledge any number of times, and ultimately, have access to expert answers for comparison and self-evaluation. The Text Analysis Object (TAO) also facilitates an iterative approach to knowledge construction. The TAO allows a student to type extended answers to questions, receive qualitative and limited summative feedback, and access to both expert and 'good student answers' for comparison and self-evaluation.

Tools, tangible and intangible

Traditionally, tools have been seen to be manifestations of human technology in the form of some physical object—an inclined plane (screw or wedge), pulleys (cranes), or cogs and gears (gear mechanisms on a bicycle), for example. The purpose of these tools was to enhance human physical power, strength and human capabilities. Examples of physical tools that support learning include the humble pen-and-paper or an abacus. In educational settings we must also consider intangible tools (e.g., language, or mathematical symbols) that support human learning and cognition.

Vygotsky (1978) proposed that learning required two mediational means—tangible tools (technical tools) and intangible tools or signs (semiotic tools). At Vygotsky's time of writing, technical tools were actual physical entities (as above), whereas semiotic tools were (and still are) the means by which cognitive functions are mediated. Examples include language, numbers, algebraic notation, mnemonic techniques, graphs and diagrams—most of which may be expressed in the form of media elements that are easily stored, retrieved, and manipulated by computers. With the advent of new technologies the definitions of tools and signs in modern times, has blurred—that is, computers have the ability to mediate cognitive processes. (Duffy & Cunningham, 1996, p. 180).

Computer-based software tools (CBSTs)

Computers combine aspects of physical tools (the hardware) and intangible tools (software). Computers are a means of storing, retrieving, displaying, and manipulating signs (e.g., language, graphs, and mathematical notation). In Figure 1 the distinction between tangible and intangible tools is represented, with particular reference to computer-based tools.

Figure 2 illustrates that CBSTs (e.g., word processors, spreadsheets, concept mapping software, authoring software, and computer programming languages) that facilitate interaction between the learner and various media elements (e.g., text, graphs, video, audio) in an appropriate educational context may also be used to support cognition. That is, some of these computer-based software tools may also function as computer-based cognitive tools.

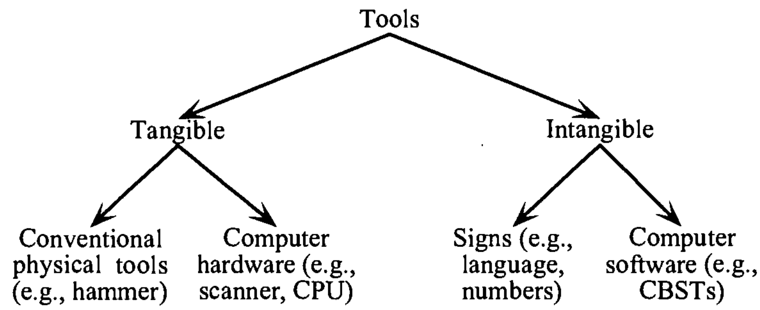

Figure 1: Tangible and intangible tools

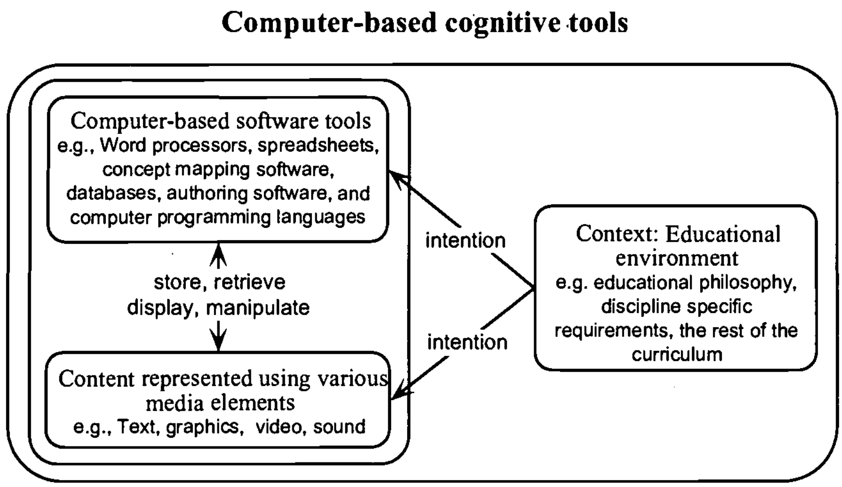

Figure 2: Computer-based cognitive tools

Computer-based cognitive tools (CBCTs)

What is a computer-based cognitive tool? In order to address this seemingly simple question, a number of interrelated issues need to be addressed including the:

- functional aspects of a CBCT;
- development of CBCTs (how do the pedagogical and functional issues influence their construction); and
- utilisation of CBCTs to the best effect.

The functional aspect concerns how students use CBCTs to mediate learning—are there any generalisable criteria (e.g., particular media elements or specific CBSTs)? The developmental perspective examines the software authoring tools used to create CBCTs—are some software authoring tools better for developing CBCTs, and/or integrating into courseware? The effective utilisation of CBCTs involves the concept of 'educational intention' or 'intent'.

A student who uses any cognitive tool effectively must necessarily engage (actively), think (deeply), and articulate their knowledge (Jonassen, 1994). In order to mediate cognition, a computer-based cognitive tool should:

- engage the student actively;
- support a deep approach to learning (thinking and reflection);
- provide support for a student to articulate her or his knowledge; and
- be embedded in an educational environment or context with a particular educational intent.

The key difference between a computer-based software tool and a computer-based cognitive tool is the educational intent or educational context. Thus, CBCTs are learning tools with which students communicate, articulate their thought processes, solve problems, engage in collaborative processes and think. CBCTs are also charged with instructional intent—the intent of the educational, or courseware designer. The computer is the storage, presentation, manipulation and creation device for various types of media—the technology that facilitates the use and function of a CBCT, and a part of the learning environment. The utilisation of the computer, CBCTs and media elements in order to achieve a particular set of student learning outcomes is influenced by the perspective of teaching and learning held by the educational designer. A CBCT may be thought of one component in the learning environment that requires computer-based media elements in order to support and enhance student learning.

The student constructs meaning by using the CBSTs in an educational context, by manipulating media elements from a particular content domain. Many CBSTs that by intent and educational context are utilised by a student as CBCTs may be described as generic tools. Examples of CBSTs that have become CBCTs by inclusion in a particular learning environment/ context are provided in Table 1.

Table 1: Examples of CBSTs in educational contexts as CBCTs

CBSTs as CBCTs	Educational context
databases	Used by students to develop case-studies and build clinical reasoning skills in veterinary microbiology (McNaught, Whithear & Browning, 1994).
spreadsheets	As part of a course teaching statistics to engineering students (Spedding, 1998).
concept mapping tools	Students and academics use a concept mapping software (Helfgott, Shankland, Stafford & Samson, 1997) tool to organise, plan, and display concepts in chemistry (Kennedy & McNaught, 1997).
software tools for developing semantic relationships	The use of Nud*ist for qualitative analysis of transcription (interview) data in educational evaluation (Gahan & Hannibal, 1998).
computer programming languages	The computer programming language, Logo has been used widely in primary schools to support a wide range of student learning styles by the creation of personal media (Papert, 1993).

The focus of this paper is not about the cognitive or metacognitive strategies intrinsic to the learner—but the external tools that extend and enhance their thinking processes. People do not learn from computers any more than they learn from a CBCT. The potential is there for people to learn *with* a CBCT. An example is a calculator. It is only using the calculator software (a CBST) in an appropriate context, with intent (motivation) that understanding can be arrived at. A student may use a calculator to find the logarithm of a number with little understanding of what a logarithm represents. However, the use of the same CBST in a chemistry class to explore the effects of small changes in the value of pH in a solution (the acidity or concentration of the hydrogen ions in a solution is defined as $-\log_{10}[H^+]$) is using the calculator software as a cognitive tool.

Computer-based cognitive tools can facilitate problem-solving by providing tools to access, manipulate and structure data from large, customisable, subject databases (Whithear, Browning, Brightling & McNaught, 1994). Carefully designed CBCTs can scaffold learning by modelling complex environments or expert problem-solving strategies. Computer-based cognitive tools can also provide relevant context-sensitive feedback by requiring a student to externalise (articulate, report, discuss, think-aloud) what are very often, internal processes (Collins, Brown & Newman, 1989).

Many examples of computer-facilitated learning environments have a variety of CBCTs integrated within the software. *Exploring the Nardoo* (an award-winning CD-Rom) has been developed using a synthesis of the ideas from 'constructivist learning environments, situated learning and problem-based learning in rich information landscapes to form the basis for effective design' (Harper & Hedberg, 1997, p. 14). The Nardoo provides an interface with access to number of very detailed databases of content. The databases contain plant and animal descriptions, pre-determined values of measures of water quality (e.g., nitrogen, oxygen, phosphorous, water turbidity), procedural knowledge, a number of presentation genres for knowledge construction and presentation—accessed by the student using a variety of CBCTs and supported by access to multiple forms of media. There are a number of CBCTs embedded in, and fundamental to, the Nardoo software. They include:

- three student-controlled simulators;

- a number of genre writing templates for students to structure their notes and presentations of findings; and
- a 'text tablet'.

Principles of successful use of CBCTs

CBCTs must be incorporated into a well-structured CFL environment that does not impose high cognitive demands by virtue of a complex user interface. Students will then be better able to engage in higher order thinking processes involving reflection, synthesis and analysis.

Computer-based cognitive tools are software constructions that:
- are simple for students to use;
- function best in a constructivist learning environment;
- provide the opportunity for students to address meaningful questions in a realistic context and receive appropriate and timely feedback;
- encourage students to 'take on' the ownership of their own learning;
- off-load basic cognitive demands while the learner focuses on higher level processes;
- facilitate the development of deeper and richer knowledge structures;
- facilitate collaborative and negotiative learning experiences that provide opportunities for students to explore, test, and validate their conceptions; and
- are unintelligent tools (unlike those claimed by intelligent tutoring systems) that facilitate a dialogue between teachers and learners and feedback appropriate to the task.

(after Duffy & Cunningham, 1996, p. 187 & Jonassen & Reeves, 1996, p. 698)

In addition, CBCTs extend some of the characteristics above through their facility to offer intrinsically different representations or views of data and/or phenomena not possible through other means and hence provide new understandings (e.g., powerful user-controlled visual simulations to make abstract concepts more visible).

Computer-based cognitive tools are not intended to make the task easier, or reduce information processing (Jonassen, 1994). In the evaluation of the two CBCTs briefly described here students have (sometimes grudgingly) admitted that a CBCT (e.g., the interactive graphing tool) required them to work harder for the answer. The students also thought this was 'probably better' for them because they couldn't simply click on an answer provided by the lecturer. Using CBCTs requires a student to:
- analyse and compare different representations of content (which may be in different forms of media elements);
- construct, refine and represent mental models; and
- articulate her or his understanding in some meaningful way.

Using CBCTs is not a 'free ride', it is demanding, challenging, and basically hard work. The following two examples briefly illustrate the relationship between media elements, instructional intent, and computer-based cognitive tools. The references provide more complete descriptions.

Cognitive tools in action: Two examples

The Interactive Graphing Tool (IGT) is intended to overcome some of the criticisms of static or animated versions of graphical knowledge. Instead, the IGT requires students to sketch a graph on screen, using the mouse as a drawing tool, and can respond to a wide range of common graph types including logarithmic, exponentials, curves, and straight lines. The IGT facilitates an iterative approach to articulating and understanding graphical representations of knowledge by actively involving students in the construction of these representations, and providing customisable (by the academic) multiple responses for more appropriate feedback (Kennedy & Fritze, 1998). Students receive qualitative feedback, may revise their articulation of graphical knowledge any number of times, and ultimately, have access to expert answers for comparison and self-evaluation. Figure 3 shows both the steps required for teachers to use the IGT, and also how the IGT responds to student input. The IGT has been evaluated in the teaching of kinetics in chemistry.

Another CBCT is the Text Analysis Object (TAO). The TAO facilitates the development of text-based extended question-and-answer problems. The design of the TAO focused upon developing a learning tool that facilitates extended answer/ short answer questions. Using the TAO, a student is able to generate a more meaningful answer by articulating her or his understanding, rather than merely recognising the lecturer's representation of the knowledge, as in multiple-choice questions. The TAO has been designed to support an iterative approach to knowledge construction by requiring a student to type an answer to a question into a text field, submit the answer for checking by a software algorithm, and then receive meaningful feedback. The student then has the opportunity to refine her or his answer a number of times, each time receiving feedback. Feedback provided by

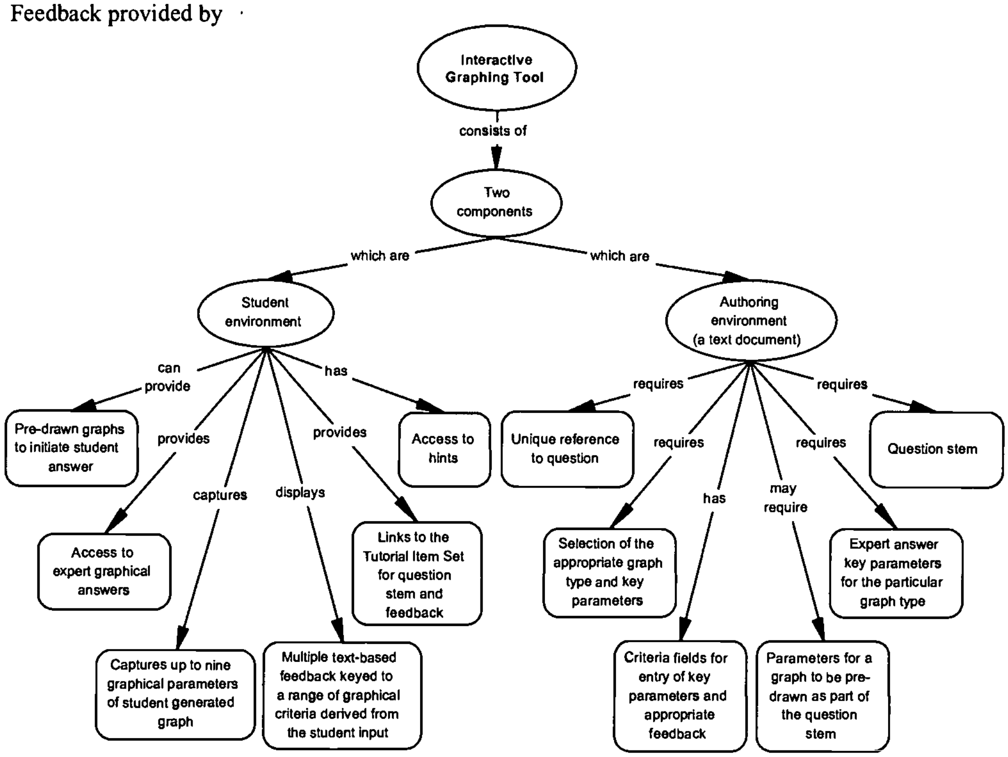

Figure 3: The functionality of the IGT

the TAO software engine to the student is determined by using a key word and key phrase search of the text entered by the student. The TAO software engine/ software algorithm has been designed to utilise a two-tiered, hierarchical feedback mechanism—distinguishing between concepts (major ideas or principles) and details (generally factual knowledge) in providing feedback to students (Kennedy, Ip, Adams & Eizenberg, 1999). Academic staff provide the information about concepts and details that the TAO engine uses in providing feedback to students. This is time consuming but valuable if the work is seen as a way of progressively building up effective learning resources. The TAO has been evaluated in the teaching of anatomy to medical students.

References

Collins, A., Brown, J. S. & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honour of Robert Glaser* (pp. 453-495). Hillsdale, NJ: Lawrence Erlbaum Associates.

Duffy, T. M. & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 170-198). New York: Simon & Schuster Macmillan.

Gahan, C. & Hannibal, M. (1998). *Doing qualitative research using QSR NUD*IST.* London: Sage Publications.

Harper, B. & Hedberg, J. (1997). Creating motivating interactive learning environments: A constructivist view. In R. Kevill, R. Oliver & R. Phillips (Eds), *What works and why, ASCILITE'97.* Proceedings of the Australian Society for Computers in Learning in Tertiary Education (ASCILITE) Annual Conference (pp. 11-31). Curtin University of Technology, Perth: Academic Computing Services.

Helfgott, D., Shankland, J., Stafford, J. & Samson, T. (1997). *Inspiration* (Version 5.0) [Software]. Portland, Oregon: Inspiration Software Inc. <http://www.inspiration.com/>

Jonassen, D. (1994, First published and discussed on ITForum from May 2 to June 1, 1994). *Technology as cognitive tools: Learners as designers.* <http://129.7.160.78/intro.html>. ITForum.

Jonassen, D., H. & Reeves, T., C. (1996). Learning *with* technology: Using computers as cognitive tools. In D. Jonassen, H. (Ed.), *Handbook of research on educational communications and technology* (pp. 693-719). New York: Macmillan.

Kennedy, D. M. & Fritze, P. (1998). An Interactive Graphing Tool for web-based courses. In T. Ottmann & I. Tomek (Eds), *ED-MEDIA & ED-TELECOM 98.* Proceedings of the 10th World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications (pp. 703-708). Freiburg, Germany: Association for the Advancement of Computing in Education.

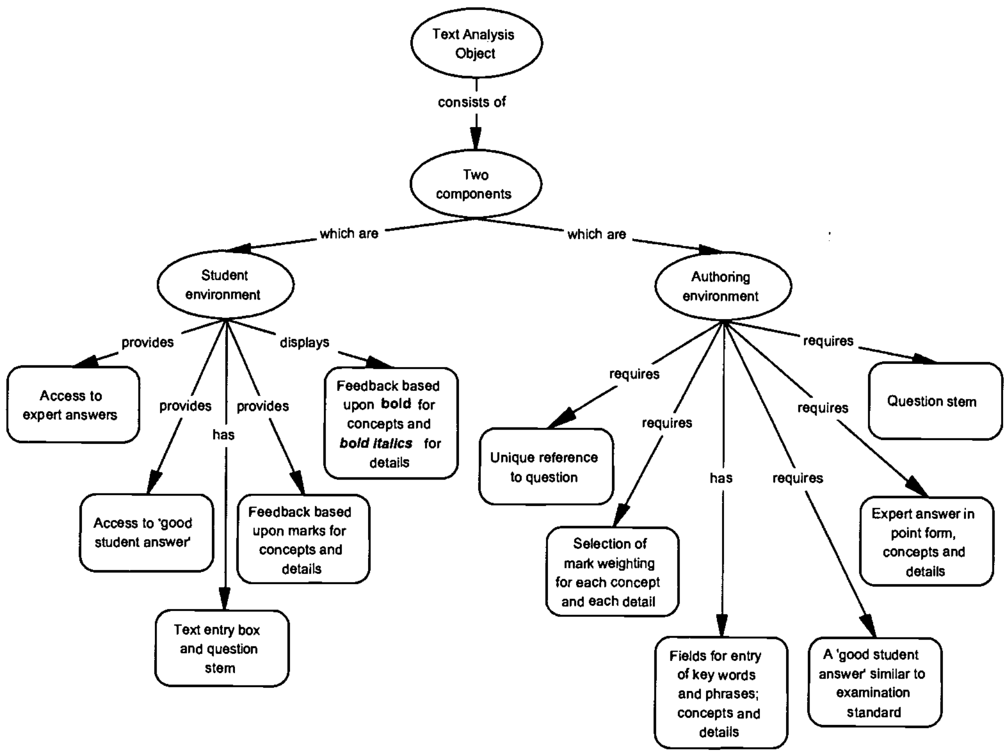

Figure 4: The functionality of the TAO

Kennedy, D. M., Ip, A., Adams, C. & Eizenberg, N. (1999). Developing generic interactive learning tools to engage students: The Text Analysis Object for web and CD-Rom. In B. Collis & R. Oliver (Eds), *ED-MEDIA & ED-TELECOM 99.* Proceedings of the 11th World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications (pp. 558-563). Seattle, USA: Association for the Advancement of Computing in Education.

Kennedy, D. M. & McNaught, C. (1997). Use of concept mapping in the design of learning tools for interactive multimedia. *Journal of Interactive Learning Research, 8*(3/4), 389-406.

McNaught, C., Whithear, K. & Browning, G. (1994). The role of evaluation in curriculum design and innovation: A case study of computer-based approach to teaching veterinary systematic bacteriology and mycology. In K. Beattie, C. McNaught & S. Wills (Eds), *Interactive multimedia in university education: Designing for change in teaching and learning* (Vol. A-59, pp. 295-307). Amsterdam: Elsevier Science B. V. (North-Holland).

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer.* New York: BasicBooks.

Spedding, T. A. (1998). Teaching statistics to engineers – Towards developing a multimedia teaching environment. In T. Ottmann & I. Tomek (Eds), *ED-MEDIA & ED-TELECOM 98.* Proceedings of the 10th World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications (pp. 1379-1384). Freiburg, Germany: Association for the Advancement of Computing in Education.

Vygotsky, L. (1978). *Mind in society.* Cambridge, MA: Harvard University Press.

Whithear, K. G., Browning, G. F., Brightling, P. & McNaught, C. (1994). Veterinary education in the era of information technology. *Australian Veterinary Journal, 71*(4), 106-108.

NOTICE

Reproduction Basis

☒ This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").