DOCUMENT RESUME

ED 423 299 TM 029 106

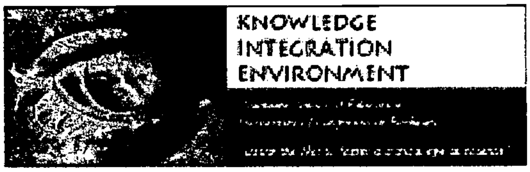
AUTHOR	Cuthbert, Alex; Hoadley, Christopher M.
TITLE	Designing Desert Houses in the Knowledge Integration Environment.
SPONS AGENCY	National Science Foundation, Arlington, VA.
PUB DATE	1998-04-00
NOTE	8p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Diego, CA, April 13-17, 1998). For related paper, see TM 029 107.
CONTRACT	RED-9453861
PUB TYPE	Reports - Descriptive (141) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Cooperation; *Criteria; *Design; Intermediate Grades; Junior High Schools; Middle Schools; *Problem Solving; *Science Instruction; Thermodynamics
IDENTIFIERS	*Knowledge Integration Environment; Middle School Students; *Scaffolding

ABSTRACT

This paper presents a synthesis of several studies that support the hypothesis that properly scaffolded design problems lead to the types of convergent thinking and knowledge integration that have been difficult to achieve in the Computer Supported Intentional Learning Environment (CSILE) system. The focus is on a middle school science unit on thermodynamics in which students design a desert house. How design problems contribute to knowledge integration is considered. Design problems are a unique class of problems that require students to elaborate on the initial task, develop constraints, and select justifiable solutions paths. Most of the complex work in engineering, multimedia design, composition, programming, and, to some extent, scientific investigation can be classified as design. The three themes outlined in this paper: (1) providing appropriate resources; (2) developing shared criteria; and (3) encouraging iterative refinement, serve as guidelines for educators and researchers seeking to develop design-based curricula for science education. The challenge for educators is to design environments in which students can coordinate different levels of description along with strategies and criteria for evaluating solutions. (Contains 4 figures and 15 references.) (Author/SLD)

Running Head: DESIGNING DESERT HOUSES

Designing Desert Houses In The Knowledge Integration Environment



Alex Cuthbert & Christopher M. Hoadley
University of California at Berkeley
4533 Tolman Hall #1670, Berkeley CA 94720-1670
(510) 642-9717 voice, (510) 642-3769 fax
alx@socrates.berkeley.edu, tophe@cs.berkeley.edu

Abstract

How can design problems contribute to knowledge integration? Design problems are a unique class of problems which require students to elaborate upon the initial task, develop constraints, and select justifiable solutions paths (Goel, 1995.) Most of the complex work in engineering, multimedia design, composition, programming, and, to some extent, scientific investigation can be classified as design. The three themes outlined in this paper, (a) providing appropriate resources, (b) developing shared criteria, and (c) encouraging iterative refinement, serve as guidelines for educators and researchers seeking to develop design-based curriculum for science education. The challenge for educators is to design environments in which students can coordinate different levels of description along with strategies and criteria for evaluating solutions.

The design of this research has been a cooperative effort of the KIE research group. We would like to acknowledge the contributions of the members of this group: Steve Adams, Flavio Azevedo, Phil Bell, Doug Clark, Betsy Davis, Chris Hoadley, Sherry Hsi, Doug Kirkpatrick, Brian Levey, Marcia Linn, Jim Slotta, Judy Stern, Ricky Tang, and Laura Telep. This material is based upon research supported by the National Science Foundation under grant RED-9453861. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

Correspondence concerning this article should be addressed to Alex Cuthbert, Education in Mathematics, Science, & Technology (EMST), Graduate School of Education, 4533 Tolman Hall #1670, University of California, Berkeley, Berkeley, CA 94720-1670. Electronic mail may be sent via Internet to alx@socrates.berkeley.edu.

Paper presented at the Annual Meeting of the American Educational Research Association, April, 1998, San Diego, CA. Available from the authors or ERIC.

The focus of many prominent educational researchers in the past two decades has been to develop methods for encouraging students to formulate questions to guide their own learning activities (Brown, 1992; Scardamalia & Bereiter, 1991; Chi, 1989; Linn, 1995). Intentional learning environments like CSILE, where students direct their own work with the help of collaborative software, developed out of earlier research on reciprocal teaching and metacognition (Brown & Palinscar, 1989). Scardamalia and Bereiter's investigations with CSILE highlighted the need to examine the levels of agency in knowledge building, or more specifically the levels of autonomy given to students in question-asking activities.

The idea that students can take control of their learning processes captivated educators working within a social-cultural framework as well as those aligning themselves with the under-specified tenets of constructivism. The ability of students to enhance their knowledge and understanding through a dialectical process of question-generation and self-explanation prompted researchers to formulate methods for encouraging this knowledge-building process. The most common approach was to develop ways of making the learning process visible for students (Gomez, Pea, et. al., 1995; Pea, 1994).

One such idea, the creation of student-generated community knowledge bases, attempted to make metacognitive activities visible by making them publicly-accessible (Scardamalia & Bereiter, 1991; Edelson & O'Neill, 1994). Difficulty with getting students to contribute productively to these systems (and, for that matter, other open-ended computational mediums like Logo and Boxer) was incorrectly assigned to the lack of initial content in these environments. For example, use of procedural guidance, templates and libraries, even reflective prompts was not enough, in many cases, to scaffold students so that they could contribute productively without substantial help from teachers (or armies of graduate students.) So while stunning examples of "learning" emerged from research labs, teachers had difficulty with these projects because of a variety of interrelated factors including difficulty structuring problems, student's lack of ownership of the work, and a lack of context-sensitive guidance.

The theoretical focus on cognitive and epistemological issues moved so far from the "learning as a by-product of work" model that, initially, many students and teachers had difficulty with the abstract nature of the knowledge-building activities offered by these new learning environments. The questions of the benefits of collaborative versus autonomous work became sidelined as logistical issues and assessment problems arose.

Perhaps the most intriguing and overlooked finding was the ability of students to generate "divergent" process of knowledge building (e.g., generating questions and hypotheses) (Scardamalia & Bereiter, p.63). This capability contrasted with the difficulties students had with the "convergent" processes of developing constraints and formulating coherent arguments. The need for some organizing structure lead CSILE's designers to adopt an approach where social arrangements were orchestrated. This social approach contrasted with the task analysis model which the intelligent tutoring systems had pursued successfully for a limited class of problems. The idea here was that elaboration and decomposition would happen spontaneously, given the correct social arrangements. This approach contributed to more equitable levels of participation in addition to making the connections between student work visible.

The Challenge. If students have trouble with convergent processes, how can we help them develop constraints and formulate coherent arguments? To address this challenge, we present a synthesis of several studies which support the hypothesis that properly scaffolded design problems lead to the types of convergent thinking and knowledge integration that were difficult to achieve in CSILE.

What Are Design Problems? Typically, design problems are characterized by their ill-structured nature, the need for iterative refinement of solutions, and the lack of obvious transitions to achieve solutions. Most engineering problems, software design, architecture, and composition tasks all fall under the heading of "design". Within design, calculations, measurements, and other problem solving skills come into play. However, design problems are unique in that success is measured by the fit between the design criteria and the solution. Convincing people that your design is good is not as simple as providing a proof, equation, or even a piece of supporting evidence, though frequently these justifications are assembled. Rather, argumentation, negotiation, and the application of design criteria are required to convince people that a design solution is viable. This process is necessary because design problems typically do not have a single "right" answer. And it is this process of justification, of coordinating multiple perspectives, which contributes to, and in some sense defines, knowledge integration.

The nature of design problems lends them to the type of refinement we seek to encourage. The challenge for educators is to create environments in which students can develop a repertoire of models for evaluating solutions (Linn, 1995). Simply, providing forums for the exchange of ideas and resources is not enough. To help students approach open-ended problems, we need to help them develop strategies and criteria by modeling the process of design. In our work, we achieve this goal using representations which link people, resources, design issues, justifications, and principles. This type of social representation is compelling and memorable for students in addition to providing them with a general framework for approaching complex problems.

The Knowledge Integration Environment. KIE provides an ideal context for design problems by integrating a number of custom tools with an Internet browser and help facility. KIE is designed for use as part of a middle school science curriculum focusing on thermodynamics. Using KIE, students engage in theory comparison, design, and critique activities. Students develop specifications for their house designs, drawing on laboratory work from earlier in the semester. Through the course of the two week house design activity, they refine their initial designs and their associated explanations of the factors affecting heat flow[1]. The final reports include sketches of the house designs along with details about building materials, color, orientation, windows, roofing, and heat flow during different times of the day. An on-line peer review/pin-up process helps students refine these final reports along with giving them a chance to exhibit their work.

---

[1] For more detailed information on KIE, see Bell, Davis, & Linn, 1995.

Paper presented at the Annual Meeting of the American Educational Research Association, April, 1998, San Diego, CA. Available from the authors or ERIC.

Providing Appropriate Resources. We would like students to develop an elaborated problem definition and then formulate constraints to narrow their options. However, the initial examples which students see constrain their process of design at the very point when we want to encourage a broader problem definition. For example, the pilot study for Houses In The Desert compared a mud, straw, and brick house to help students focus on the insulating value of various materials. Not surprisingly, many students created dome-shaped mud houses. Later iterations used more schematic examples in an attempt to provide conceptual rather than concrete models. Finally, we found that requiring students to merge their design with their partner's lead to more principled evaluation of alternatives and a wider range of original designs. This approach balances the development of constraints with the need for an expanded problem definition.

To familiarize students with the general issues, our approach has been to use carefully selected sites which focus on scientific principles. Then students can search the design library for evidence to support specific aspects of their house design. The library contains examples of different components of the house (e.g., insulation, windows, roofing) along with annotations describing how the site relates to the heating and cooling issues of the house design problem.

A Case For Design Libraries

We provide both a common set of evidence for the class along with a library of design resources. The common set of evidence creates a shared body of information which the teacher and students can refer to in discussions. The KIE Design Library, on the other hand, is searchable by keyword and small enough to be browsed by topic. Searching through the bounded space of the Design Library prepares students to explore the more unstructured Internet and add their own content to the library in a more reflective and informed manner.

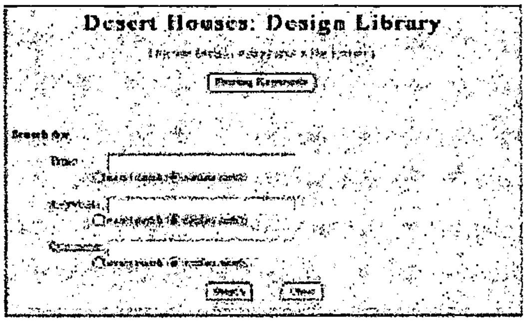


Figure 1. Design Library Search Form

From a guidance perspective, the Design Library models the process of searching for and critiquing evidence by providing queries used to locate the site, annotations of the scientific material, and links to design strategies supported by the evidence. In fact, we created the categories for the library using design components generated by students in previous experimental runs. Since these resources relate to specific components of the problem (e.g., building materials, windows, etc.), it is easier for students to link pieces of evidence to sections in their final design report.

Developing Shared Criteria. Peer review and collaboration are the most productive when students have common metrics for critiquing each other's work. Evaluating design problems is difficult without shared criteria, given the range of possible solutions. For educators, developing shared criteria is a particularly challenging goal because it requires students to articulate implicit methods of evaluation. Our research suggests that students need help structuring open-ended problems if they are to develop explicit criteria for evaluating solutions. Development of this criteria involves both self-explanation and abstraction and frequently occurs through exposure to case studies, templates, and narratives. To some extent, the design library helps students decompose and structure the problem. However, we found that students have trouble developing coherent strategies for approaching open-ended problems in much the same way that they have trouble with the convergent processes of composition.

One reason for this difficulty is that criteria for solving open-ended design problems emerge as constraints and resources are assembled in support of different positions and solutions paths. Investigating the ways in which workspaces are reconfigured and resources assembled (Hall, 1996) can provide insights into the ways in which shared criteria develop within different communities.

Modeling Design Strategies

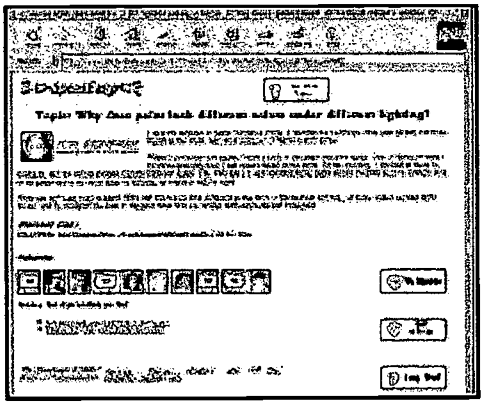
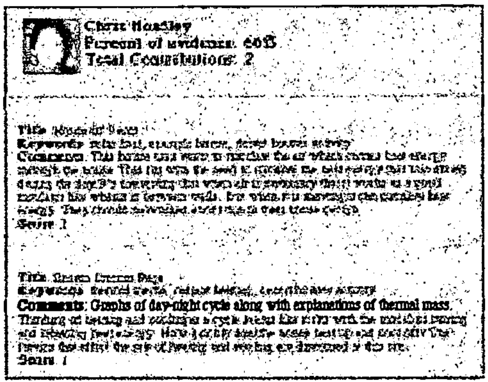


Figure 1. SpeakEasy Discussion



Total Contributions: 2

Comments: Graphs of day-night cycle along with explanations of thermal mass.

Figure 2. Design Library: Visualize Seeded Contributions

To help students identify different positions and solution paths, we used the SpeakEasy discussion tool to model two distinct design strategies: insulation versus heat storage and ventilation. SpeakEasy provides a framework for scientific argumentation, incorporating social information such as the pictures of the various discussants. Seeding a discussion with comments reflecting two distinct design strategies (insulate versus store and release heat energy) helps students structure the house design problem (see Fredericksen & White, 1997, for a similar approach). These strategies are mirrored in the contributions to the Design Library, reinforcing the perspectives developed in the SpeakEasy discussion. The result was an increase in the number of students using the more complex heat capacity strategy as compared with previous semesters.

<u>Encouraging Iterative Refinement.</u> Frequently, students decide on an approach early on and consider themselves "done". This type of design fixation is a well-documented challenge for educators using project-based learning. To address this problem, we measured the effects of several approaches for encouraging iterative refinement and creating stable representations of the problem (see Cuthbert & Hoadley, in press).

Revising & Merging Initial Designs

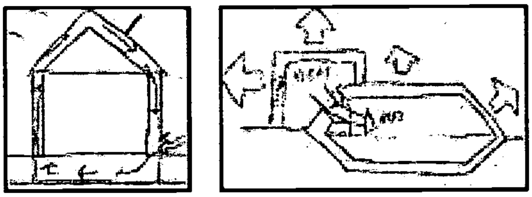


Figure 3a. Initial Designs

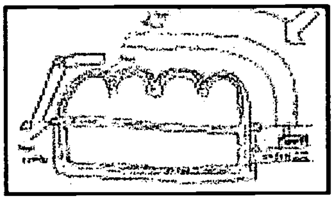


Figure 3b. Final Design

Students begin the house design activity by elaborating upon the problem statement and creating sketches of their own individual house designs. In Figure 3, students enhanced their initial designs, moderating the heating effects of direct sunlight. The retractable house cover lets the sunlight heat up the passive solar tanks on the roof during the afternoon. The heated water is circulated through the basement to create radiant heat throughout the night. In their final report, the students used principles from the lab "Sunlight-SunHeat" in conjunction with Internet evidence about thermal mass.

Analysis and self-critique are uncommon activities for students who are used to producing an answer and having it accepted or rejected. The iterative nature of design problems can encourage reflective, critical thinking, and knowledge integration through self-critique and peer review.

Heat Flow Analysis

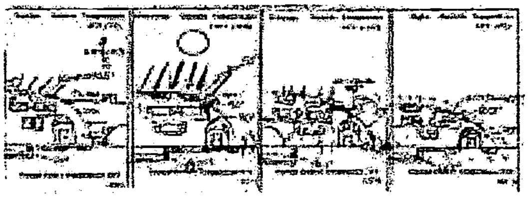


Figure 4. Heat Flow Drawings

For example, the house design project includes a "heat flow analysis" worksheet where students describe the factors influencing heat flow at different times of day. Students draw heat flow arrows and use principles to justify the direction they claim heat is flowing. The size of the arrows is relative to the rate of heat flow.

In addition to helping students develop a functional, multi-faceted representation of heat flow, this worksheet helps them reflect upon the relationship between the components of the problem (i.e., sunlight, ground, dwelling, and surround.)

Paper presented at the Annual Meeting of the American Educational Research Association, April, 1998, San Diego, CA. Available from the authors or ERIC.

Implications

Situations addressed by design problems are frequently part of a dynamic system with interrelated components and identifiable dependencies. Helping students understand these dependencies can greatly aid them in approaching design problems. For example, in the house design problem, the surfaces (ground, dwelling, etc.) are all effected by the angle and intensity of the sunlight. The factors which determine the relative temperatures of these materials are complex but uniform in nature (e.g., reflectivity, conductivity, contact with other materials, etc.) Students can identify these factors by independently examining pieces of evidence or through interaction with their teacher and peers.

Our assessments must reflect these requirements and measure students' ability to interrelate different elements of a problem. We can look at students explanations in terms of their ability to describe heat flow using principles, everyday experiences, and references to laboratory work. One promising path for this type of evaluation is to look at the types of comments generated during the peer review process. A student's ability to productively critique a solution which is different from their own requires perspective taking abilities which, we believe, are indicative of knowledge integration.

KIE helps students construct this interwoven situation model by providing social supports in the form of collaborative tools and discussion spaces. In addition, the categories for the design library map onto the components found in student designs, helping make the process of decomposing the task visible for students. Similarly, we facilitate the process of developing shared criteria by providing appropriate resources linked to design strategies. The challenge is making this criteria visible for students. By encouraging analysis and refinement, we can highlight the need for criteria. This need becomes critical when students critique each other's work, merge their initial designs, and consider alternative solution paths.

Suggestions for questions to ask the panel:

1. How does your approach encourage students to refine their ideas?
2. How does your environment maintain a stable representation of student perspectives?
3. How can design problems complement laboratory work?

References

Bell, P., Davis, E. A., & Linn, M. C. (1995). *The knowledge integration environment: theory and design.* U.C. Berkeley.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, 2(2), 141-178.

Brown, A. L. & Palinscar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.), Knowing, Learning, and Instruction. Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Lewis, M.W., Reimann, P., & Glaser, R. (1989). Self-Explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.

Cuthbert, A. & Hoadley, C. (1998) Using KIE to help students develop shared criteria for house designs. Proceedings of the *Annual Meeting of the American Educational Research Association*, San Diego, CA.

Cuthbert, A., Bell, P., Hoadley, C. (1997). Tracking activity patterns in on-line environments: Implications for instructional design. Proceedings of the *7th International Conference on Human-Computer Interaction (HCI)*, San Francisco: CA.

Edelson, D. C. and K. O'Neill (1994). The CoVis Collaboratory Notebook: Computer Support for Scientific Inquiry. The *Annual Meeting of the American Educational Research Association*, New Orleans, LA, April.

Fredericksen, John R. & White, Barbara Y. (1997) Cognitive facilitation: a method for promoting reflective collaboration. In R. Hall, N. Miyake, & N. Enyedy (Eds.) Proceedings of *Computer Support for Collaborative Learning 1997*, pp. 53-62.

Goel, V. (1995). *Sketches of Thought.* MIT Press.

Gomez, L., Pea, R., Edelson, D., D'Amico, L., Fishman, B., Gordon, D., McGee, S., O'Neill, K., & Polman, J. (1995). The Learning through Collaborative Visualization Project. Proceedings of the *Annual meeting of the American Educational Research Association*, San Francisco, CA.

Hall, R. (1996). Representation as shared activity: Situated cognition and Dewey's cartography of experience. The Journal of the Learning Sciences.

Linn, M. C. (1995). Designing computer learning environments for engineering and computer science: The Scaffolded Knowledge Integration Framework. *Journal of Science Education and Technology.*

Pea, R. (1994). Seeing What we build together: Distributed Multimedia Learning Environments for Transformative Communication. *The Journal of the Learning Sciences* 3(3): 285-299.

Scardamalia, M. & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *The Journal of the Learning Sciences* (pp. 37-68), Lawrence Erlbaum Associates, Inc.

Paper presented at the Annual Meeting of the American Educational Research Association, April, 1998, San Diego, CA. Available from the authors or ERIC.

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

ERIC®

TM029106

REPRODUCTION RELEASE

(Specific Document)

I. DOCUMENT IDENTIFICATION:

Title: Designing Desert Houses in the Knowledge Integration Environment

Author(s): Alex Cuthbert and Christopher M. Hoadley

Corporate Source:

Publication Date: 4/98

II. REPRODUCTION RELEASE:

In order to disseminate as widely as possible timely and significant materials of interest to the educational community, documents announced in the monthly abstract journal of the ERIC system, *Resources in Education* (RIE), are usually made available to users in microfiche, reproduced paper copy, and electronic media, and sold through the ERIC Document Reproduction Service (EDRS). Credit is given to the source of each document, and, if reproduction release is granted, one of the following notices is affixed to the document.

If permission is granted to reproduce and disseminate the identified document, please CHECK ONE of the following three options and sign at the bottom of the page.

The sample sticker shown below will be affixed to all Level 1 documents	The sample sticker shown below will be affixed to all Level 2A documents	The sample sticker shown below will be affixed to all Level 2B documents
PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 1	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE, AND IN ELECTRONIC MEDIA FOR ERIC COLLECTION SUBSCRIBERS ONLY, HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2A	PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY Sample TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC) 2B
Level 1	Level 2A	Level 2B
☒	☐	☐
Check here for Level 1 release, permitting reproduction and dissemination in microfiche or other ERIC archival media (e.g., electronic) *and* paper copy.	Check here for Level 2A release, permitting reproduction and dissemination in microfiche and in electronic media for ERIC archival collection subscribers only	Check here for Level 2B release, permitting reproduction and dissemination in microfiche only

Documents will be processed as indicated provided reproduction quality permits.
If permission to reproduce is granted, but no box is checked, documents will be processed at Level 1.

I hereby grant to the Educational Resources Information Center (ERIC) nonexclusive permission to reproduce and disseminate this document as indicated above. Reproduction from the ERIC microfiche or electronic media by persons other than ERIC employees and its system contractors requires permission from the copyright holder. Exception is made for non-profit reproduction by libraries and other service agencies to satisfy information needs of educators in response to discrete inquiries.

Sign here,→ please

Signature: Christopher Hoadley

Printed Name/Position/Title: Alex Cuthbert and Christopher M. Hoadley

Organization/Address:
4533 Tolman Hall #1670
University of California at Berkeley
Berkeley CA 94720-1670

Telephone: (510) 642-9717

FAX: (510) 642-3769

E-Mail Address: alx@socrates.berkeley.edu

Date: 5/23/98

(over)

III. DOCUMENT AVAILABILITY INFORMATION (FROM NON-ERIC SOURCE):

If permission to reproduce is not granted to ERIC, or, if you wish ERIC to cite the availability of the document from another source, please provide the following information regarding the availability of the document. (ERIC will not announce a document unless it is publicly available, and a dependable source can be specified. Contributors should also be aware that ERIC selection criteria are significantly more stringent for documents that cannot be made available through EDRS.)

Publisher/Distributor:

Address:

Price:

IV. REFERRAL OF ERIC TO COPYRIGHT/REPRODUCTION RIGHTS HOLDER:

If the right to grant this reproduction release is held by someone other than the addressee, please provide the appropriate name and address:

Name:

Address:

V. WHERE TO SEND THIS FORM:

Send this form to the following ERIC Clearinghouse:

However, if solicited by the ERIC Facility, or if making an unsolicited contribution to ERIC, return this form (and the document being contributed) to:

ERIC Processing and Reference Facility
1100 West Street, 2nd Floor
Laurel, Maryland 20707-3598

Telephone: 301-497-4080
Toll Free: 800-799-3742
FAX: 301-953-0263
e-mail: ericfac@inet.ed.gov
WWW: http://ericfac.piccard.csc.com

EFF-088 (Rev. 9/97)
PREVIOUS VERSIONS OF THIS FORM ARE OBSOLETE