J. EDUCATIONAL COMPUTING RESEARCH, Vol. 7(2) 121-164, 1991

SYNTHESIZING INSTRUCTIONAL TECHNOLOGIES AND EDUCATIONAL CULTURE: EXPLORING COGNITION AND METACOGNITION IN THE SOCIAL STUDIES*

DEVIN G. THORNBURG
Adelphi University

ROY D. PEA
Institute for Research on Learning

ABSTRACT

This research was initiated to examine instructional technologies and educational cultures in relation to identified cognitive and metacognitive strategies used in school tasks. The project involved activities from the social studies curricula that were presented through two new software programs intended to support the development of problem-solving and reasoning strategies—IDEA [Interactive Decision Envisioning Aid, Pea (76)] and Notecards (34)—and through instructional approaches based upon "cognitive apprenticeship" views of learning [Collins, Brown, and Duguid (36)]. After piloting the project, ten high school juniors participated in instruction with these technologies and redesigned methods, composing essays about their selection of arguments about a candidate for U.S. President and about a "most important social issue." Essays about these topics written prior, during and after the project were collected and analyzed for their reasoning, using the work of Toulmin (40) and Hillocks (46). In addition, the ongoing interactions of the students with the instructional technologies were recorded and analyzed to assess their cognitive and metacognitive strategies as they occurred. Quantitative analyses revealed significant ($p < .05$) increases in the "breadth" and "depth" of students' reasoning in the "presidential candidate" essays as a result of the project (independently of the presented knowledge base), but little or no improvement in their reasoning in the "issue" essays (intended as transfer tasks). Data collected from students' ongoing use of the technologies is also analyzed and reported, including positive correlations (Rho = .68, Rho = .78) between written reasoning and interactions with the "executive

*This work was partially supported by funding from the Spencer Foundation, and parts of it were presented at the annual meeting of the American Educational Research Association, March 1989.

control" functions of the software programs. These results, as well as qualitative findings, are discussed in relation to recent literature about cognition and learning with instructional technologies.

INTRODUCTION

There has been, over the years and from many disciplines, considerable speculation about the impact of computer technology on human consciousness [1-3]. These discussions are the clear offspring of a more general body of literature examining the influences of technological changes on a given culture's forms of communication and thought [4, 5]. Following the cross-cultural research of Cole and his associates [6-8], our investigation assumed that computer technologies used within the classroom setting involve a "recurrent, goal-directed sequence of activities . . . for specific purposes in specific contexts of use" [8, p. 236]. Practice involving these activities requires changes in the educational culture as well, influencing the types of cognition developed and used [6, 9]. Our research was initiated to examine instructional technologies and educational culture in relation to cognition—particularly those forms of thought that have been linked to learning in a variety of formal and informal contexts: problem-solving and reasoning strategies [10-12]. By means of an exploratory nonexperimental study, we hoped to assess the potential of two relatively new software programs for the development of the problem-solving and reasoning strategies we felt were central to learning in the domain of the social studies.

Debates have flourished about the best approach for effectively learning and using these strategies [13, 14], debates that have extended to the manner in which educational software influence their development and subsequent use in future tasks [15, 16]. One theme of these debates examines the role of "metacognitive capacities" (knowledge about one's own thinking, as well as the ongoing planning, monitoring, and evaluation of one's performance on a task) in acquiring and using knowledge in school and everyday contexts: how these capacities, for example, might allow the learner to control and orchestrate problem-solving and reasoning strategies [17-19]. There is mounting evidence that metacognitive abilities are central to effective strategy use [20-22]. Yet there has been very little consensus as to how these capacities themselves develop, their specific role in overall cognitive development [17, 23, 24], which of the instructional components associated with metacognition to emphasize, or in what instructional form [20, 25, 26].

There have been substantial efforts to assess the potential of new instructional technologies for answering these questions: the facilitation of the learner's strategic ability, metacognitive knowledge, and subsequent use of these abilities and knowledge in other tasks [27-29]. The research to date has pointed to the importance of developing and researching effective instructional methods—a

significant part of the educational culture—for use of these technologies [5, 6, 30, 31]. Such initiatives assume, as did Vygotsky [32, 33], that actions involving "external" tools become, through their involvement in cultural practice in particular contexts, increasingly symbolized and internalized as cognitive processes. These processes can then organize future action in similar contexts.

From a research standpoint, the technologies involved can provide a detailed account of the learner's activity on a task, allowing for a rich assessment of the learning process. A central question to many cognitive researchers—how cognitive strategies and metacognitive knowledge about tasks develop—can also be empirically examined with these technologies. Much of the new educational software can provide, for example, "replay" files that record the learner's interaction with the computer in sequential form. There is a precedent for using these process files to allow the researcher to chart patterns of and changes in use over time, making possible inferences about the cognitive strategies involved, and how and when they were used [5, 34, 35].

Research should be undertaken to explore how cognition, curriculum, and teaching method might be reorganized to integrate the use of the computer in the learning and ongoing use and "executive control" of defined cognitive strategies. The project we developed attempted to examine the impact of instructional technologies and methods on the use of cognitive strategies for tasks chosen from social studies curricula. We felt that this type of exploratory study would add to understanding of the learning process within school topics, from a cognitive perspective, by using the technologies involved as tools of instruction and research. We further surmised that the project would offer some indications of what teaching methods might be optimal when using such technologies to facilitate strategy acquisition and use. Parts of this larger research initiative were to examine, in more detail, the relationship between cognitive strategies and metacognitive knowledge as they develop during the learning process, and potential involvement of what was learned in future task performance.

Identifying the Cognitive Strategies

Although many higher-order strategies are used within a traditional school curriculum, we were particularly interested in identifying those that are also considered to be effective in more informal contexts—maximizing the relevance of the project to the students who participated and the potential transfer of these strategies for use in school and informal situations [7, 10-12, 36, 37]. Strategies for solving and reasoning through problems have been linked, historically, to learning on both formal and informal settings [11, 38], particularly those problems best described as "ill-defined" with no one best solution [39-41].

We understood problem solving as distinguishable "stages" of activity, including: classification/definition of a problem, assemblage of optional solutions for the problem, development and evaluation of a rationale for selecting an option,

and review of the decision-making process as a whole [41-43]. Reasoning in social studies was understood as the learner's ability in "argumentation" [40, 44, 45]. Toulmin [40] developed a model of argumentation we used in the project that includes the following "primary traits" of arguments: "claims," assertions or conclusions; "data," the foundation of evidence for the claim; "warrants," propositions frequently involving rules, principles, or inference-licenses that show how the data and claim are related; "qualifiers," the degree to which the data bears on the claim by virtue of the warrant; and "rebuttals," conditions of exception to a claim. Hillocks analyzed written arguments with two additional features: "propositions," an overarching, controlling claim to which most of the other aspects of an argument relate, and "opposing arguments," elaborated exceptions to a claim that can then undergo rebuttal [46].

The ideas of Brown, Collins and Newman [37], Toulmin [40], Perkins [41], Willard [45], and Hillocks [46] are included in the conceptualization of reasoning used within the instructional method and measures of cognitive strategy. Reasoning was operationalized by the presence and elaboration of each of the above features in written essays or reports of the students, using the scoring system developed by Hillocks [46] and adapted for use in this project.

If the instructional technologies and methods proved to facilitate the acquisition and use of these strategies with specific problems, it was important for us to assess the use of them with other tasks as an indicator of transfer of what was learned. Many have argued that the division of school knowledge itself into discrete, sequenced subjects and traditional teaching methods within these subject areas (lecture, recitation, linear approaches to research) are considerable impediments to developing an educational culture that facilitates the learning and future use of these strategies [12, 36, 47, 48].

Recent reviews of transfer research, however, have highlighted the complexity of designing and evaluating effective technologies and methods, partly because of the challenge of developing rigorous transfer criteria and research methods in concert with the technologies used [9, 49, 50]. Transfer tasks here were selected so as to allow for testing the utility of a predictive model of "procedural" (or strategy) transfer, such as that articulated by Kieras and Polson [51]. The central assumption of their model is that procedures shared by two tasks will determine the degree of transfer and amount of necessary training time needed to master the second task. When the conditions necessary for using a procedure matches a specific pattern in the task, the procedure is used [51]. Recent research in the area of human/computer interactions have largely supported this model of transfer [51-53], although its relevance to cognition for more culturally typical complex tasks remains questionable [47]. Tasks were also selected from the same domain of knowledge in order to substantiate claims that use of a single knowledge base for target and transfer tasks facilitates similar representations of the two by the learner, resulting in positive transfer of problem-solving and reasoning strategies [49, 54, 55].

A Rationale for the Selection of Social Studies Tasks

Social studies is one subject area understood to centrally involve decision making and reasoning, tasks that often focus on citizenship and current social issues [56-59]. Unlike many disciplines, social studies predominantly involves "ill-defined" problems with no one optimal solution [59]. Kitchener has argued that these types of problems might involve another type of metacognition she terms "epistemic cognition" [60]. She argues that this level of knowledge involves the learner's awareness that there is no "best" solution and, as such, the task requires the use of personal beliefs to make a decision. Therefore, decision-making and argumentation strategies, frequently based on subjective values and beliefs, are particularly important in social studies topics [56]. Social studies teachers, however, appear to rely overwhelmingly on classroom recitation and textbook reading, which are highly ineffective methods in the development of the conceptual understanding necessary to use the domain information in strategic ways [56, 61].

For these reasons, social studies seemed a good choice for a domain context in which to explore higher-order thinking, and new instructional technologies and methods designed to improve cognitive skills. Tasks for our high school students included selection of a President of the United States for 1988 (as a target task), and deciding upon what they considered the "most important social issue facing Americans" (as a transfer task), then writing essays about the reasons for their choices. We chose the target task for two general reasons: the tradition of research and learning emphases on votership and political decision making [44, 62, 63]; and the timeliness of the topic—insuring the availability of relevant information and maximizing the project participants' interest. Information about current social issues was therefore used as a knowledge base for these tasks, situating learning of social studies topics addressed in both formal and informal settings.

We also assumed that decision making and reasoning about social or political concerns are necessarily value based, influencing how a social problem is conceptualized in memory, which of the alternative solutions to the problem are selected, the relative importance of relevant information, and how these selections are warranted by the individual [44, 59]. People may tend to remember and organize information of social and political problems in memory by use of categories that reflect their belief system [64]. Over the years, researchers have found that people choose logically correct alternatives using more effective procedures on problems with familiar data [65-67]. The individual's ability to examine alternatives and information that are not valued may facilitate the development of argumentation.

Smith suggests that writing assignments involving argumentation and persuasion may be a key factor in developing reasoning skills in social studies [68]. Writing assignments are more in keeping with traditional school work (a fundamental concern of this project) than verbal interviews or protocols, which are typically used to examine problem-solving and reasoning strategies [59, 69, 70].

Although there is no consensus yet about the relationship of thinking to writing processes [71-73], neither writing ability nor writing instruction was the focus of the project. We felt it would be necessary, however, to control for the writer's ability, the potential influence of the organization of relevant knowledge, type of essay, and audience on written content and form [74, 75].

Technologies as Strategic Tools: IDEA and Notecards

Pea argues that a productive approach in examining use of technologies in education is to define the cognitive strategies necessary to be in control of one's own learning and to then design new technologies to help support their use [9]. Given our emphasis on solving and reasoning strategies with ill-defined problems, we chose software programs that were developed for these purposes but that had been largely unresearched in their use with school-related topics.

The cognitive strategies targeted by the IDEA program (Interactive Decision Envisioning Aid, Pea, [76]) involve making decisions about everyday problems. The program defines the decision-making process in stages, designed to maximize the learner's metacognitive experiences: the *options* module helps the student through problem development, using strategies to generate a list of alternatives; the *criteria* module supports plan definition and monitoring, including critical analyses of positive and negative consequences of selecting alternatives [41]; the *appraisal* module supports monitoring as well, using comparisons of evaluations made to highlight aspects of the evaluator's thinking processes. The IDEA program is iterative, allowing the user to move to different phases of the decision-making process opportunistically, as empirical research on decision making indicates humans do so without the support of computer technologies [76].

A particular strand of decision-making research that Pea [76] used to support the development of IDEA is Multiattribute Utility Theory (MAUT) [77-79]. One general premise within the theory is that each of the alternative solutions of a problem be further broken down into attributes that can be evaluated using numerical values. Each attribute can then be given a rating of its relative importance in the overall decision. Further, each alternative can be rated in relation to its "utility" on each attribute. These two ratings are multiplied for each attribute; the products are then summed for each alternative yielding a highest score for the "best" alternative [80]. The ratings in MAUT, called "location measures" [77], are usually based on a "0" to "100" scale [81]. Two key assumptions made with MAUT are that evaluation of alternatives should be comparative, and that judgment of magnitude (which is part of the evaluation) is best supported by assignment of numerical values [77]. We see the principle utility of MAUT as a means of externalizing results of evaluation processes, not in blindly accepting the results of its numerical methods.

An additional IDEA component is the *executive control map* that graphically depicts the modules and their relationships, "graying out" the modules on the map as they are completed to reduce working memory demands of the problem-solving task. Although other modules are intended to support the development of monitoring and controlling of the strategies used (a type of metacognitive activity), we argued that use of the executive map would offer metacognitive knowledge about the task itself during the decision-making process.

Figure 1 depicts the main screen and executive map from the IDEA environment. By use of a "mouse" control (a hand-held control device whose movement on a table top corresponds to a moving arrow on the screen; a press of the mouse button makes computer events take place) and pointing to the icons on the upper border of the individual windows, new windows were opened on the screen. Each of the icons to the left of the "Main Idea Area" caption represented different modules in the decision-making process. The map offered the same information in word and tree structure form which could be retrieved by using the U.S. map icon in the main screen. As a student completed a module, the corresponding branch on the map was grayed out.

Figure 1 also offers the work of a student in the *options* module, represented by the person and lightbulb icon, including the four windows available in the module. Here, the student entered the "List of Options" or generated the options by use of the incomplete sentences listed in the "Brainstormer." If the student elected to fill in the sentences, they were asked by a screen prompt to choose two options listed in the "List of Options" they would have liked to use for the task. As sentences are completed by the student, more were automatically added to the window based on the options and descriptors generated in the first sentences. (The darkened words in the sentences in the "Brainstormer" can be changed with the mouse to fit the syntax created by the filled-in word.)

The "Classifier" offered the options and descriptors used to generate them in the "Brainstormer," although the student could enter this window directly. Similarly, the "Outline" window depicted options and descriptors in outline form from "Brainstormer" work or direct entry to that window. The *constraints* model (the "X" icon) involved entering which options were not being given further consideration and the reasons for this.

The *criteria* module, represented by the "thumbs up" icon, involves selection of descriptors of alternative solutions by a sentence fill-in task for an option the student liked and one not liked, as depicted in Figure 2. (The verb is changed according to the student's sentiments about the option.) As in the *options* module, the "Opposites" window listing the criteria could be entered directly by the student. Each criterion chosen automatically generated its opposite to create a continuum. These descriptors or criteria were then used to create the "perfect" option in the "Perfect Spot" window, with the use of a visual slider, where the student rated each criterion from 0-100. The relative importance of each criterion was then rated from 0-100, using the pies as a visual cue, independently of the "perfect option" ratings. Figure 2 offers a depiction of this.

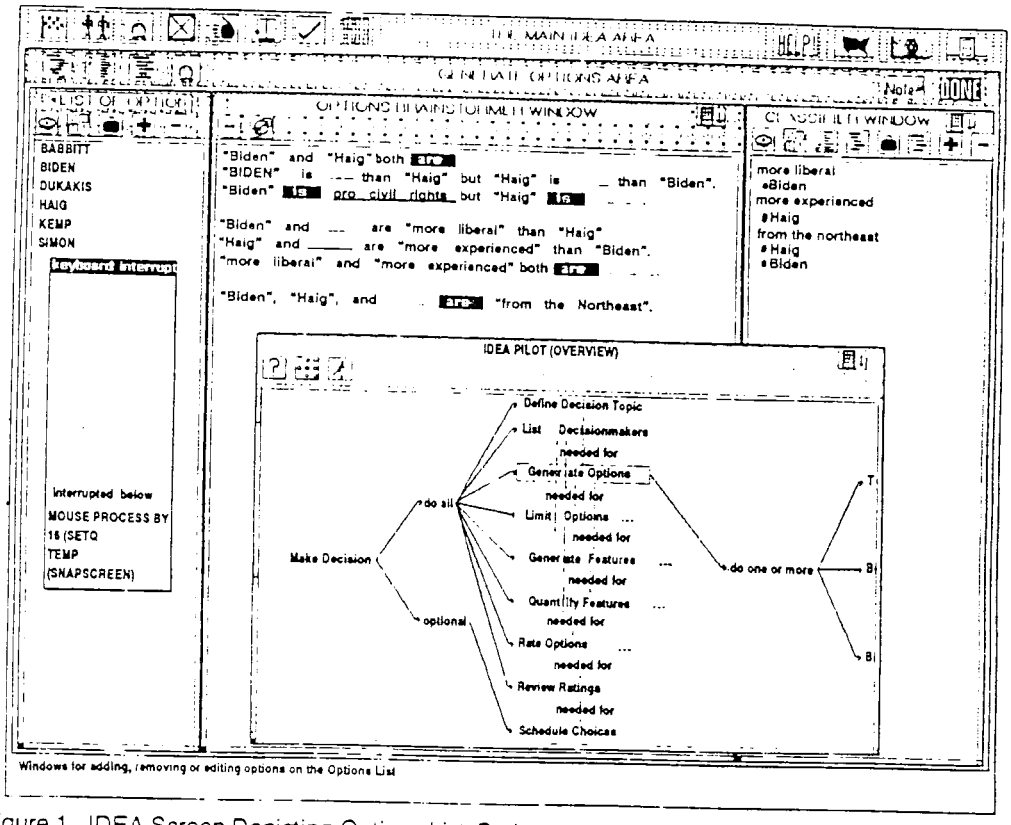

Figure 1. IDEA Screen Depicting Options List, Brainstormer, Classifier, and Executive Map Windows as Created by Pilot Student.

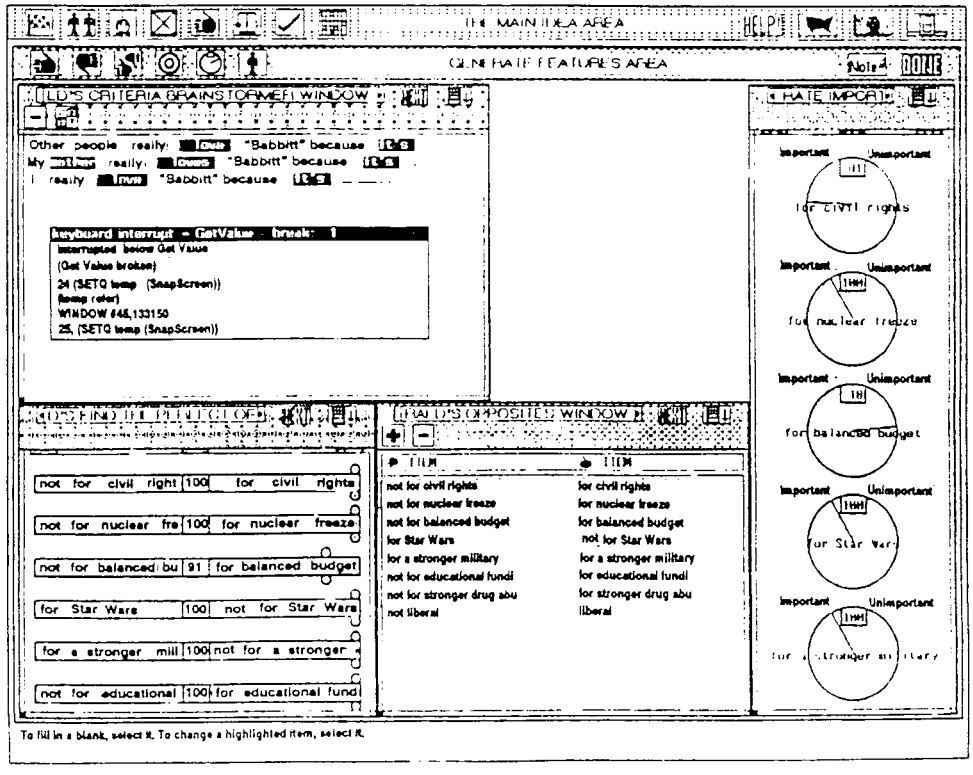

Figure 2. IDEA Screen Depicting Criteria Brainstormer, Opposites, Perfect Options, and Rate Importance Windows as Created by Pilot Student.

The *appraisal* module (the balance icon) involved rating each of the candidates holistically (0-100) and then by the established, now weighted criteria (0-100) using the visual sliders. These ratings, by option, were then presented together for comparison—the holistic rating and the average of the weighted criteria rating. The student might have then revised either set of ratings. Figure 3 presents the windows from this module. The *review ratings* module (the arrows icon) represented the averages of the two ratings for each option, in ranked order. Several windows could be viewed on the screen at once but only those windows related to one module. The student could go back at any point to a previous module to revise work. For example, criteria could be added or values changed after the module was removed from the screen.

Previous research with the IDEA program yielded findings that supported its use to enhance problem-solving strategies in such areas as assigning household chores to family members [82, 83]. But IDEA was not designed to provide the problem-related information considered critical to effective use of decision-making strategies in school-related topics [14, 54, 59]. A pilot study highlighted the difficulty students would have without both a knowledge base and explicit strategies for searching and organizing their own knowledge base. Both the organization of a knowledge base and explicit tracking of strategies for processing and grouping this knowledge are supported by the Notecards system [34], created at Xerox Palo Alto Research Center. It is a computer program intended to help in the writing process and in supporting complex textual discourse such as argument-building and belief revision [34]. Notecards is presently used by over 100 scientists at Xerox and other research institutions throughout the country. It supports extraction of notes from information in reference material, and helps with the organization of the final product [84]. Preliminary, anecdotal studies with Notecards—such as its support in the writing of a doctoral dissertation [85]—have offered some indication of its effectiveness in the structuring of written arguments.

By filing and shuffling the *notecards* according to categories created by the user, one can develop idea structures based on text that can be explicitly linked by directed, labeled arrows as "evidence," "evidence against," and other conceptual relationships. There are four major concepts in the Notecards system [84]: *notecards* themselves; the *links* between cards (themselves) which may be listed separately and be based on words from the cards' titles or the text on the cards; the *fileboxes*, semantic categories where the cards are kept; and the *browsers*, which are graphic depictions of the three other elements and their relationships, designed to guide the user's search processes. We argued that these browsers would serve a similar function as the executive control map in IDEA, allowing the students to reflect on how they might conceptualize the knowledge related to their final decision. Cognitive researchers have called such guides "expert system shells," that offer learners metacognitive experience through construction of their own knowledge base [49, 86].

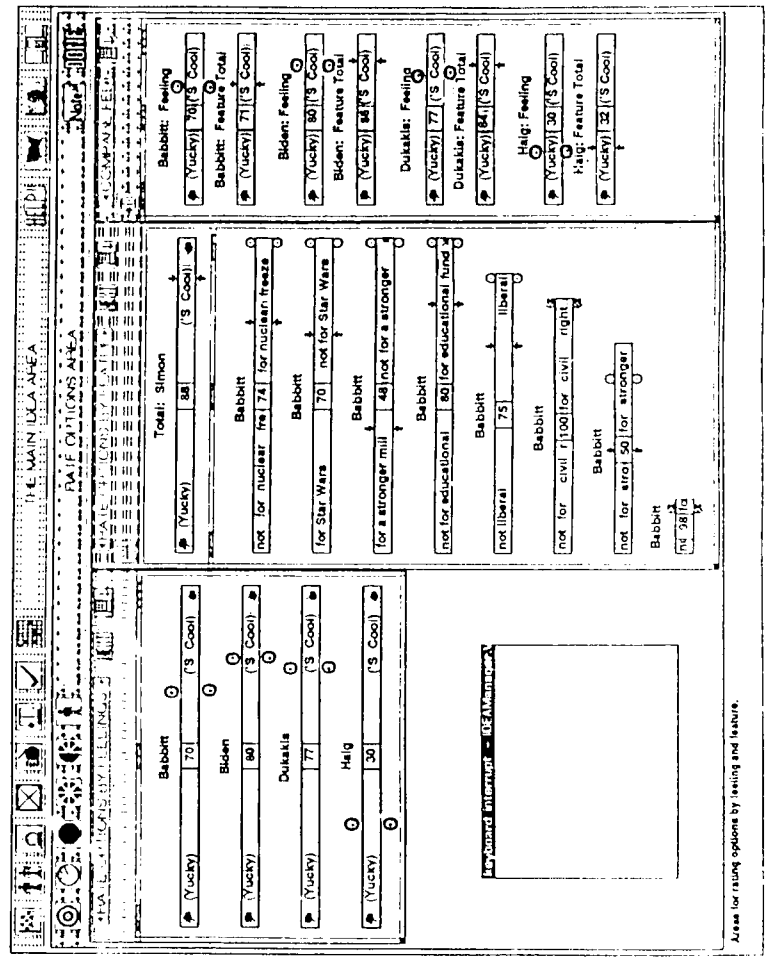

Figure 3. IDEA Screen Depicting Rating Options by Feelings (Holistic), Rating Options by Features, and Comparison Windows as Created by Pilot Student.

Figure 4 offers images of the "Table of Contents," a filebox, and a notecard as they appear on the screen of the Notecards systems from the pilot study. A notefile first must be "opened" by selecting from the "Notefile Ops" menu, Figure 4, with a mouse. Then, the "Table of Contents" filebox from the "Show Box" menu was opened. This listed all of the fileboxes, notecards, and browsers in that notefile, making retrieval of information possible in several places.

As Figures 4 and 5 show, several cards and fileboxes could be viewed on the screen at any one time. Only a portion of each card and box was visible, however, so that the student used the mouse to "scroll" the card up or down. Cards could be moved about or removed from the screen by using the mouse to retrieve menus from the upper black border of each card or box. The student might have created notecards or fileboxes to write out notes and organize information deemed important upon viewing the two master files. These were saved for future reference in a "To Be Filed" filebox contained in the "Show Box" menu.

The creation and use of one's own filing system from a larger, already organized knowledge base would reflect a form of metacognitive activity including, for example, the learner anticipating what information should be remembered for accomplishing the task goal: a type of "metamemory" ability [20, 23]. When writing the text of the essay, notecards were used and information from the knowledge base could be directly transferred to the text by mouse commands. As with word processors, text could be edited, deleted, or elaborated on an ongoing basis. These writing activities are controlled by and contribute to the learner's metacognitive knowledge.

Restructuring the Educational Culture

We were concerned with developing instructional methods that would address problem-solving and reasoning strategies within the chosen tasks by offering metacognitive activities, as well as methods that would facilitate the students' use of the technologies we had chosen. Collins, Brown, and Duguid propose viewing learning as an "apprenticeship," rooting the curriculum back into the real world tasks [36]. An apprenticeship model highlights learning expert strategies for handing complex tasks, and by participating in the context of their use. Their synthesis of cognitive research of educational practices is undergirded by a "Vygotskian" framework of learning: the development of thought is understood as internalization of social dialogue.

Brown, Collins and Newman advocate several procedures related to this model, including "modeling" the targeted skills (while verbalizing one's thinking as the task is being executed) with the students imitating these skills on a different, but parallel task [37]. If necessary, the skills are "scaffolded" for the student. This involves offering extensive help (such as repeating the modeling process), only after allowing the students to take on as much of a task as they can on their own. Control is gradually turned over to the students, a process called "fading," the

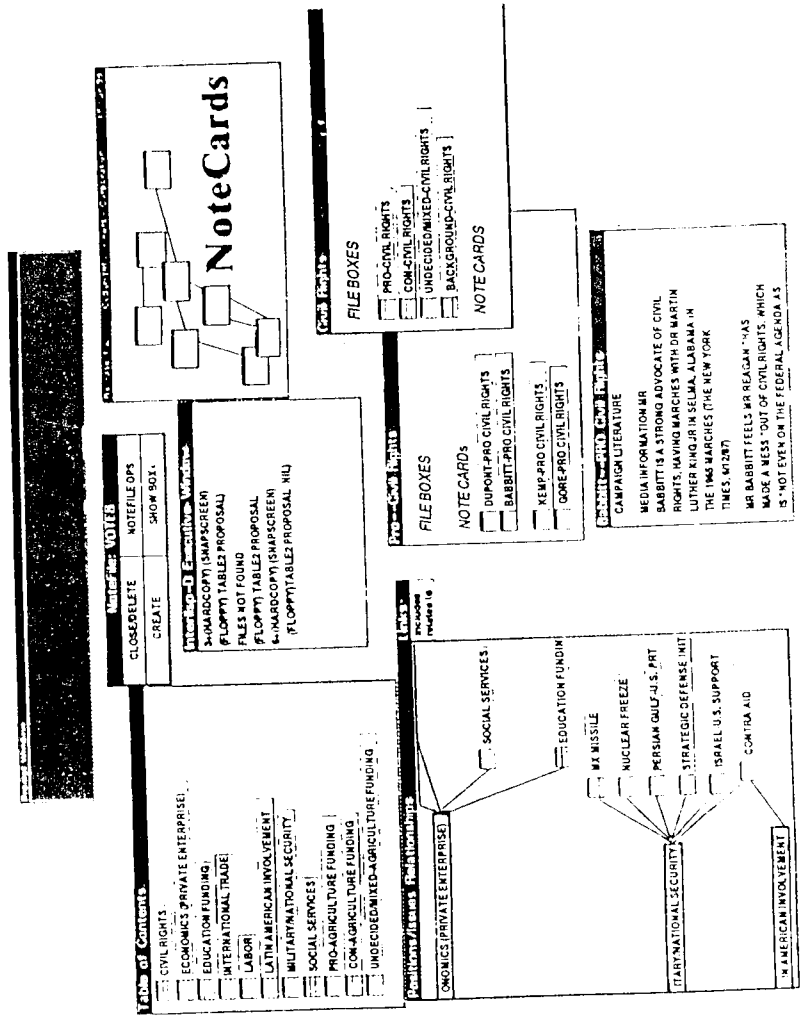

Figure 4. Notecards Screen Depicting Table of Contents, Positions/Issues Browser, and Civil Rights Filebox and Notecards.

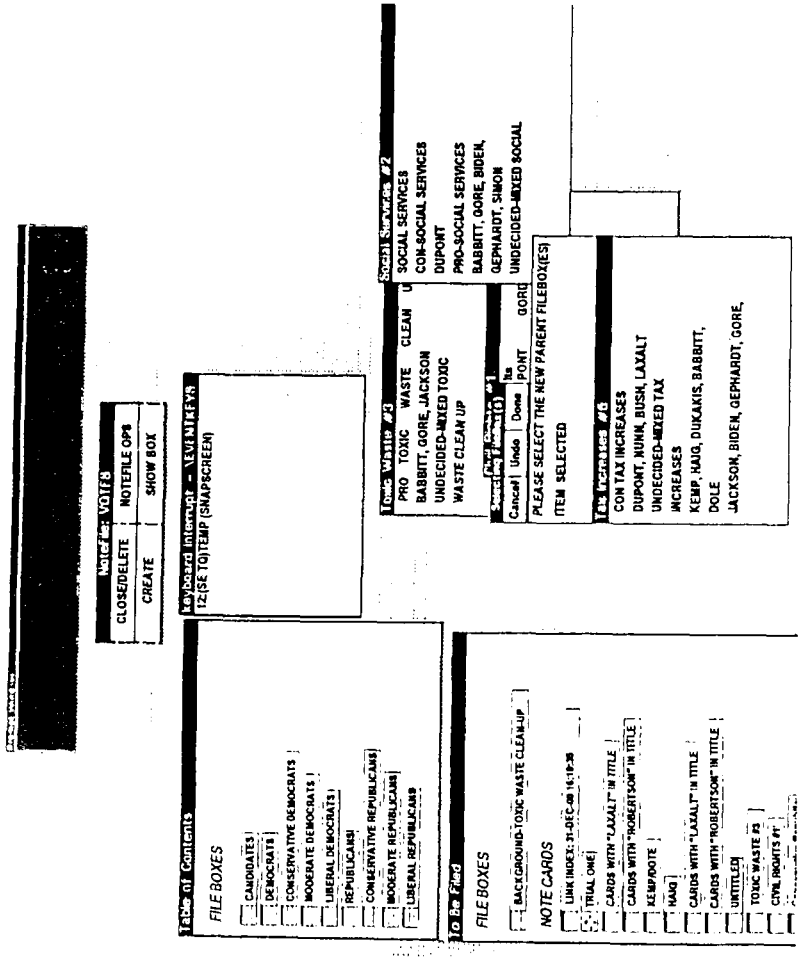

Figure 5. Notecards Screen Depicting Table of Contents, 'To Be Filed" filebox, and Pilot Student's created Notecards.

instructor then monitoring the students' performance. Finally, the students are allowed to "solo" [37]. Central to their model is the evaluation of the students' mastery of knowledge and strategies involved in a task (such as "replaying" their previous performance, encouraging the learner to articulate the strategies used, [37]). These evaluative processes are intended to help facilitate the learner's metacognitive awareness about the task.

Currently, there are other important initiatives to design similar instructional approaches with the use of instructional technologies [30, 87]. Their preliminary work with elementary school-aged children in the language arts, social studies, and mathematics using computer- and videodisc-based programs suggest to us that such approaches can facilitate dramatic improvements in the learner's acquisition and use of knowledge bases and cognitive strategies in these subject areas [27, 30, 87].

Apprenticeship techniques were used for all aspects of the instruction, including learning to use IDEA and Notecards. As each aspect of the two software programs was presented, use of that aspect was modeled (while "thinking aloud") using the task of selecting and writing about "the best President of the United States since 1960." The students' attempts to use the technologies were scaffolded and monitored, and eventually replayed, evaluated, and discussed. When writing the essay, Toulmin's [40] argumentation structure was presented in apprenticeship fashion. For example, students were encouraged to find problems with their arguments by modeling a verbalized analysis of a portion of sample essay text involving a claim, data, and warrant [40, 41]. Methods for structuring arguments were discussed and modeled for the student as well. Separate notecards in the Notecards system, each with advice phrases relating to these argumentation features, were presented to the students and modeled in their use while the students wrote the Notecards-based essay. This "procedural facilitation" [88], considered a type of "scaffolding," allows the student to review these advice cards in random order and choose to use the advice or not on a particular card.

Table 1 is a detailed outline of the sequence of instruction and methods, as well as the advice cards, used in the project. Each of the statements (reflecting the aspects of written argumentation as outlined by Toulmin [40] and Hillocks [46]) appeared on a separate advice card that the student could choose to review at any point during composition of the assigned essay.

Project Dimensions for Empirical Study

The combined utilization of IDEA and Notecards in order to enhance the learner's decision-making and reasoning strategies has not been previously researched. Yet it holds promise for illuminating roles of new technologies in enhancing the development of critical reasoning, as in the case of social studies learning. Because this research was without direct precedent, we considered it an exploratory, descriptive study. We wanted to examine, using a multiple case-study approach, changes in the students' written arguments before, during, and after

Table 1. Instructional Method/Advice Cards

First Week—Two Sessions
1. Introduction to Notecards—Modeling Notecards (Example Problem)
   A. Opening files and cards
   B. Searching links and organization
   C. Creating one's own file
2. Categorization with Notecards—Model Notecards Use/ Search Strategies
   A. Modeling search strategies (Example)
   B. "Scaffolding" the tasks indicated above

---

1. Reflection on Notecards/Search Strategy
2. Discussion of Decision/Reason Separation and Searching for Pros/Cons (Candidate Topic)
3. "Soloing" Notecards Use (Candidate Topic)

Second Week—Two Sessions
1. Reflection on Notecards/Search/Organization Strategies (Candidate Topic)
2. Soloing on Notefile Retrieval (Candidate Topic)
3. Introduction to IDEA—Modeling IDEA Use (Example)
   A. Modeling Options/Criteria/Appraisal Modules
   B. Modeling Map use
   C. Modeling Iterative use of IDEA
4. Options/Notecards Strategy use of IDEA
   A. Scaffolding Options/Notecards use
   B. Fading Options/Notecards use
   C. Soloing Options/Notecards use

---

1. Reflection on Options Creation/Notecards Use
2. Soloing on Notecards Retrieval (Candidates)
3. Constraints/Criteria/Appraisal Use (Example)
   A. Modeling of Constraints/Criteria/Appraisal
   B. Scaffolding of same
   C. Fading/Soloing of same

Third Week—Two Sessions
1. Reflection on Constraints/Criteria/Appraisal
2. Open Review Ratings Module (Candidates)
3. Discussion of Reasons versus Evidence—Essay
4. Soloing on Review of IDEA/Notecards Use

---

1. Reflection of Review Process/Discussion of Argument Structure
2. Writing Notecards-Based Essay (Example)
   A. Modeling strategy for writing text
   B. Modeling "advice card" use
3. Scaffolding Writing Essay (Candidates)
   A. Scaffolding writing text
   B. Scaffolding advice card use
4. Fading/Soloing Notecards-Based Essay

Fourth Week—Two Sessions
1. Reflection on Notecards-Based Essay
2. Soloing on Writing/Revising Notecards Essay

---

1. Soloing on Post-Instruction Essays

Advice Cards

"I need to give more:
. . . reasons"
. . . evidence"
. . . beliefs"
"I need to give clearer:
. . . reasons"
. . . evidence"
. . . beliefs"
"I need to give more/ clearer:
. . . counters"
. . . rebuttals"

their involvement in the project. This approach would allow for more detailed examination of the technologies—which were not specifically developed for this project—as well as the targeted strategies. We hoped to explore, for example, what the potential relationships were between experience with the structural aspects of the Notecards knowledge base and decision-making model within IDEA and the structural aspects of the final written arguments. Conceivably, such inquiry would provide important information about the ways in which future instructional tools specifically intended for support of problem-solving and reasoning strategies might be designed.

Assuming that the project would demonstrate some facilitation in the development and transfer of cognitive strategies, we wanted to examine how changes in the strategies used were related to the technologies and methods on the one hand, and to metacognitive activity on the other. Our assumptions were as follows: 1) that if there were a similarity in content chosen and developed in the two instructional technologies, this knowledge selection might represent the student's personal belief system; 2) that, as the student acquired this knowledge, used in both technologies, and became more aware of this belief system, metacognitive (or epistemic) knowledge would increase; 3) that this higher knowledge might, in turn, determine the strategies used to accomplish the stated task goals (strategies that could be inferred from evaluation of the student's interaction with the instructional technologies); and 4) that comparative examination of the strategies used with the technologies and the arguments developed in the essays might help us understand ongoing changes in the use of cognitive strategies and metacognitive activity by the student.

METHOD

Pilot Study

Given the exploratory nature of this investigation, we felt it crucial to run a pilot study to assess the student's potential facility in using the instructional technologies, to further design the instructional activities and their sequence, to provide training of two judges for the project, and to assess the reliability of the scoring methods developed for the written essays. Three students, all high school juniors, were involved in the pilot that ran for two months, with each participant attending twelve sessions over the time period. (Recruitment and selection procedures paralleled those described below.) At the end of each session, the student was interviewed by us about their reactions to the activities that day. They were also given brief questionnaires about the various components of the IDEA and Notecards systems.

Based on these findings, certain modifications or additions were made in IDEA's programming, the Notecards knowledge base on the presidential candidates (see Table 2), and the modeling verbalizations of the project instructor

Table 2. Operative Organization of Notecards Knowledge Base

Fileboxes	*Notecards*	*Links*
Democrats	**CANDIDATES**	
Liberal	Babbitt, Bruce	
Moderate	Bush, George	
Conservative	Dole, Robert	
	Dukakis, Michael	"Opposes"
Republicans	Dupont, Pete	"Agrees with"
Liberal	Gephardt, Richard	"Views on"
Moderate	Gore, Al	
Conservative	Haig, Alexander	
	Jackson, Jesse	
	Kemp, Jack	
	Robertson, Pat	
	Simon, Paul	
Abortion	**ISSUES** (Broken down into	"Relates to"
AIDS education	("Pro," "Con," "Mixed,"	
AIDS funding	and "Background")	
AIDS testing		
Balanced budget		
Contra aid	"Candidates PRO . . ."	
Drug abuse	"Candidates CON . . ."	
Israel—U.S. support	"Candidates MIXED . . ."	
Japan—Trade		
Missile defense shield	(Based on campaign literature,	
MX missile	media information, and interest	
Nuclear freeze	group literature)	
Persian Gulf—U.S.		
School prayer		
Social security increases		
Strategic defense initiative		
Tax increases		
Toxic waste clean-up		
	POSITIONS (Broken down into	
Agricultural funding	"Pro," "Con," "Mixed," and	
Civil rights	"Background")	"Includes"
Education funding		
International trade	"Candidates PRO . . ."	
Labor	"Candidates CON . . ."	
Latin American involvement	"Candidates MIXED . . ."	
Military/National security		
Private enterprise	(Based on campaign literature,	
Social Service funding	media information, and interest	
	group literature)	

(available upon request from the authors). Table 2 represents the categories and structure of information available to the student about the candidates and social issues, based on media coverage, interest group literature, and campaign materials from the six months prior to the pilot study.

The figures depicting the two instructional technologies are based on the work of one of the students in the pilot program. Students in the pilot study were requested to write essays on presidential candidate and social issue selection before, during, and after the pilot was completed, their essays scored by two judges (who served during the formal project as well). The judges were two postgraduate students in the social sciences, part of the overall research team.

Selection of Research Participants

The participants in this study were adolescents entering their junior year in high school. While younger students may be developmentally capable of the critical reasoning involved [89, 90], high school social studies curricula more frequently include learning about current events [61]. This project was thus in keeping with topics the selected students would be expected to study. Students were recruited from New York City high schools during the summer months through contacts with teachers and youth groups. Students were screened on the following bases: entrance into the junior year of high school the following September; reporting a high interest in writing; self-identification as "good" writers; and availability during the selected time of the project.

Twelve students, divided equally by sex, were then selected, representing a range of social backgrounds (as research results on sex and socio-economic differences within the domains of political reasoning, decision making, and computer programming and literacy show no uniform trends [91, 94]). They were paid a nominal fee for their involvement. They and their parents were informed that the intention of the study was to examine higher-order thinking and written argumentation about social studies topics through the use of new instructional technologies.

Ten students (mean age: 15,8) participated in the project until its completion. They were all prospective juniors in high school. Nine of the ten attended public high schools in the New York City area, one attended parochial school. They came from homes where parents' vocations varied greatly, ranging from commodities broker to registered nurse to television technician. There were six girls and four boys participating in the study. Six students were Black; four were Caucasian. All of the students reported having grades in the 85-95 range in all subjects. All considered themselves to be "good writers" and "fairly knowledgeable" about current events. Most of the students had no previous experience with computers; two of them had enrolled in a one-semester course on computer literacy.

Instruments

Student work from the pilot study indicated that students tended to use the information selected from Notecards as the options and criteria in IDEA and as the content of the final essays. Furthermore, they tended to use certain levels of information from the Notecards environment for developing particular aspects of the decision-making and argumentation strategies used. We decided, then, to focus on ways to measure the knowledge and strategies used within the instructional technologies to examine the changes in the students' thinking about the tasks, both during and after the project's conclusion. The measures described here are those that relate most directly to the focus of this article: problem-solving, reasoning, and metacognitive strategies.

Measures of written argumentation — An essay on "Who you (the student) would choose for President of the United States in 1988 and why others should vote for that candidate" served as the context for a number of the decision-making and reasoning measures obtained. Students were asked to write the essay prior to the learning project with pencil and paper and, again, at the end of the project on the Notecards system. Measures to be obtained from these essays were drawn from the research of Hillocks [46], who has developed a rating system for analyzing the structure of written arguments. Based on Toulmin's [40] model of argument, Hillocks [46] breaks down arguments in the following structure: *proposition* (the major claim of the essay, constraining the essay to come); *claim* (the reason for the proposition); *data* (evidence to buttress the claim); *warrant* (a value attached to the claim, often implied, that explains the relationship of claim and data); *qualification* (exceptions to the proposition or claim); *opposition/counterargument*; and *rebuttal* (of the opposition).

Each aspect is scored from 0-2 (2 being high), depending on the clarity, support, and elaboration of that aspect of the argument. A bonus of two points is given when a claim, data related to the claim, and the warrant explaining the relationship each receive a "2." Repeating of arguments is not scored. An interpretation of the Hillocks [46] system as used in this study is available upon request from the authors.

The description of the scoring method is suggestive of a structural analysis of the argument as well as judgement of the category type and quality of each statement made. Hillocks proposes that a positive correlation exists between use of more elaborated statements in developing arguments and a more "hierarchical, nested" structure to the argument itself [46]. Less elaborated arguments are frequently more "linear" or "chain-like" in structure. The structure of these written arguments were diagrammed to assess Hillocks' [46] views and to trace structural changes resulting from the instruction received during the project.

Transfer/maintenance essay measures — Measures to assess transfer of strategic knowledge used with the target task were obtained from handwritten essays by the students, without the availability of the instructional technologies or

methods. These included two essays on the "most important social issue"—before and immediately after their formal learning sessions had occurred, and two "candidate" essays—immediately after the sessions' conclusion and exactly two months later. Students were given the same instructions and constraints with these essays as before, as well as the same scoring system and measures used to assess argumentation.

Measures of information source and type — The other two measures obtained from these essays involved judges' use of an "information source matrix" of: 1) the percentage of the essay based on Notecards versus non-Notecards information, and 2) position/issue versus candidate-based information. Each aspect of the essay that had been previously scored under the Hillocks [46] system for written arguments was scored in these terms. For example, in the first case, the number of statements in each essay involving information in/not in the Notecards system was established. The matrix was also used for obtaining percentages on the criteria developed in IDEA. This system was used during the pilot study; interrater reliability was .94.

Process measures of strategy use — We were interested in examining the cognitive strategies used in interaction with the two technologies, particularly if there were similarities in how the student decided upon and wrote about the candidate of choice. A central feature of the IDEA program is "abstract replay" files that record not keystrokes, but the number and type of interactions with IDEA operations in their sequence [76]. Instructional and experimental sessions could be replayed and watched as well as analyzed for distinctive use patterns. We were unable to obtain replay files of the type, number, and sequence of interactions with the Notecards operations. We therefore created data sheets to record the Notecards interactions by hand.

Out of several process measures obtained, four seemed most important in establishing that students viewed the two technologies as supportive of using similar information with each: top-ranked candidate in IDEA, after completion of the final module; the candidate written about in Notecards; the total number of criteria rated above "75" in importance in IDEA; and the number of claims made in the Notecards-based essay. The first two measures were determined by a coding system, converting choices into ordinal data, developed prior to the pilot study (see Table 3). The coding system was derived from the work of Hausmann [95] on the spectrums of "political ideology" and "party affiliation." We decided to tally counts of criteria above "75" because of "response clustering" that will occur at both ends of subjective rating scales [77]. We argued, as have others, that clustering from 75-100 would represent a meaningful similarity in these criteria [97].

Measures of metacognitive activity — Based on recent research findings about the development of metacognition [18, 22], we developed a "metacognitive

Table 3. Candidate Codes of Political Ideology [95]

CANDIDATE	CODE
Babbitt, Bruce	1.2
Bush, George	2.2
Dole, Robert	2.2
Dukakis, Michael	1.2
Dupont, Pete	2.3
Gephardt, Richard	1.2
Gore, Al	1.2
Haig, Alexander	2.3
Jackson, Jesse	1.1
Kemp, Jack	2.3
Robertson, Pat	2.3
Simon, Paul	1.1
POLITICAL PARTY	**IDEOLOGY**
Democrats = 1	Liberals = .1
Republicans = 2	Moderates = .2
	Conservatives = .3

index" derived from process data available on the IDEA and Notecards systems. Of the several process measures we recorded, the following were used as indicators of metacognitive activity used in the index:

- creation of one's own notecards in the Notecards system (reflecting a planning strategy for subsequent writing and/or awareness of one's memory limitations)
- creation of one's own browsers in the Notecards system (also a planning strategy for subsequent writing)
- use of the Notecards knowledge base during interaction with IDEA (awareness of access to information available on Notecards, provided options or criteria are based on Notecards information)
- use of work done on IDEA during writing of the Notecards essay (awareness of access to decisions made in IDEA as the basis for arguments developed in the Notecards essay, provided the IDEA information is written about in the Notecards essay)
- review of previous work in IDEA, prior to stated completion of the final IDEA module (awareness of review strategies as effective in problem solving)

- use of the executive map in IDEA, prior to stated completion of the final IDEA module (awareness of planning and review strategies as effective in problem solving)

Each of these categories received a "1" by the two judges if the student's process files indicated use of that category; a "0," if not. By counting frequencies, the student could score a "0-6" on this index, a higher score reflecting greater indication of explicit metacognitive activity during the project.

Procedures

During the week prior to instruction, the students were asked to come to the research lab, briefly told about the scope of the study, and asked to write the preinstructional essays on who they would choose for President and what is the most important social issue facing Americans. They were to give their reasoning for their choices in these essays. They were requested to make the audience for these essay an "intelligent immigrant to the U.S. who is naive about American politics and social issues" in an effort to develop and consistently maintain an audience as part of the writing process [74, 75]. For the preinstructional candidate essay, the students were told that "having information about who is a formal candidate, the current issues being discussed, and factual data is helpful, but not necessary, as gaining knowledge in these areas is part of the reason for the project." They were also told to choose the candidate they would vote for without regard for who they believe could be realistically elected.

They were given no time limit to compose these first essays (nor were there time limits on later essays they wrote). These essays were collected and scored by the judges the same day, and the project instructor discussed their performance on the essay with them the first day of formal instruction. As previously indicated, the methods used during the project are outlined in Table 1, a timeline of the sequence of tasks. The students were asked to attend 2 two-hour sessions per week for four weeks. All sessions were individual and one-to-one. The specific information given verbally around each task was made available in print within the Notecards system for reference during each instructional session. After each session, process data (based on the measures described above) was collected by the judges. The instructor would discuss the inferences he made about the student's performance with the student during the following session, based on this process data.

The students were then asked to handwrite essays on their candidate choice and issue selection—with, again, the intelligent "immigrant" naive about American politics as the audience—on the last scheduled day of contact. These essays were collected and scored by the judges the same day they were written. The students were then contacted two months after the last instructional day and requested to rewrite the essay on candidate selection; they were then collected and scored.

Diagramming of the essays was undertaken by us after all of these other procedures had occurred but prior to our analysis of the data.

Data Analysis

Scoring of the essay-based measures using the interpretation of Hillocks' [46] system (previously described) was undertaken by two judges. The essays were scored in random order independently by each judge. The judges were blind to the essay type and identity of the student during the scoring procedure. The judges did not confer on these scores until all essays had been reviewed. Each judge was also responsible for scoring each essay using the "information source matrix" and "metacognitive index" previously described. In case of disagreement, the judges conferred until a consensus score was reached. Out of over 3500 statements receiving argumentation scores on the students' essays, discussions were necessary on 538 statements (15.47%) in order to reach a consensus score. No discussion was necessary about the scoring of information type or frequency of metacognitive activity, as there was complete consensus between the two judges.

Frequency of scores by category on the written essays were tabulated. These scores were treated as ordinal data in the analyses, since the distance between any two ranked values, e.g., between a frequency of "1" and "2" on "claims," was not known and there was no "0" score awarded for each reasoning category [96-99]. These data were considered "correlated" [97] and nonindependent [96] in that subjects were administered the same instruments over time with scores statistically compared. The recommended test for these argumentation score comparisons was the Wilcoxon Matched-Pairs Signed Ranks Test [98, 99]. Results were compared against critical values for one-tailed tests as we wanted to assess if there were significant increases in scores.

Other data were treated as ordinal, as well—codings for candidate choice, number of "75+" criteria and claims, frequency of argumentation scores and criteria that were Notecards-based and issues/positions-based—as the normality of their population distributions could not be assumed [98, 99]. The cognitive (and metacognitive) effort necessary to review or develop each additional feature of IDEA and Notecards could not be assumed to be the same, further warranting use of an ordinal scale in the choice of statistical test. Siegel [98] and Lynch and Huntsberger [99] recommend Spearman's Rho Correlation Coefficient for testing such data. Obtained Rho values were assessed as one-tailed tests as we were interested in positive correlations between the data described in the previous section.

Qualitative analyses were based on a series of comparisons of summary or process data between or within particular activities during the instructional method. Type, number, and sequence of interactions during each phase of Notecards and IDEA use were compared to every other phase and to the obtained scores and diagrammed structure of the written essays. Particular themes noted in the related literature on decision-making and reasoning strategies and written argumentation guided analysis of these findings. It was conceivable to us that these comparisons would prompt further statistical comparisons of the data to corroborate a trend discovered by this systematic examination of computer interactions and written argumentation.

RESULTS

Distinctions in Argumentation Scores

Our descriptive analysis of frequency data of argumentation in the essays suggested that there might be a conceptual (and psychological) distinction between scores of "2" and "1" under each category. Specifically, we noted increases in "2's" (explicit and elaborated elements) as a result of the project and some decrease in the frequency of "1's" (explicit but unelaborated elements). In order to determine whether statistical separation of total frequency of argumentation aspects and frequency of elaborated aspects of argument was warranted, correlations between total and elaborated frequencies of argumentation aspects were obtained. Using Spearman's Rho Correlation Coefficient for ordinal data [98, 99] and establishing $p < .05$ (two-tailed) as the significance level, overall frequencies of each aspect of argument and frequency of "2" scores of each aspect for all written essays were compared. None of these correlations reached levels of significance. That is, overall and elaborated frequencies of each aspect by essay type were not correlated. These categories, overall frequencies and elaborated frequencies of argumentation aspects, were therefore treated separately in the subsequent analyses.

Changes in the "Breadth" of Argumentation

In order to assess improvement of reasoning strategies on candidate selection and transfer and maintenance of this knowledge on subsequent essays, comparisons were made among frequencies of the total and elaborated aspects of argument in the various essays using the Wilcoxon Matched Pairs Signed Rank Test at a $p < .05$ significance level [98, 99]. Table 4 depicts the results of these comparisons for total frequencies of argumentation aspects for all essays. Each column of the table represents comparisons between two essays of the total (elaborated and unelaborated) frequency of scores. Each row depicts an aspect of argumentation. The values represent the total frequencies for all students—the earlier essay, to the left of the ratio sign; the later essay, to the right. Levels of significance are given at the bottom of the tables. An assumption of this statistical method is that N must be equal to or greater than 5 for results to be meaningful [99]. Several of the comparisons—labelled with a "*" on the table to indicate "insufficient data"—involved too small of an N to be analyzed.

Table 4. Comparisons of Argumentation Category Frequency (Elaborated and Unelaborated) by Essay

Aspect of Argument	Pre-Candidate/ Notecards	Pre-Candidate/ Post-Candidate	Pre-Candidate/ 2 Months Post	Notecards/ Post-Candidate	Notecards/ 2 Months Post	Pre-Issue/ Post-Issue
	Essay Comparisons					
Proposition	10/10	10/10	10/10	10/10	10/10	11/10
Claim	60/79*	60/75*	60/74*	79/75	79/74	34/54*
Data Claim	14/58*	14/37*	14/48*	58/37	58/48	19/17
Warrant	12/60*	12/68*	12/83*	60/68	60/83	14/24
Qualification	3/6[a]	3/8[a]	3/12[a]	6/8[a]	6/12[a]	0/5[a]
Counter Claim	6/20*	6/21*	6/23*	20/21	20/23	5/12[a]
Counter Data	0/1[a]	0/7[a]	0/7[a]	1/7[a]	1/7[a]	0/2[a]
Counter Warrant	0/0[a]	0/10[a]	0/3[a]	0/10[a]	0/3[a]	0/1[a]
Rebuttal Claim	3/16[a]	3/23[a]	3/22[a]	16/23	16/22	0/9[a]
Rebuttal Data	0/13[a]	0/7[a]	0/11[a]	13/7[a]	13/11[a]	1/3[a]
Rebuttal Warrant	0/11[a]	0/10[a]	0/12[a]	11/10[a]	11/12[a]	0/7[a]

* = $p < .05$ (one-tailed)
[a]Insufficient (N <8) data

Significant increases were found in the total frequency of data claims, warrants, counter claims, and claims and data rebutting arguments from the preinstructional candidate to the Notecards-based essay. The total frequency of data claims, warrants, qualifications, contrasting arguments, and rebuttals to these views increased in both the postinstructional and maintenance essays from the preinstructional essay. No significant changes were found in total argumentation frequency between the Notecards-based and postinstructional candidate essays, and between the Notecards-based and maintenance essays, supporting our hypothesis that argumentation strategies would be transferred and maintained on these essays. Increases in the number of data claims from the Notecards-based to the postinstructional candidate essay, and the number of warrants from the post-instructional candidate to the maintenance essay approached significance, suggesting some development of evidence and/or articulation of values in the students' written arguments after the project's conclusion.

We also hypothesized that strategic knowledge developed by the project would transfer to a written essay on a similar topic—issue selection. Increases in the frequency of claims and warrants were significant from the preinstructional to postinstructional essays on issue selection, indicating some transfer of the decision-making/argumentation strategies used for the Notecards-based essay. No other significant increases were found, however, failing to lend further support to our hypothesis that this knowledge could transfer to a similar topic and context.

Changes in the "Depth" of Argumentation

The previous results reflect what might be called the overall "breadth" of argumentation, as represented by total (elaborated and unelaborated) frequency of each aspect of argument. Elaborated responses were defined as clear, specific, circumscribed statements with explicit references ("AIDS is a major social problem for all Americans"); unelaborated responses were more general, vague responses with no particular referent ("AIDS is a major problem"). The "depth," or elaboration, of these arguments was examined as well. Table 5 represents the results of these analyses. Each column of the table depicts comparison of two essays; rows represent elaborated aspects of argumentation. Comparisons of elaborated responses are given in the same format as on Table 4. Significance levels are given at the bottom of the table.

It was expected that there would be significant increases in frequency of elaborated aspects of argument from the pretreatment candidate to the Notecards-based essay. Significant increases were found in the claim, data claim, warrant, and counter claim, rebuttal data, and rebuttal warrant frequencies of elaborated scores from the preinstructional to Notecards-based essay on candidate selection, further supporting our hypothesis that the project would produce improvements in written argumentation knowledge. These noted increases in elaboration of claims,

Table 5. Comparisons of Argumentation Category Frequency (Elaborated Only) by Essay

		Essay Comparisons					
		Pre-Candidate/ Notecards	Pre-Candidate/ Post-Candidate	Pre-Candidate/ 2 Months Post	Notecards/ Post-Candidate	Notecards/ 2 Months Post	Pre-Issue/ Post-Issue
	Proposition	10/10	10/10	10/10	10/10	10/10	11/10
	Claim	24/55*	24/42*	24/54*	55/42	55/54	15/29
	Data Claim	5/55*	5/34*	5/41*	55/34	55/41	4/11
	Warrant	5/43*	5/50*	5/71*	43/50	43/71*	0/15[a]
Aspect	Qualification	1/4[a]	1/8	1/14*	4/8	4/14	4/4[a]
of	Counter Claim	0/17*	0/16	0/17*	17/16[a]	17/17	0/9[a]
Argument	Counter Data	0/1[a]	0/7[a]	0/5[a]	1/7[a]	1/5[a]	0/2[a]
	Counter Warrant	0/0[a]	0/0[a]	0/2[a]	0/0[a]	0/2[a]	0/1[a]
	Rebuttal Claim	0/13	0/14	0/16*	13/14	13/16	0/6[a]
	Rebuttal Data	0/11	0/7[a]	0/9	11/7	11/9	0/3[a]
	Rebuttal Warrant	0/7[a]	0/7[a]	0/10	7/7[a]	7/10[a]	0/7[a]

* = $p < .05$ (one-tailed)
[a]Insufficient (N <8) data

evidence, backing, and opposing and rebutting statements paralleled the increases found in total frequencies of argumentation.

Significant increases were found in elaborated data claims, warrants, qualifications, counter claims, and rebuttal claims from the preinstructional to postinstructional essay. Significant increases were found in the frequency of elaborated claims, data claims, warrants, qualifications, counter claims, and rebuttal claims, data, and warrants from preinstructional to maintenance essay. As with comparisons of overall frequencies between the candidate essay written before the project and the candidate essay written two months after its conclusion, there was development of more elaborated statements in almost all aspects of argumentation.

We expected that strategies representative of more elaborated argumentation would transfer and be maintained on later essays. No significant changes were found from the Notecards-based to the postinstructional essay in the frequency of elaborated scores, nor from the Notecards-based to the maintenance essay, supporting hypotheses addressing transfer and maintenance of argumentation knowledge. This parallels the previous findings of total frequencies of argumentation: strategies were transferred and maintained for two months on essays of candidate selection.

We also expected that elaborated aspects of argument would significantly increase with an essay on a similar topic. No significant increases were found in elaborated scoring frequencies from the preinstructional to postinstructional essays on issue selection, again failing to support the hypothesis that transfer of strategic knowledge would be evident on a similar topic.

Changes in Notecards-Based Information in Essays

We were concerned that the transfer and maintenance of the strategic knowledge to subsequent candidate essays merely reflected the student's learning of the information in the Notecards knowledge base, independent of its organization and other instructional supports. A descriptive comparison of the relative amount of Notecards-based information among the preinstructional, Notecards, transfer and maintenance essays is depicted in Figure 6. These percentages are based on total frequency of elaborated and unelaborated scores for each aspect of argument. Total percentages of Notecards based information in the students' Notecards, transfer, and maintenance essays were tabulated. Figure 6 is a graphic comparison of these percentages for each student. Students are represented on the horizontal axis; percentage of Notecards-based information on the vertical axis. As would be expected, the percentage of Notecards-based information used in the preinstructional essay was considerably lower than that used in the Notecards-based essay. But the percentage of Notecards-based information tended to decrease from the Notecards based essay to the postinstructional and maintenance essays, supporting the notion that exposure to the Notecards knowledge base was

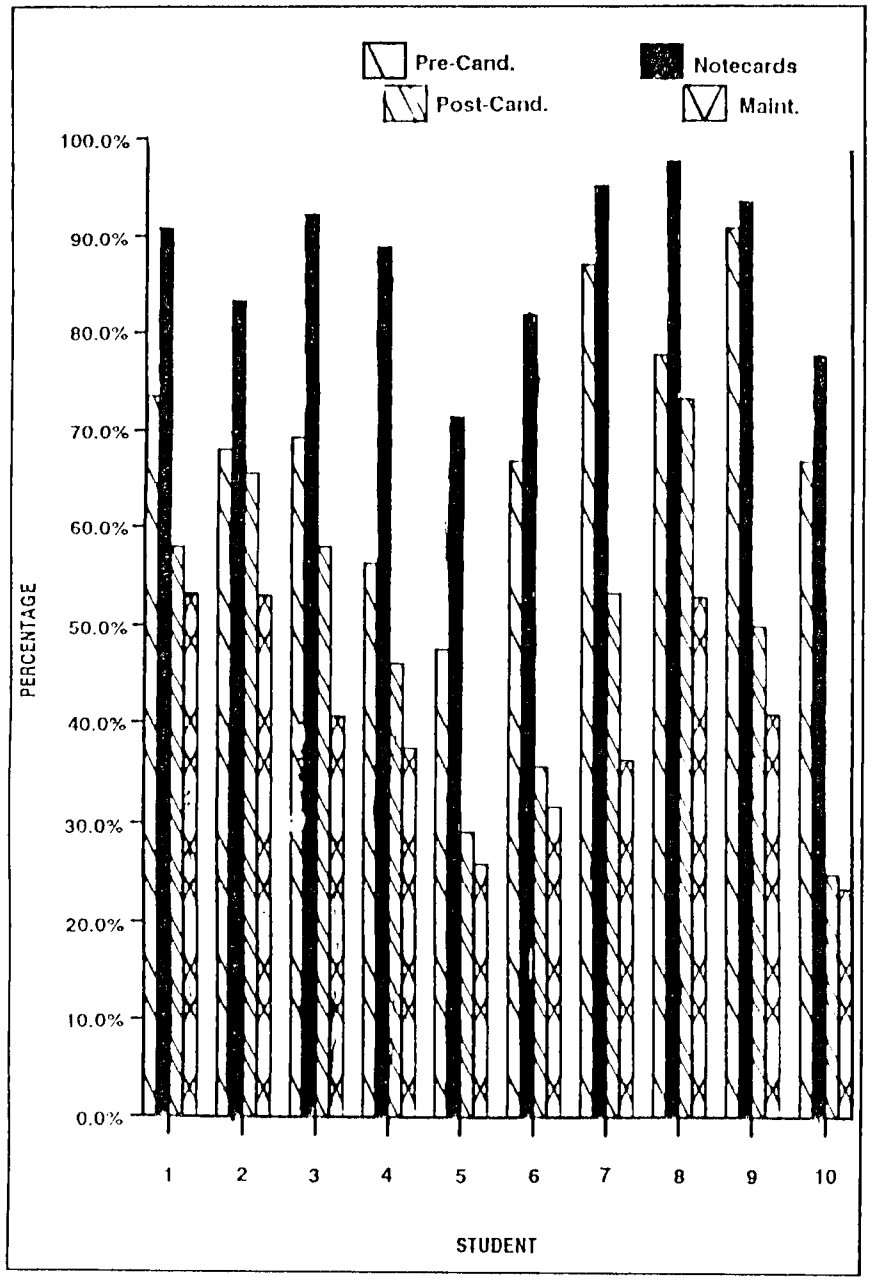

Figure 6. Percentage of Notecards-based information by student in Precandidate, Notecards, Post Candidate and Maintenance Essays.

insufficient to explain the transfer and maintenance of argumentation strategies on the topic of candidate selection. Mean decreases in percentages (N = 10) were 13.0 percent between the Notecards and postinstructional candidate essays; 20.8 percent between the Notecards and maintenance essays.

Comparisons of Information Used in Notecards and IDEA

We felt that comparisons of candidates, criteria/claims, and Notecards-based information used in criteria/claims might offer indicators of the relative impact of the two instructional technologies on the content and "structure" of the Notecards-based essay. Spearman's Rho Correlation Coefficient [98, 99] was chosen as the appropriate statistical test for these comparisons. A significance level of $p < .05$ (one-tailed) was established. Table 6 is a summary of these statistical comparisons. Aspects of the Notecards-based essay are represented by the columns in Table 6; summary data from the IDEA and Notecards programs are listed in the rows. Significant correlations were found between the coded top-ranked candidate in IDEA and the candidate written about in Notecards (Rho = .99); the amount of Notecards-based knowledge in IDEA-based criteria and total claims on the essay (Rho = .89); and between the number of criteria rated above 75 in IDEA and the total number of claims in the Notecards-based essay (Rho = .68).

Comparison of Cognitive Strategy Use and Metacognitive Activity

We also wanted to examine whether the largely theoretical relationship between cognitive and metacognitive strategy development could be empirically substantiated. To do this, we correlated "metacognitive index" scores with total and elaborated frequencies of argumentation on the Notecards-based essay. As before, we chose Spearman's Rho Correlation Coefficient [98, 99] as the appropriate statistical test, using the same one-tailed significance level. Table 6 also offers these statistical comparisons. Significant correlations were found, both between the index and total frequency of argumentation (Rho = .68) and the index and the elaborated frequency of argumentation (Rho = .78).

Qualitative Findings

Systematic comparison of the type, number and sequence of interactions with Notecards and IDEA, essay argumentation scores and their diagrammed structures was undertaken. Several major trends can be noted. Student responses, throughout the study, tended to parallel the organization of the task environment (in Notecards and IDEA) and/or instructions related to a particular task. For example, most students reviewed information from the Notecards knowledge base on order of its appearance—from top to bottom—in the Table of Contents (see Figure 4) when first introduced to the software.

Table 6. Correlations of IDEA/Notecards Process Data with Essay Argumentation Frequencies

		Notecards Essay Argumentation Data					
		Propositions	% Notecards—Claims	Claims (Total)	Claims (Elaborated)	Data Claims (Total)	Data Claims (Elaborated)
IDEA/	Top-Ranked Candidate	.99*					
Notecards	% Notecards—Criteria		.89*				
Data	# Criteria >75%			.68*	.52		
	# Fileboxes			.51	.38		
	# Notecards					.36	.30
	Metacognitive Index			.68*	.78*		

* = $p < .05$ (one-tailed)

However, after several strategies that could be used to search the information were discussed in the following session, the order of review became more varied and diverged from the organization of the knowledge base. Most students followed the module order of IDEA without revising previous work. The order of review of Notecards information during work with IDEA paralleled the order of information requested in IDEA. Within those organizational constraints, students appeared to discriminate as to which information they considered. For example, even though Notecards-based information with a heading beginning with the letter "a" would be reviewed before information beginning with a "d," not all information beginning with "a" was reviewed by the student. Most frequently, information reviewed in Notecards would be entered in IDEA, suggesting that information chosen for review in Notecards reflected the student's familiarity with and/or value placed on that information.

Secondly, students varied widely in their demonstration of metacognitive activity during the project. Information about other levels of organization of the Notecards and IDEA programs—beyond what was offered prominently on the screen—was frequently not reviewed. Browsers in Notecards that depicted conceptual links between different issues or candidates were usually neglected. Whereas the argumentation structure in the students' essays involved linkages between the candidate and their views on issues, the links created in the Notecards knowledge base also emphasized the connections amongst the various issues (such as "military" being related to "SDI" and "nuclear freeze"). Only two students opened browsers on these issue-to-issue links. Contextual information (the background and history of the social issues) in Notecards, similarly, was rarely read. We had anticipated that this information might serve as a source for warrants in written arguments. However, most students relied on personal information or experience to offer a warrant to an argument rather than the history offered on each issue.

Reference to the executive map or reviewing work in previous modules of IDEA, even when verbalizing the need to revise that work, was somewhat limited. Three students went back to revise, in two cases to alter ratings after disagreeing with the top-ranked candidate in the final module. Although some students wrote out their own notes on the information they covered in the Notecards system, students varied in reviewing their notes when deciding upon a candidate in IDEA or writing about the candidate in the Notecards system.

Thirdly, although candidates and criteria considered in the two software programs were those written about by the students in the subsequent essays, similarly in the strategies for deciding about and structuring the paper around this information were not clear beyond this "top level" of organization. For example, the order of presentation of information in the essays did not follow the order of review or the ascribed relative value of the information prior to writing the essay.

In other aspects of the project, however, the differences between students' activities were more striking than the similarities. Two general profiles emerged

as we reviewed the data: those students that tended to explore more structural aspects of IDEA and Notecards (the browsers, executive map) also tended to review and revise their work more and write essays with a more elaborated, "nested" organization—both before and after the project; and those students who interacted less with the two technologies, rarely reviewed or revised work, and wrote essays of a more general, "linear" argumentation structure. The first group of students used more of the information available within Notecards for the Notecards-based, posttreatment candidate, and issues essays, yet tended not to use the advice cards when composing their work. This group also tended to write more counterarguments and rebuttals after the project's conclusion, as well as producing posttreatment issue essays that were markedly more detailed than those they wrote before instruction began. The second group used less information from Notecards for the Notecards-based essay and, when they did, they tended to use the literal text in their writing. They referred to advice cards more frequently than the other group, going through the entire set at least once.

We cannot characterize the two groups as distinct on all aspects described, but these profiles describe nine of the ten students who completed the study. None of the information known about these students at the beginning of the project (reported achievement in social studies or English, experience with computers, gender, cultural background) allows for delineation of these same two groups.

DISCUSSION

Results of this study support our prediction that the two computer technologies and the related instructional method would facilitate the development of written argumentation about selection of a political candidate, particularly in the generation and elaboration of evidence, counterarguments, and values as they relate to decision making and reasoning about social issues. These particular strategies were maintained, and perhaps further developed, months after access to the knowledge base had ended. The positive effects of these new technologies on problem solving and reasoning is significant, particularly in the context of recent research suggesting minimal facilitation of these strategies with other, more familiar programs such as LOGO [100, 101]. Equally important is the finding that these strategies were maintained well after the project had ended. Although this might be understood as the result of maturational processes deemed responsible for strategy improvement [89] or for transfer of this knowledge to other problems [20, 90], neither possibility precludes our belief that the project facilitated later, equally effective use of these same strategies. And the essays' contents suggest that the students continued to read, listen, and think about their candidate choice after the project's end.

Exposure to the information separate from the technological and instructional supports, it might be argued, contributes more to explaining the development of written reasoning found than the supports themselves [102, 103]. In a general sense, this addresses the relative influence of "declarative" knowledge on the development of the solution. For example, large increases from the preinstructional to the Notecards-based essay were found in statements reflecting information available on the Notecards system. The significant increases found in several aspects of argumentation between these two sets of essays could be the result of reading the knowledge base—regardless of the technologies or instructional method.

However, the percentage of Notecards-based information declined on subsequent essays while the elaboration of written arguments was maintained. Furthermore, the frequency of higher scores on "data claims" (evidence based on information) significantly increased from the Notecards to the postinstructional essay even though the students did not have continuing access to the knowledge base. This suggests to us that strategies acquired during the project developed somewhat independently of the domain-specific knowledge.

The choice to use Hillock's [46] scoring method as an outcome measure for the study—based on Toulmin's [40] model and the conceptual overlap of the aspects of argumentation in his scoring method with critical components of reasoning in other research [11, 102, 104]—proved valuable for highlighting a distinction between an argumentation structure and the definition and elaboration of the structure's components. The structure of the essays of most students who began using more elaborated arguments and counterarguments by the end of instruction changed from a "linear," "summary" structure to a more "nested," "hierarchical," "analytic" one [46, 75]. One student's Notecards-based essay was structured as a "dialogue" between the writer and the chosen candidate; in later essays, the writer "orchestrated" a dialogue between several candidates. This would seem to indicate advanced cognitive development, coordinating alternative aspects to a problem [89, 105] requiring, we believe, the development of planning and metacognitive capacities [74, 106].

The larger research issues addressed were the potential for transfer of strategic knowledge to a topic we viewed as similar, and the relationship between metacognition and strategy use. The results indicated, to our surprise, a relative lack of transfer of argumentation to the "issue" essays. Transfer that did appear to occur was of a "narrow" type: from the Notecards environment to the handwritten essay on candidate selection and the general "breadth" of arguments made about the most important issue. We made every effort to avoid failing to enhance transfer with the establishment of tasks and teaching methods proposed by the cognitive research on transfer and maintenance of strategic knowledge [12, 25, 107]. However, certain critical elements in the instructional methods might have been absent for transfer to occur. For example, although the strategic knowledge involved in these tasks was explicitly discussed and modeled with students in this project, it is possible that lack of "conditional" knowledge, when and why to apply strategies, prevented the students from seeing the transfer task as similar [108]. Had the researcher explicitly discussed the elements of structural and procedural similarity

between the candidate and issue selection tasks, the positive transfer to the issue task might have been more significant [20, 49].

Rather than a design failure, however, we propose that this demonstrates a failure to support the "common elements" models in recent transfer research [10, 12, 49, 51-53]. The distance between the two tasks—perhaps best determined by knowledge and strategy elements they had in common—was relatively small. Theoretically, the selection and writing about a candidate and issue have several common strategic elements including scanning of information about options, weighing these options, and development of reasons for the final selection. In addition, the transfer task potentially involved the same knowledge base and organization as the candidate selection task, following these models, which should have facilitated use of similar argumentation strategies. That this did not occur may have had more to do with another category of tasks elements—the representational [49].

Learners may represent problems quite differently, suggesting that representations may be greatly influenced by assumptions made about the tasks themselves [25, 109, 110]. Reasoning about a candidate, explicitly involving one's *personal* opinion, might be different from reasoning about a *social* issue, involving assessment of *social* opinion. How one's belief system is brought to bear on each topic—the perspective—might therefore be different [102]. As discussed in the instructional methods, students were instructed to decide upon a candidate based on their own choice—versus who could be elected—because all three students in the pilot study explicitly asked for this to be clarified. In addition, students tended to use their general beliefs about other people's concerns to buttress their selection of an issue—resulting in more claims and warrants than data or evidence in these essays—versus using information represented in Notecards knowledge base to which they would personally react, as in the candidate essays. Both trends indicate to us that cognitive models of transfer need to consider the belief system or the perspective of the learner in relation to the task—something that common elements approaches, for example, fail to do [47]. Future research on perspective-taking in relation to strategy development and transfer—a central aspect of Vygotsky's [33] theory of cognition—seems a very important area to us, particularly in social studies topics.

Failure to represent tasks in similar ways may also be the result of individual differences in cognitive development [49]. Metacognitive awareness may be central to how the problem is represented, and the knowledge and strategies that are selected [73, 106]. The significant correlations between our metacognitive index and argumentation scores on the essays support that there is such a relationship: the students who engaged in metacognitive activities during the project tended to have broader and more elaborated arguments.

Due to the limited capacities of attention in relation to a relatively large volume of information in the computer program environments themselves, use of this "higher-order" information as support in conceptualizing a solution was difficult.

People may use a "simplified problem space," ignoring some information, to solve a problem. Some researchers have emphasized the constraints tasks may place on decision making, including the problem "size" and the number of available alternative solutions [49, 90, 111]. Over 400 notecards and fileboxes of information made up the Notecards knowledge base; each module in IDEA involved several activities simultaneously presented on the screen. Large problems with many solutions or steps toward a solution make processing information for planning, deciding, and evaluating all the more difficult. It is conceivable that if a student had had extended practice with the technologies, "automatizing" more of the basic skills, more metacognitive activity could have occurred with correspondingly greater facility in using the problem-solving and reasoning strategies [49].

We hoped to find statistical support for the ways we viewed these technological environments to be similar. If certain elements were similar, we reasoned, this would offer more systematic "practice" for students in the examination of their beliefs and leading to a particular argumentation structure. The statistical comparisons based on these observed similarities, addressing correlations of targeted activities' frequencies, were supported, particularly in the more general, organizing aspects of the IDEA environment and the argumentation in the Notecards-based essay. "Options" in IDEA became "propositions" in the essay; the frequency of top-ranked "criteria" and overall "criteria" in IDEA matched the frequency of "claims" in the essay. More frequently reviewed fileboxes of "issues/positions" in Notecards usually become "criteria" in IDEA and, without exception, the "criteria" in IDEA were later used as "claims." These similarities suggest to us systematic "practice" or problem-solving and reasoning strategies while interacting with both technologies which, we would argue, contributed to the significant increases in breadth and depth of written arguments.

There were qualitative indications that activities in the two software programs and instructional method directly supported the students' use of more expert decision-making and reasoning strategies as discussed in the theoretical and research literature. Students' interaction with the software programs were behaviorally similar to the problem-solving or reasoning strategies presented by the researcher of computer screen during a particular phase of the project. When advised to "broaden" the search of Notecards information to model after expert strategies in decision making and reasoning (the second session of instruction), students tended to review a greater variety of fileboxes of information than in the first session (where information was reviewed in order of appearance similar to text reading) even though interaction frequency was roughly equivalent in the two sessions. Students tended to revise or add to their writing of the Notecards essay after reviewing the advice cards.

Particularly striking is the tendency of students to search the Notecards file in an order supported by the decision-making activities in IDEA: initial "divergent" and brief review of information while generating options and criteria; "convergent"

and in-depth review of information when evaluating criteria for each option; and focussed review of information on the chosen option prior to writing the paper on that option. Guilford [112], in discussing the cognitive operations in problem solving, proposes that the use of divergent and convergent production followed by evaluation of the problem solution are predominant phases in the decision-making process.

It has been assumed in past research with such programs as LOGO that technological supports were sufficient to develop cognitive and metacognitive strategies. However, results of many studies have largely refuted this premise [113, 114]. In order for the metacognitive activity identified with problem solving and reasoning to develop, for example, available "hierarchical" supports might be explicitly modeled and/or integrated into a procedural facilitation method similar to the one used here. We would propose, for example, that diagramming of the students' essays and (somewhat like a text analysis strategy [115]) contrasting these with structural diagrams of the Notecards knowledge base, the IDEA environment, and various models of argumentation might facilitate the development of metacognitive knowledge. This would be part of the process of "reflection" and "articulation" advocated by, for example, Collins and Brown and their associates [31, 36, 37]. There is a potential tradeoff in this approach, as students required to use these hierarchical structures would be more constrained in the formulation of their arguments. Yet as a systematic process for reviewing one's personal beliefs and the subsequent way a task is represented, it might prove invaluable as an instructional method.

REFERENCES

1. G. Bateson, Information and Codification, in *Communication*, J. Ruesch and G. Bateson (eds.), Norton Books, New York, 1968.
2. A. M. Turing, Computing Machinery and Intelligence, *Mind, 59*:236, 1950.
3. J. Weizenbaum, *Computer Power and Human Reason*, W. H. Freeman, San Francisco, California, 1976.
4. M. Scriven, The Mechanical Concept of Mind, *Mind, 62*:246, 1953.
5. R. D. Pea and K. Sheingold, *Mirrors of Minds: Patterns of Experience in Educational Computing*, Ablex Publishing, Norwood, New Jersey, 1988.
6. Laboratory of Comparative Human Cognition, Culture and Cognitive Development, in *Handbook of Child Psychology*, W. Kessen (ed.), Volume 1, Wiley Publishing, New York, 1983.
7. D. Newman, P. Griffin, and M. Cole, *The Construction Zone: Working for Cognitive Change in School*, Cambridge University Press, Cambridge, 1989.
8. S. Scribner and M. Cole, *The Psychology of Literacy*, Harvard Press, Cambridge, Massachusetts, 1981.
9. R. D. Pea, Beyond Amplification: Using the Computer to Reorganize Mental Functioning, *Educational Psychologist, 20*, pp. 167-182, 1985.

10. R. H. Ennis, Critical Thinking and Subject Specificity: Clarification and Needed Research, *Educational Researcher, 18*, pp. 4-10, 1989.
11. K. M. Galotti, Approaches to Studying Formal and Everyday Reasoning, *Psychological Bulletin, 105*, pp. 331-351, 1989.
12. D. N. Perkins and G. Saloman, Are Cognitive Skills Context Bound?, *Educational Researcher, 18*, pp. 16-25, 1989.
13. S. McCormick and J. Zutell (eds.), *Cognitive and Social Perspectives for Literacy Research and Instruction*, National Reading Conference, Chicago, Illinois, 1989.
14. L. Resnick and L. Klopfer (eds.), *Toward the Thinking Curriculum: Current Cognitive Research*, Association for Supervision and Curriculum Development, Baltimore, Maryland, 1989.
15. J. D. Bransford, L. I. Goin, T. S. Hasselbring, C. Z. Kinzer, R. D. Sherwood, and S. M. Williams, Learning with Technology: Theoretical and Empirical Perspectives, *Peabody Journal of Education, 64*, pp. 5-26, 1988.
16. M. Cochran-Smith, J. Kahn, and C. L. Paris, Teachers, Children, and Word Processing: Working with a Felicitous Tool, Paper presentation, Annual Meeting of the American Educational Research Association, 1989.
17. D. F. Bjorklund, *Children's Thinking: Developmental Function and Individual Differences*, Brookes/Cole, Pacific Grove, California, 1989.
18. J. C. Campione, A. L. Brown, and M. L. Connell, Metacognition: On the Importance of Understanding What You Are Doing, in *The Teaching and Assessing of Mathematical Problem-Solving*, R. Charles and E. A. Silver (eds.), L. Erlbaum, and National Council of Teacher of Mathematics, Hillsdale, New Jersey, 1988.
19. D. Thornburg, "Task Proficiency" Rather than "Student Proficiency": Convergences in the Research on Learning and the Implications for the Social Reorganization of Schooling, Paper presentation, Annual Meeting of the American Educational Research Association, 1990.
20. E. C. Butterfield and G. D. Nelson, Instruction of Knowledge, Strategies, and Metacognition as Ways to Promote Positive Transfer of Different Types, *Cognition and Instruction, 6*, pp. 41-68, 1989.
21. N. Cole, Conceptions of Educational Achievement, *Educational Researcher, 19*, pp. 2-7, 1990.
22. P. A. VanLeuvan, M. C. Wang, A. McGill, and L. Porembo, The Use of Monitoring and Checking Processes in the First and Second Grade, Paper presentation, Annual Meeting of the American Educational Research Association, 1989.
23. T. Beuhring and D. W. Kee, Developmental Relationships among Metamemory, Elaborative Strategy Use, and Associative Memory, *Journal of Experimental Child Psychology, 44*:3, pp. 377-400, 1987.
24. E. C. Butterfield, T. O. Peck, and V. Peck, Developmental Aspects of the Feeling of Knowing, *Developmental Psychology, 24*, pp. 654-663, 1988.
25. E. C. Butterfield, On Solving the Problem of Transfer, in *Practical Aspects of Memory* (Volume 2), M. M. Gruneberg, P. E. Morris, and R. N. Sykes (eds.), Academic Press, London, 1988.
26. S. A. Cohen, J. Hyman, L. Ashcroft, and D. Loveless, Mastery Learning vs. Learning Styles vs. Metacognition: What Do We Tell the Practitioners?, Paper presentation, Annual Meeting of the American Educational Research Association, 1989.

27. J. D. Bransford, R. D. Sherwood, T. S. Hasselbring, C. K. Kinzer, and S. M. Williams, Anchored Instruction: Why We Need It and How Technology Can Help, in *Advances in Computer-Video Technology*, D. Nix and R. Spiro (eds.), L. Erlbaum, Hillsdale, New Jersey, in press.
28. B. Bruce and A. Rubin, *Writing Quills: A Situated Evaluation of Using Computers for Writing in Classrooms*, L. Erlbaum, Hillsdale, New Jersey, 1990.
29. J. Littlefield, V. Delclos, S. Lever, K. Clayton, J. Bransford, and J. Franks, Learning Logo: Method of Teaching, Transfer of General Skills and Attitudes Towards School and Computers, in *Teaching and Learning Computer Programming*, R. E. Mayer (ed.), L. Erlbaum, Hillsdale, New Jersey, 1988.
30. The Cognition and Technology Group at Vanderbilt, Anchored Instruction and Its Relationship to Situated Cognition, *Educational Researcher, 19*, pp. 2-10, 1990.
31. A. Collins, Toward a Design Science of Education, in *New Directions for Educational Technology*, E. Scanlon and T. O'Shea (eds.), Springer-Verlag, New York, 1989.
32. L. S. Vygotsky, *Mind in Society: The Development of the Higher Psychological Processes*, Harvard Press, Cambridge, Massachusetts, 1978.
33. L. S. Vygotsky, *The Collected Works: Volume 1. Problems of General Psychology*, Plenum Press, New York, 1987.
34. J. S. Brown, Process versus Product: A Perspective on Tools for Communal and Informal Electronic Learning, in *Report from the Learning Lab: Education in the Electronic Age*, S. Newman and E. Poor (eds.), Educational Broadcasting System, WNET: New York, 184.
35. G. Foreman and P. Pufall (eds.), *Constructivism in the Computer Age*, L. Erlbaum, Hillsdale, New Jersey, 1988.
36. A. Collins, J. S. Brown, and P. Duguid, Situated Cognition and the Culture of Learning, *Educational Researcher, 18*, pp. 5-17, 1989.
37. J. S. Brown, A. Collins, and S. E. Newman, The New Apprenticeship: Teaching Students the Craft of Reading, Writing, and Mathematics, in *Cognition and Instruction: Issues and Agendas*, L. B. Resnick (ed.), L. Erlbaum, Hillsdale, New Jersey, 1988.
38. R. Gagne, *The Conditions of Learning* (3rd Edition), Holt, Rhinehart, and Winston, New York, 1977.
39. H. A. Simon, *Reason in Human Affairs*, Stanford University Press, Palo Alto, California, 1983.
40. S. Toulmin, *The Uses of Argument*, CambridgeUniversity Press, New York, 1958.
41. D. N. Perkins, *Knowledge as Design*, Harvard Press, Cambridge, Massachusetts, 1986.
42. G. Polya, *How to Solve It: A New Aspect of Mathematical Method*, Princeton University Press, Princeton, New Jersey, 1945.
43. A. Schoenfeld, Metacognitive and Epistemological Issues in Mathematical Understanding, in *Teaching and Learning Mathematical Problem Solving*, E. Silver (ed.), L. Erlbaum, Hillsdale, New Jersey, 1985.
44. L. Vedung, *Political Reasoning*, Basic Books, New York, 1982.
45. C. A. Willard, *Argumentation and the Social Grounds of Knowledge*, University of Alabama Press, University, Alabama, 1983.

46. G. Hillocks, Analyzing the Structure of Written Argument, Paper presentation, Annual Meeting of American Educational Research Association, 1987.
47. R. D. Pea, Socializing the Knowledge Transfer Problem, *International Journal of Educational Research, 11*, pp. 639-663, 1987.
48. G. Saloman and D. N. Perkins, Rocky Road to Transfer: Rethinking Mechanisms of a Neglected Phenomenon, *Educational Psychologies, 24*, pp. 113-142, 1989.
49. E. C. Butterfield and G. D. Nelson, Theory and Practice of Teaching for Transfer, *Educational Technology Research and Development, 37*, pp. 5-38, 1989.
50. D. B. Palumbo, Programming Language/Problem-Solving Research: A Review of Relevant Issues, *Review of Educational Research, 60*, pp. 65-89, 1990.
51. D. Kieras and P. G. Polson, An Approach to the Formal Analysis of User Complexity, *International Journal of Man-Machine Studies, 22*, pp. 365-394, 1985.
52. P. G. Polson, S. Bouvair, and D. Kieras, Transfer between Text Editors, in *Conference Proceedings of Human Factors in Computing Systems and Graphics Interface*, J. M. Carroll and P. P. Tanner (eds.), Association for Computing Machinery, New York, 1987.
53. P. G. Polson, E. Muncher, and G. Engelbeck, A Test of a Common Elements Theory of Transfer, in *Human Factors in Computing Systems: CHI '86*, M. Mantei and P. Oberton (eds.), Association for Computing Machinery, New York, 1986.
54. M. T. H. Chi, Interactive Roles of Knowledge and Strategies in the Development of Organized Sorting and Recall, in *Thinking and Learning Skills*, Volume 2, S. F. Chipman, J. W. Segal, and R. Glaser (eds.), L. Erlbaum, Hillsdale, New Jersey, 1985.
55. D. Gentner, The Mechanisms of Analogical Learning, in *Similarity and Analogical Reasoning*, S. Vosniadou and A. Ortony (eds.), Cambridge University Press, New York, 1989.
56. D. Alverman, Strategic Teaching in the Social Studies, in *Strategic Teaching and Learning: Cognitive Instructions in the Content Areas*, B. F. Jones, M. Palincsar, L. Ogle, and S. Carr (eds.), Association for Supervision and Curriculum Development, Washington, D.C., 1987.
57. I. L. Beck, M. G. McKeoun, and E. W. Gromoll, Learning from Social Studies Texts, *Cognition and Instruction, 6*:2, pp. 99-158, 1989.
58. B. G. Massialas and G. J. Papagiannis, Toward a Critical Review of Computers in Education: Implications for Social Studies, *The Social Studies, 78*, pp. 47-53, 1987.
59. J. F. Voss, T. Greene, T. A. Post, and B. A. Penner, Problem-Solving Skill in the Social Sciences, in *The Psychology of Learning and Motivation* (Volume 17), G. H. Bower (ed.), Academic Press, New York, 1983.
60. K. S. Kitchener, Cognition, Metacognition, and Epistemic Cognition: A 3-Level Model of Cognitive Processing, *Human Development, 26*, pp. 222-232, 1983.
61. H. Hertzberg, *Social Studies Reform, 1880-1980*, Social Science Education Consortium, Boulder, Colorado, 1981.
62. C. M. Lusk and C. M. Judd, Political Expertise and the Structural Mediators of Candidate Evaluations, *Journal of Experimental Psychology, 24*:2, pp. 333-352, 1988.
63. C. Wilcox, Risk Taking and Presidential Voting, *Journal of Social Psychology, 129*, pp. 99-158, 1989.

64. S. F. Larsen, Remembering Reported Events: Memory for News in Ecological Perspectives, Paper presentation, Conference on Practical Aspects of Memory and Cognition, 1986.
65. M. Cole, J. Gay, J. Glick, and D. W. Sharp, *The Cultural Context of Learning and Thinking*, Basic Books, New York, 1971.
66. I. L. Janis and L. Mann, *Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment*, Free Press, New York, 1977.
67. J. F. Marquette and K. A. Hinkley, Voter Turnout and Candidate Choice: A Merged Theory, *Political Behavior, 10*:1, pp. 52-76, 1988.
68. A. Smith, Promoting Reasoning Skills: An Interdisciplinary Approach, *The Social Studies, 77*, pp. 260-263, 1985.
69. R. J. Tierney, A. Soter, J. O'Flahavan, and W. McGinley, The Effects of Reading and Writing upon Thinking Critically, *Reading Research Quarterly, 24*:2, pp. 134-173, 1989.
70. D. Wood, *How Children Think and Learn: The Social Contexts of Cognitive Development*, Basil Blackwell, Limited, Oxford, England, 1989.
71. W. Chafe and J. Nichols, *Evidentiality: The Linguistic Coding of Epistemology*, Ablex Publishing, Norwood, New Jersey, 1986.
72. R. D. Pea and D. M. Kurland, Cognitive Technologies for Writing, in *Review of Research in Education*, E. Rothkopf (ed.), American Educational Research Association, Washington, D.C., 1987.
73. B. L. Wong, R. Wong, and J. Blenkinsop, Cognitive and Metacognitive Aspects of Learning Disabled Adolescents' Composing Problems, *LD Quarterly, 12*:4, pp. 300-322, 1989.
74. L. Flower and J. R. Hayes, A Cognitive Process Theory of Writing, *College Composition and Communication, 32*, pp. 365-387, 1981.
75. G. Hillocks, The Writer's Knowledge: Theory, Research, and Implications for Practice, in *The Teaching of Writing: 85th Yearbook of the National Society for the Study of Education, Part II*, A. R. Petrosky and D. Bartholomae (eds.), University of Chicago, Chicago, Illinois, 1985.
76. R. D. Pea, *Learning General Thinking Skills with Computers*, Proposal to the Spencer Foundation, 1986.
77. W. Edwards and J. R. Newman, Multiattribute Evaluation, in *Judgement and Decision Making: An Interdisciplinary Reader*, H. R. Arkes and K. R. Hammond (eds.), Cambridge University Press, New York, 1986.
78. H. J. Einhorn and R. M. Hogarth, Judgement and Decision: Theory and Application, *Annual Review of Psychology, 32*, pp. 53-88, 1981.
79. R. L. Keeney, Multiattribute Utility Theory, *Operations Research, 30*, pp. 803-838, 1982.
80. P. Slovic, B. Fischhoff, and S. Lichtenstein, Behavioral Decision Theory, *Annual Review of Psychology, 28*, pp. 1-39, 1977.
81. J. E. Russo and B. A. Dosher, Strategies for Multiattribute Binary Choice, *Journal of Experimental Psychology: Human Learning and Memory, 9*, pp. 676-696, 1983.
82. R. D. Pea, J. Cohen, C. Brunner, N. Mellen, and K. Webster, IDEA: Tools for Learning Systematic Decision Analysis, Paper presentation, American Educational Research Association, Washington, D.C., 1987.

83. J. Cohen and R. D. Pea, *IDEA: A Support Environment for Interactive Decision Envisioning*, Video presentation, Computer-Human Interaction SIG of the Association for Computing Machinery, 1988.
84. F. G. Halasz, T. P. Moran, and R. H. Trigg, Notecards in a Nutshell, in *Proceedings of the 1987 ACM Conference of Human Factors in Computer Systems*, Toronto, Canada, CHI+ GI '87, pp. 45-52, 1987.
85. F. G. Halasz, Reflections on Notecards: Seven Issues for the Next Generation of Hypermedia Systems, *Communications of the ACM, 31*:7, 1988.
86. J. Larkin, F. Reif, J. Carbonnell, and A. Gugliotta, FERMI: A Flexible Expert Reasoner with Multi-Domain Inferencing, *Cognitive Science, 12*, pp. 101-138, 1988.
87. G. Saloman, T. Globerson, and E. Guterman, The Computer as a Zone of Proximal Development: Internalizing Reading-Related Cognitions from a Reading Partner, *Journal of Educational Psychology, 81*:7, pp. 620-627, 1989.
88. M. Scardamalia and C. Bereiter, Cognitive Coping Strategies and the Problem of "Inert Knowledge," in *Thinking and Learning Skills* (Volume 2), S. F. Chipman, J. W. Segal, and R. Glaser (eds.), L. Erlbaum, Hillsdale, New Jersey, 1985.
89. R. Case, *Intellectual Development: From Birth to Adulthood*, Academic Press, New York, 1985.
90. R. S. Siegler, *Children's Thinking*, Prentice-Hall, Englewood Cliffs, New Jersey, 1986.
91. N. Hess and L. Torney, *Children's Political Thinking*, Holt, Rinehart, and Winston, New York, 1971.
92. M. C. Linn, Gender Equity in Computer Learning Environments, *Computers and the Social Sciences, 1*, pp. 19-27, 1985.
93. B. I. Newman and J. N. Sheth, the "Gender Gap" in Voter Attitudes and Behavior, *Journal of Advertising, 13*, pp. 4-16, 1984.
94. L. A. Shanoski, An Analysis of the Effectiveness of Using Microcomputer Assisted Mathematics Instruction with Primary and Intermediate Level Students, *Dissertation Abstracts International, 47*, pp. 3653A, 1987.
95. J. W. Hausmann, Teaching a Systematic Approach to Prudent Voting, *The Social Studies, 77*, pp. 176-178, 1985.
96. C. J. Drew and M. L. Hardiman, *Designing and Conducting Behavioral Research*, Pergamon Press, New York, 1985.
97. J. P. Guilford and B. Fruchter, *Fundamental Statistics in Psychology and Education*, (5th Edition), McGraw-Hill, New York, 1973.
98. S. Siegel, *Nonparametric Statistics for Behavioral Sciences*, McGraw-Hill, New York, 1956.
99. M. D. Lynch and D. V. Huntsberger, *Elements of Statistical Inference for Education and Psychology*, Allyn and Bacon, Boston, Massachusetts, 1976.
100. D. Klahr and S. M. Carver, Cognitive Objectives in a LOGO Debugging Curriculum: Instruction, Learning, and Transfer, *Cognitive Psychology, 20*, pp. 362-404, 1988.
101. R. Lehrer, T. Guckenberg, and O. Lee, Comparative Study of the Cognitive Consequences of Inquiry-Based Logo Instruction, *Journal of Educational Psychology, 80*, pp. 543-553, 1988.

102. R. A. Carlson and D. E. Dulany, Diagnostic Reasoning with Circumstantial Evidence, *Cognitive Psychology, 20*, pp. 463-492, 1988.
103. R. S. Siegler, How Domain-General and Domain-Specific Knowledge Interact to Produce Strategy Choices, *Merrill-Palmer Quarterly, 35*, pp. 1-26, 1989.
104. D. Kuhn, E. Amsel, and M. O'Loughlin, *The Development of Scientific Thinking Skills*, Academic Press, New York, 1987.
105. B. Inhelder and J. Piaget, *The Growth of Logical Thinking from Childhood to Adolescence*, Basic Books, New York, 1958.
106. C. S. Englert, T. E. Raphael, K. L. Fear, and L. M. Anderson, Students' Metacognitive Knowledge about How to Write Informational Texts, *LD Quarterly, 11*, pp. 18-46, 1988.
107. M. L. Gick and K. J. Holyoak, The Cognitive Basis of Transfer, in *Transfer of Learning: Contemporary Research and Applications*, S. M. Cormier and J. D. Hagman (eds.), Academic Press, New York, 1987.
108. B. F. Jones, *Strategic Teaching and Learning: Cognitive Instruction in the Content Areas*, Association for Supervision and Curriculum Development, Alexandria, Virginia, 1987.
109. D. C. Berry and D. E. Broadbent, Problem Solving and the Search for Crucial Evidence, *Psychological Research, 50*, pp. 229-236, 1989.
110. C. Wilcox, Risk Taking and Presidential Voting, *Journal of Social Psychology, 129*, pp. 161-168, 1989.
111. L. E. Bourne, R. L. Dominowski, and E. F. Loftus, *Cognitive Processes*, Prentice-Hall, Englewood Cliffs, New Jersey, 1979.
112. J. P. Guilford, *The Nature of Human Intelligence*, McGraw-Hill, New York, 1967.
113. J. Hawkins and K. Sheingold, The Beginning of a Story: Computers and the Organization of Learning in Classrooms, in *Uses of Microcomputers and Other Technology in Education*, J. Culbertson and L. L. Cunningham (eds.), University of Chicago, Chicago, Illinois, 1986.
114. J. H. Patterson and M. S. Smith, The Role of Computers in Higher Order Thinking, in *Microcomputers and Education*, J. A. Culbertson and L. L. Cunningham (eds.), National Society for the Study of Education, Chicago, Illinois, 1986.
115. J. Snowman, Learning Tactics and Strategies, in *Cognitive Classroom Learning*, G. Phye and T. Andre (eds.), Academic Press, New York, 1986.

Direct reprint requests to:

Dr. Devin G. Thornburg
Department of Educational Psychology
Adelphi University
116 Harvey Hall
Garden City, NY 11530