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ABSTRACT

The development and evaluation of several microcomputer-based strategies designed to facilitate learning how to solve mathematics word problems by personalizing examples in accord with individuals' background and interests are described in this paper. The first of two studies conducted with fifth and sixth grade students to evaluate these strategies used a personalized lesson on the division of fractions which was presented by computer-assisted instruction (CAI). Students were randomly assigned to three treatments in which personalized, concrete, or abstract contexts were used as the background themes for word problems. Major dependent variables were three achievement subtests used to assess different types of learning, task attitudes, and lesson completion time. The second study replicated the design and procedures of the first one using computer-generated print versions of the personalized materials. Comparisons with standard nonadaptive instructional materials, which were consistent across studies, showed strong advantages for the personalized examples on both achievement and attitude measures. Follow-up research is being performed to extend the strategy to older students by allowing undergraduate education majors to select the preferred themes for example problems in a CAI statistics lesson. Supplemental materials provided include sample problems, student reactions to personalized examples, data tables, a diagram of the contextual factors affecting CAI, and a list of 28 references. (MES)

Computer-Based Instruction Research: Implications for Design

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Running Head: CBI Research: Implications for Design

Abstract

Solving verbal problems is one of the more difficult challenges in mathematics learning at all educational levels. The present paper describes the development and evaluation of several microcomputer-based strategies designed to personalize examples in accord with individuals' backgrounds and interests. In one study a personalized lesson on division of fractions was presented to elementary school children by computer-based instruction (CBI); in a second study computer-generated <u>print</u> versions of the personalized materials were administered. Comparisons with nonadaptive (standard) instructional materials were consistent across studies by showing strong advantages for the personalized examples on both achievement and attitude measures. Follow-up research is being performed to extend the strategy to older students by allowing them to select preferred themes for example problems in a CBI statistics lesson.

Computer-Based Instruction Research: Implications for Design

In a recent article David Berliner (1986) reminds us of some ideas about teaching and learning proposed by the early 19th century philosopher/psychologist J. F. Herbart. Specifically, Herbart theorized that people learn new information only as it relates to what is already in their minds. Systematically relating instructional material to existing knowledge can therefore support the dual purposes of facilitating meaningful learning and increasing interest in the task. Over 100 years later these same ideas are expressed in the contemporary writings of noted cognitive theorists such as Ausubel (1968), Glaser (1984), and Mayer (1975). The research described in this paper was designed to apply these notions to mathematics learning, specifically, the solving of verbally stated problems.

Context Model

The instructional theory underlying the present research interests is philosophically grounded in current cognitive interpretations of learning (Anderson, 1984; Ausubel, 1968; Mayer, 1975; Rumelhart & Ortony, 1977). These conceptions interpret memory as consisting of systematically arranged networks of connected facts and ideas, called schemata. When new information is easily integrated into existing schemata, meaningful learning is engendered. The challenge for instructional design is to develop ways of facilitating the development of these cognitive structures in students through applications of technology, given that each individual enters the learning situation with different experiences, interests, motivations, and subject-matter knowledge. CAI is well-equipped to address such individualized needs, but that potential is largely unused in conventional applications.

Our specific theoretical orientation focuses on the role of the contextual properties of mathematics instruction in relation to learner characteristics and cognitive abilities. The literature on problem-solving suggests that novices (e.g., young math students) tend to be more attentive to instructional contexts than are experts who tend to focus more on intuitions and general heuristics that transfer across many different problem-solving domains (Chi, Feltovich, & Glaser, 1981; Chi, Glaser, & Rees, 1982; Dreyfus & Dreyfus, 1986). The novice may therefore, view all problems dealing with a certain physical property, such as velocity, as the same even though their structures may be quite different.

Within this framework and drawing upon several of our own preliminary investigations in laboratory and school settings, our interest concerns the influences on mathematics learning of three types of contextual factors.

We have represented them pictorially in Figure 1. The first factor, which we call extrinsic contextual properties, concerns the nominal features of the lesson, i.e., the actual set of materials presented to the learner. Attributes of this category would typically include the type and quantity of information provided (text, problems, figures, etc.), task difficulty and readability, the teaching approach used (tutorial, drill, etc.), delivery medium, and the adjunct aids (examples, questions, and prompts) incorporated. Separate from these external attributes are what we call intrinsic contextual properties that determine the relatability of the material to students' knowledge schema and interests. Accordingly, two math lessons may be identical in structure, difficulty, and teaching orientation, but differ substantially in meaningfulness as a function of the types of themes and applications they convey (Ross, McCormick, & Krisak, 1986). The nominal lesson may therefore be very different from the functional lesson with regard to what they learner attends to, processes, and recalls (Shuell, 1986). A third factor, which we call social contextual properties, concerns the influences on learning of interacting with other students in classroom setting. A given lesson may thus have very different implications for performance, attitudes, and socialization when administered in individualized as opposed to group-learning situations (Johnson & Johnson, 1986). The three types of contextual properties are assumed to operate interactively, as represented in Figure 1. For example, the quantity of instructional support (extrinsic context) considered optimal for a student might significantly vary depending upon the familiarity of the applications conveyed (intrinsic context) and whether the student is learning alone or in a group.

Insert Figure 1 About Here

In our future research, computer-based instructional strategies relating to each type of contextual influence will be examined independently and in combination. The strategies specifically concern the variables of text density (extrinsic), meaningfulness of problem themes (intrinsic), and learning group size and composition (social). Major assumptions are that the strategies will enhance learning and improve attitudes toward mathematics instruction; and comprise practical and logical extensions of the learning adaptations featured in conventional CAI methods and software. In the remainder of this paper we will describe our recent investigations of the intrinsic component of the contextual model, namely microcomputer-based strategies for personalizing math materials for elementary school students.

Personalizing Strategies

The difficulty that many students experience on verbal problems (National Assessment of Education Progress, 1979) appears to stem less from a lack of computational skills than from the inability to comprehend what the problems are asking (De Corte, Verschaffel, & De Win, 1985; Knifong & Burton, 1985; Muth, 1984; Riley, Greeno, & Heller, 1983; Zweng, 1979). Several factors, such as poor reading skills (Marshall, 1984) and lack of familiarity with problem structures (Mayer, 1982; Rosen, 1984), contribute to these difficulties. Of present concern are the contextual or "thematic" properties of verbal problems in relation to students' backgrounds and interests. To return to the assumptions by Herbart noted in the introductory paragraph, it seems likely that a math problem describing some abstract or highly technical application would have more limited potential to facilitate information processing and meaningful learning than one describing something familiar and interesting to the individual (e.g., using percentages to calculate one's intramural batting average or free-throw accuracy). Effective mathematics teachers routinely search for ways of capitalizing on students' natural interests, such as integrating lessons with class field trips (Wright & Stevens, 1983), with students' academic backgrounds (Ross, 1983), or with interesting applications in books (Jones, 1983) and newspapers (Daruwalla, 1979). Although these approaches are certainly commendable, a common weakness is their orientation to the activities of a group rather than to the idiosyncratic experiences of individuals. Individualizing materials overcomes this limitation but is obviously impractical for typical classroom teachers to achieve.

The present research was based on the assumption that individualized adaptation could become feasible for classroom use when supported by computer-based instruction (CBI). Specific objectives of the strategy considered were to: (a) "personalize" verbal problem contexts for each individual; (b) orient the personalized contexts to diverse background and interest variables (e.g., hobbies, interactions with friends, etc.); and (c) automate the tasks of lesson preparation and administration. Theoretical support was provided, in part, from earlier research by Ross (1983) which demonstrated the effectiveness of adapting the contexts of examples presented in a statistics unit to college students' academic majors (also see Ross & Bush, 1980; Ross, McCormick, & Krisak, 1986). Nursing students performed best when the contexts concerned medical applications, whereas education students performed best when the contexts concerned teaching. The present strategy extended this orientation by adapting to the individual rather than to the group, and at the elementary school level.

For an illustration of the basic approach, consider the verbal problem presented in the bottom section of Table 1. Such a problem may not appear very unusual without knowing that only one student will experience it in that exact form. Specifically, the problem was uniquely constructed for a student named Steve whose best friends are Joe and Chris and whose favorite drink is cola. Other students would receive a structurally and thematically similar problem context, but the referents specified (the people and events) would be adapted to <u>their</u> personal experiences. We hypothesized that such personalized contexts would increase task motivation by describing applications of high interest to learners. We also expected them to improve comprehension by making it easier to interpret important information in the problem statements.

Insert Table 1 About Here

These assumptions were tested in two studies conducted with fifth- and sixth-grade students. In one study the presentation medium was CBI and in the other it was print material generated by the same computer program. Detailed descriptions of these studies are available in other sources (Anand & Ross, in press; Ross & Anand, in press). The purpose of the present paper is to discuss this research from a more applied perspective, while extending the findings to new analyses of the personalized model's effects on attitudes and performance. In a concluding section, it will describe our current efforts to develop a comparable CBI model appropriate for adapting word problems to individual students at the high-school or college level.

Study I: CBI Model

Several months prior to the study we met with the math teachers at the site elementary school to discuss the curriculum and identify any areas in which the children appeared to experience special difficulties. There was unanimous agreement that "division of fractions" was a definite problem area and an excellent topic for the development of supplementary materials. Using class materials and teacher suggestions we designed a CBI lesson dealing with this topic. The adaptive component of that lesson and its evaluation are reviewed in the following sections.

Subjects and Design

Subjects were 96 fifth- and sixth-grade children representing approximately equal numbers of males and females, and of Blacks (n=50) and Caucasians (n=46). The students were randomly assigned to three treatments, in which personalized, concrete, or abstract contexts were used as the background themes for word problems. Major dependent variables were three achievement subtests used to assess different types of learning, task attitudes, and lesson completion time.

Materials

Biographical questionnaire. Prior to the study, students provided background information about themselves on a "biographical questionnaire." Among the categories included were homeroom teacher's name, birthdate, favorite relative, household pets, family's supermarket, favorite food, favorite restaurant, and friends' names.

Instructional unit. The math unit began with instructions and prerequisite math facts. The next section introduced and demonstrated the following four-step solution to dividing fractions: (a) identify the dividend and the divisor, (b) write the whole number as a fraction, (c) invert the divisor to obtain its reciprocal, and (d) multiply the dividend by the reciprocal of the divisor to obtain the answer. The rule application was then repeated for four additional problems, all containing an integer numerator and fraction divisor. The lesson was programmed in BASIC for use with an Apple IIe or compatible microcomputer.

Contexts were varied by altering the referents and background themes of the five example problems while keeping the numerical values and types of measurement units constant. Abstract contexts involved the use of general referents in problem statements, such as "quantity," "fluid," "liquid," and so forth, without a meaningful background theme (see top section of Table 1). Concrete contexts used specific standard referents, such as "Mary," "English," "an artist," and so forth to convey realistic but hypothetical applications (see Table 1, middle). Personalized contexts replaced abstract and concrete referents with personally familiar items obtained from the biographical questionnaire. The personalized information for a given student was entered on program DATA statements in a prescribed order, so that, for example, Value 1 was always birthdate, Value 2 was best friend's name, and so forth. In re-examining the example in Table 1, note that italicized words represent personalized referents selected for the given student ("Steve").

Achievement test. The achievement posttest consisted of 11 items, organized into a "context" section (1-6), "transfer" section (7-9), and "recognition" section (10-11).

Context problems were patterned after lesson examples, which involved dividing a whole number by a fraction. Two of the problems were presented in abstract contexts, two in concrete contexts, and two in personalized contexts.

Transfer problems differed from lesson examples in either contextual or properties. Specifically, Item 7 was structurally identical to lesson examples, but presented only numerical values without a verbal context. The two other transfer problems featured verbal contexts, but one involved dividing a fraction by an integer (Item 8) and the other a fraction by a fraction (Item 9). The problems used on one of two parallel sets were as follows:

7. 4 - 1/6 = ?
8. 3/4 of a cake was divided equally among 3 boys. How much of the cake did each one of them get?
9. Mrs. Perkins had 17/3 lbs. of candy. She put the candy into packages of 1/3 lb. In all, how many packages of candy did Mrs. Perkins make?

The two recognition items assessed memory of the rule statement and procedures using a multiple-choice format. Six parallel forms of the test were arranged and were randomly distributed to subjects. Internal consistency reliability was determined to be .79 using the KR-20 formula.

Attitude questionnaire. An eight-item attitude scale, using Likert-type ratings, was used to assess reactions toward certain properties of the task (e.g., clarity, sufficiency, relevancy, and others). The questionnaire concluded with an open-ended item asking students to describe their feelings about "having math problems of this type."

Procedure

Students who completed their regular mathematics units on addition, subtraction, and multiplication of fractions were considered eligible for the study. Each student completed the biographical questionnaire in class. Responses by those designated to serve in the personalized treatment were recorded on tabulation sheets in a prescribed order and entered in the computer in the form of program DATA statements. The "personalized" program was then saved on the disk using the student's name as a label. From one to three students were scheduled for a given learning session. Each completed the task at a separate computer. A proctor was available in the room to answer any questions about procedures.

Results

Treatment means on achievement subtests are summarized in Table 2 (see rows labeled "CBI"). A summary of statistical results for each dependent variable follows (for more details, see Anand & Ross, in press). The results reported were obtained from one-way ANOVA's following an initial MANOVA.

Insert Table 2 about here

Context subtest. Only the context treatment main effect was significant ($p < .01$). The personalized group was superior to the abstract group. Comparisons to the concrete context group were not significant.

Transfer subtest. On the two transfer items (#'s 7 and 9) that maintained fractions as divisors (as in the learning examples), the personalized group was significantly superior to both other groups (p's$<.05$). However, on the problem presenting an integer as a denominator, all groups performed at comparable low levels.

Formula recognition. The personalized context group was superior ($p < .01$) to the abstract context group; the concrete context group did not differ from either.

Other results. Total attitude scores were higher ($p < .05$) for the personalized context group than for the concrete context group; the abstract context group did not differ from either. Analyses of lesson completion times showed no differences between treatments. Nor were any differences found between boys and girls on any outcome variables. Analyses of aptitude-treatment interaction (ATI) effects, however, indicated that low performers on the math and reading subtests of the California Achievement Test derived relatively greater benefits from the personalized contexts than did high performers.

The experimental findings thus showed the personalized materials to be beneficial across a variety of learning outcomes as well as for attitudes toward the task. A question that arose in interpreting these effects concerned the importance of the computer's role in delivering the personalized materials. Would the materials have the same impact if presented in print form rather than by CBI? This question has practical importance considering that sufficient computer resources to support CBI may not be available at many schools. If a teacher could use one computer to generate individualized print lessons and produce comparable learning benefits, a desirable cost-effective option would be available. In our next study we examined the merits of such an approach.

Study II: Print Application

Study II replicated the design and procedures of Study I with one major change. The computer was used to generate print versions of the instructional material rather than to present the lesson. This approach eliminated the need for one-to-one student contact with a computer during learning, an important practical advantage.

Methods

Subjects were 54 fifth- and sixth-grade students selected from the same student population as the Study I sample. Subjects were randomly assigned, 18 per group, to the three context groups. All materials and basic procedures used for instruction and testing were the same as Study I. In the case of the abstract- and concrete-context treatments, standard instructional manuals were printed. For the personalized-context treatment, individualized manuals were prepared by entering the appropriate personalized data in the BASIC program and executing the program with the printer on.

Results

Similar to Study I, posttest results showed the personalized-context group to: a) surpass both other groups on context items ($p<.001$); b) surpass both groups on transfer items ($p<.01$); and c) surpass the concrete-context group on recognition items (for means, see rows labeled "Print" in Table 2). Transfer benefits again were realized only when the problem structure was the one experienced during learning (i.e., fractions as divisors). Finally, results from the attitude questionnaire showed the personalized group to view the examples as more understandable and more relatable to their interests (both p's <.05) than did the concrete group. On the total attitude score and nearly all items, the ordering of groups was personalized first, abstract second, and concrete third. No learning time differences were obtained; nor was sex a significant factor on any outcomes.

Follow-up Analyses and Current Research

To extend the above findings, we performed several new analyses of the Study I and Study II data, and have initiated an investigation of a related adaptive strategy designed for use with older students. These efforts are reviewed below.

Personalization Effect Sizes under CBI and Print Modes

Judging from Table 2, the CBI and print models produced a similar pattern of results. To enable a more precise comparison of findings, we computed effect sizes (Glass, 1976) for the personalized treatment on total attitude scores and on each of the achievement subtests. The effect size scores were derived by dividing the difference between the personalized group mean and the combined control group mean by the standard deviation of the combined control group. This measure, as commonly used in meta-analyses (Kulik, Kulik, & Cohen, 1980), allows findings from different studies to be consolidated and compared using the meaningful, uniform scale of standard deviation units. The present results show effects to be remarkably consistent across experiments (see Table 3), with the exception of the larger transfer benefits in the print study. In prior work, an effect size of .5 has been interpreted as "medium-sized" and one of .8 as "large" in magnitude and importance (see Cohen, 1969; Kulik, et al., 1980). Based on these standards, the impact of the personalized contexts in the two experiments would be judged quite substantial. The smallest effects were for attitudes (in the .5 - .6 range) while the largest were for context items and total posttest (in the 1.1 to 1.5 range). Assuming posttest scores to be normally distributed, the obtained differential would place the average student in the personalized group at close to the 90th percentile of the control group.

Insert Table 3 about here

Open Ended Responses

Students' open-ended reactions to the task indicated mostly favorable reactions in all treatment conditions. Several students indicated, for example, that although math was not a favorite subject, the clear and organized presentation made the lesson fairly easy to follow. Students who received the personalized examples, however, appeared to respond more positively and enthusiastically than did control group students. To verify this impression, a quantitative analysis was performed. Students' responses were typed on index cards and given to three independent raters to evaluate on a five-point Likert scale (e.g., 1="very unfavorable"; 5="very favorable"). The ordering of the responses was varied for raters by shuffling the cards for each. Raters saw only the protocols and were thus unaware of the respondents' identities or treatment conditions. Inter-rater correlations were relatively high, ranging from .82 to .88. The average ratings for each protocol were then analyzed by a 3(context) x 2(study) ANOVA using a regression solution to control for unequal n's. The context main effect was found to be highly significant, $F(2,96) = 8.24$, $p < .001$. Follow-up Tukey HSD tests showed the mean for the personalized-context group ($M = 4.33$) to be significantly higher than the means for the abstract ($M = 3.33$) and concrete-context ($M = 3.60$) groups. No other ANOVA effects were significant. A review of the reactions reveals that many students in the personalized group explicitly identified the examples as the key factor influencing their impressions. Interested readers may examine those responses in the Appendix.

Future Directions

Based on the aforegoing results we concluded that presenting problems in familiar contexts made materials more interesting and understandable for students. Whether the presentation mode was CBI or print had no bearing on performance. The CBI application offered the practical advantage of automation and greater control in presenting the lesson. The print application, on the other hand, allowed the adaptive lessons to be administered in regular classrooms without requiring one-to-one computer contacts.

Despite the positive results, some practical limitations of the overall strategy should be noted. First, even with computer support, preparing individualized lessons still requires extra time and effort by teachers. Second, it seems likely that the novelty of personalized examples would significantly diminish over repeated uses. These considerations suggest restricting applications to the one or two course topics considered most difficult or least intrinsically interesting. Another limitation concerns the age level of the target student groups. Specifically, problem contexts describing one's teachers and friends may appear a little contrived and not very stimulating for those beyond the elementary school grades. Older students (including adults), however, do appear to have strong individual preferences for general themes, such as sports, politics, cooking, and so on (Ross et al., 1986). Based on this idea, we are currently developing an adaptive CBI lesson that allows students to select the themes for example problems at the beginning of each problem-solving exercise. The present lesson is a statistical unit on central tendency and the theme options are sports, business, education, and numerical. Evaluation of the "theme selection" strategy will involve its comparison to conditions offering standard themes and "mismatched" (non-preferred) themes. The theme-variations will in turn be crossed with parallel conditions involving selection of the number of practice examples received. An interesting question that has not been investigated in prior research is whether students will elect to receive more examples when preferred themes are represented, and vice versa.

In a recent pilot test of the materials and computer program, 17 undergraduate education majors completed the lesson under the theme-selection strategy with a fixed quantity of examples. When asked in a follow-up survey if the availability of familiar themes increased understanding, 1 student disagreed, 4 were undecided, and 12 agreed or strongly agreed. The student who disagreed, however, reacted positively to the <u>opportunity to select</u> a preferred theme by writing "... it allowed me to take the numerical context which contained the least distraction since I needed clarity and simplicity for understanding." Other reactions were: "I was able to use something of interest..."; "I learned better as it made it more applicable"; "Interested in education (themes)...enjoyed them"; "I was glad that I could choose different themes...made the computer (lesson) more interesting"; "I like it because I could pick my subject." Interestingly, the theme selections were highly varied both between and within individuals, with nearly all students selecting at least two different themes across the five problem-solving sections. A more formal test of the theme-selection strategy will take place in several controlled experiments planned for the coming year. The major hypotheses is that the strategy will enhance learning by helping students to relate the statistical concepts taught to familiar events. As followers of J. F. Herbart would probably agree, this is an old ieda given new possibilities through modern day computer technology.

References

Anand, P., & Ross, S.M. (in press). Using computer-assisted instruction to personalize math learning materials for elementary school children. Journal of Educational Psychology.

Ausubel, D.P. (1968). Educational psychology: A cognitive approach. New York: Holt, Rinehart, & Winston.

Berliner, D. (1986). Use what kids know to teach the new. Instructor, March, 12-13.

Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

Chi, M., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. Sternberg (Ed.), Advances in the psychology of human intelligence. Hillsdale, NJ: Erlbaum.

Cohen, J. (1969). Statistical power analysis for the behavioral sciences. New York: Academic Press.

Daruwalla, A. (1979). A study of the effectiveness of the use of the newspaper in the classroom on student achievement in 7th grade mathematics. Unpublished doctoral dissertation, Memphis State University.

De Corte, E., Verschaffel, L., & De Win, L. (1985). Influence of rewarding verbal problems on children's problem representations and solutions. Journal of Educational Psychology, 77, 406-470.

Dreyfus, H., & Dreyfus, S. (1986). Why computers may never think like people. Technology Review, January, 43-61

Glaser, R. (1984). Education and thinking. The role of knowledge. American Psychologist, 39, 93-104.

Glass, G.V. (1976). Primary, secondary, and meta-analysis of research. Educational Researcher, 10, 3-8.

Jones, B.M. (1983). Put your students in the picture for better problem solving. Arithmetic Teacher, 303, 30-32.

Knifong, J.D., & Burton, G.M. (1985). Understanding word problems. Arithmetic Teacher, 32, 13-17.

Kulik, J.A., Kulik, C-L. C., & Cohen, P.A. (1979). A meta-analysis of outcome studies of Keller's personalized system of instruction. American Psychologist, 34, 307-318.

Marshall, S.P. (1984). Sex differences in children's mathematics achievement: Solving computations and story problems. Journal of Educational Psychology, 76, 194-204.

Mayer, R.E. (1975). Information processing variables in learning to solve problems. Review of Educational Research, 4, 525-541.

Mayer, R.E. (1982). Memory for algebra story problems. Journal of Educational Psychology, 74, 199-216.

Muth, K.D. (1984). Solving arithmetic word problems: Role of reading and computational skills. Journal of Educational Psychology, 76, 205-210.

National Assessment of Educational Progress. (1979). Second assessment of mathematics: Mathematical applications. (Report No. 09-MA-03). Denver, CO: Educational Commission of the States.

Riley, M.S., Greeno, J.G., & Heller, J.I. (1983). Development of children's problem-solving ability in arithmetic. In H.P. Ginsburg (Ed.), The development of mathematical thinking. New York: Academic Press.

Rosen, D.R. (1984). Students schemata for algebra word problems. Paper presented at the annual meeting of the American Educational Research Association, New Orleans.

Ross, S.M. (1983). Increasing the meaningfulness of quantitative material by adapting context to student background. Journal of Educational Psychology, 75, 519-529.

Ross, S.M., & Anand, P. (in press). A computer-based strategy for personalizing verbal problems in teaching mathematics. Educational Communication and Technology Journal.

Ross, S.M., & Bush, A.J. (1980). Orienting statistics instruction for teacher candidates to classroom applications. Journal of Educational Research, 74, 19-23.

Ross, R.M., McCormick, D., & Krisak, N. (1986). Adapting the thematic context of mathematical problems to student interests: Individual versus group-based strategies. Journal of Educational Research, 79, 245-252.

Shuell, T. J. (1987). Cognitive conceptions of learning. Review of Educational Research, 56,(4), 411-436.

Wright, J. P., & Stevens, N. K. (1983). Improving verbal problem-solving performance. Arithmetic Teacher, 31, 40-42.

Zweng, M.J. (1979). The problem of teaching story problems. Arithmetic Teacher, 27, 3-4.

Table 1

CBI Study

They (examples) were very easy to understand and remember. They were very good.

Surprised with my name and everything...They are a lot more funny than regular problems.

...I didn't first know them, but now I think Iw many containers can we fill with the 4 quantities of fluid?

Concrete Context

Mike had 4 bottles of juice to pour into cups. He pours 2/3 of a bottle of juice into each cup. How many cups can Mike fill with the 4 bottles of juice?

Personalized Context

*Joe,Chris,*and other friends visit *Steve* on a weekend. *Steve* has 4 bottles of *cola* in his refrigerator. He pours 2/3 of a bottle of *cola* into each cup. How many cups can *Steve* fill with 4 bottles of cola?

Italicized words indicate personalized referents that were varied for each student.

Table 2

Treatment Means on Achievement Subtests in the CBI and Print Studies

	Context Treatment			
Subtest and Study	Abstract	Concrete	Personalized	
All Subject				
Context (6)				
CBI	1.38	2.38	4.00	2.59
Print	1.61	1.45	4.45	2.50
Transfer (3)				
CBI	.33	.42	.75	.50
Print	.33	.39	1.16	.63
Recognition (3)				
CBI	.50	.79	1.21	.83
Print	1.22	.78	1.39	1.13
Total (11)				
CBI	2.28	3.58	5.95	3.94
Print	3.17	2.61	7.11	4.30

a. Values in parentheses indicate number of items on subjects

b n=24 in each treatment

c. n=17 in each treatment

Table 3

Effect Sizes for the Personalized Treatment in CBI and Print Studies

Dependent Measure	Study	
	CBI	Print
Context	1.10	1.48
Transfer	.59	1.27
Recognition	.78	.48
Total Posttest	1.23	1.50
Attitude Total	.64	.49

Appendix
Open-Ended Reactions Referring to Personalized Examples

CBI Study

They (examples) were very easy to understand and remember. They were very good.

Surprised with my name and everything...They are a lot more funny than regular problems.

...I didn't first know them, but now I think I understand them. It made me understand these better with my name on it.

...They are more related to me and I can understand these.

I reacted very strongly because I have never seen the problems this way. ...they (examples) were easy to understand... It was very fun.

...It (example) could help others understand math better.

I thought I would not understand, but I did understand a lot. I was surprised to see my friend's name.

I was surprised because they were using my name in these situations. I could easily relate to the problems...

It was kind of interesting and understanding examples.

Print Study

I was surprised. Usually questions are the same for everyone...

I thought it was fun. Because my teacher gave me something and I do have a pet Smoky.

I though it was great to see the names of people I know. I could relate to the problem. I really liked hearing the names of my friends and my dog.

I was surprised to see my name in it and I thought it was very interesting...

Surprised they know that much about me. Good. You would be in the situations.

I was interested in what was going to happen next. You would be more interested in reading them.

Good because they (examples) make it more understandable...

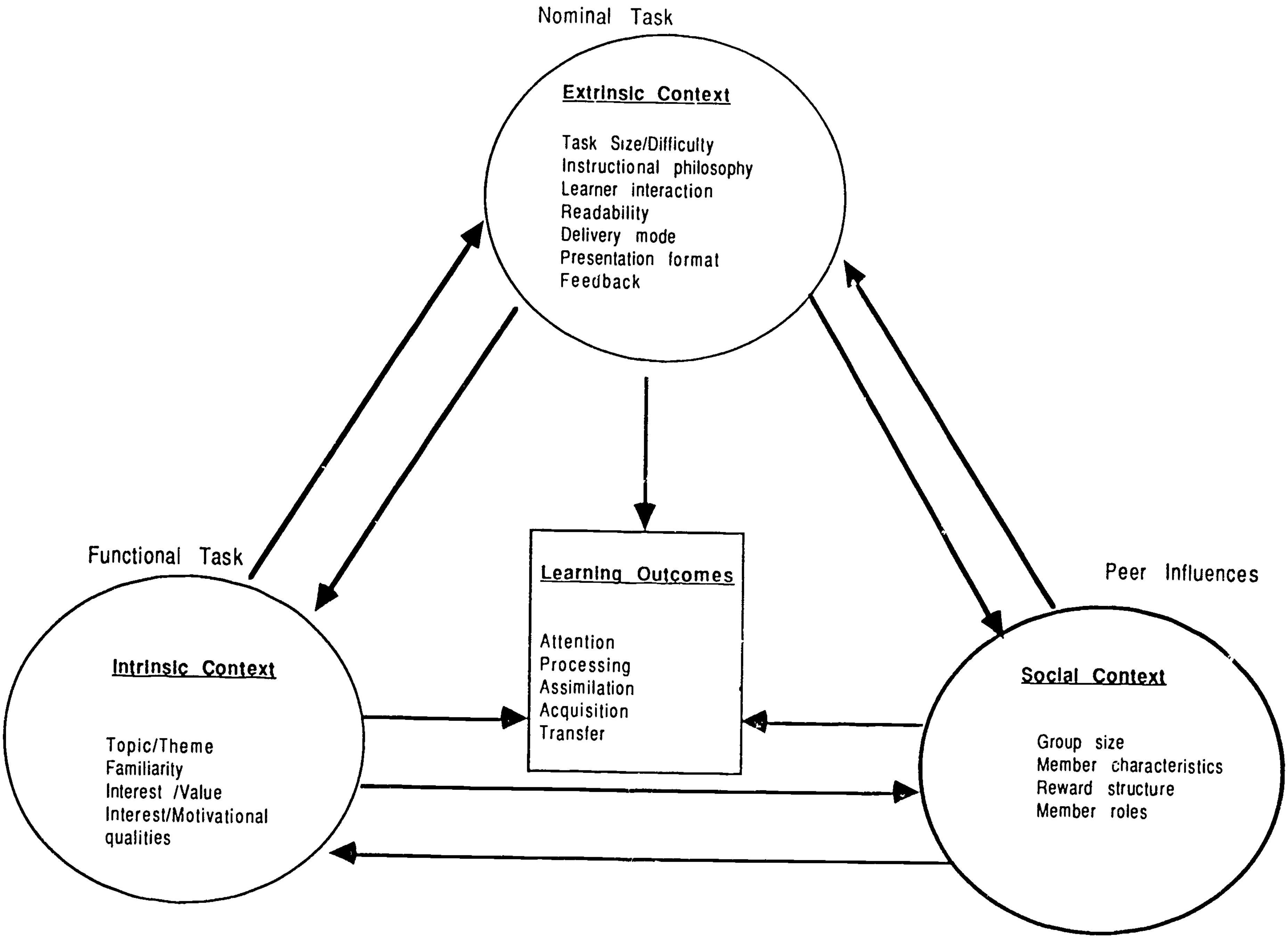

Figure 1: Contextual factors affecting CBI