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ABSTRACT

Designed to develop a more practical model for adapting context to learner interests, this study used computer-based instruction to make alternative contexts for statistics problems--sports, business, education, or no-context--available for selection by individual learners. The subjects were 227 undergraduate students enrolled in required education courses at Memphis State University. The context adaptation strategy was evaluated as it was used both independently of and in combination with learner control (LC) of the practice examples. The research design involved the manipulation of standard (prescribed) contexts versus LC-context in combination with standard instructional support versus LC-instructional support. The study also investigated the nature of LC decisions in relation to the types of instructional options made available and learner characteristics. Instruments used in the study were the Nelson-Denney Reading Test, a unit pretest, a unit posttest, and a task attitude survey. Analyses of the data revealed little difference between the treatments in achievement; students who received minimum support found the lesson faster moving than those who received maximum support; 92% of the subjects had positive attitudes toward the desirability of selecting problem themes; and learners with higher prior achievement and reading ability tended to complete the task faster, score higher on the posttest, and view the task more favorably. It was concluded that, although the achievement results failed to support the hypothesized benefits for learning, a practical model for incorporating contextual adaptation in CBI had been developed and demonstrated. (37 references) (BBM)

Title:

Uses and Effects of Learner Control of Context and Instructional Support in Computer-Based Instruction

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Uses and Effects of Learner Control of Context
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Cognitive views regarding the effective teaching of mathematical and scientific knowledge are increasingly emphasizing the importance of making connections between the learner's existing knowledge structure and new information to be learned (Mayer, 1984; Peterson, 1988). This basic principle has been applied in classroom teaching through such strategies as integrating new material with class field trips (Wright & Stevens, 1983), with stories written by the students themselves (Bush & Fiala, 1986; Ferguson & Fairburn, 1985; Hosmer, 1986; Leonardi & McDonald, 1987) or with interesting materials published in books (Jones, 1983) and newspapers (Daruwalla, 1983). It has also been demonstrated numerous times in basic research studies. Ross and his associates (Ross, 1983; Ross, McCormick, & Krisak, 1983), for example, adapted the thematic context of explanations and examples on a statistics lesson to college students' academic majors in education or medical fields. Results consistently showed higher performance, particularly on transfer problems, for the adaptive condition relative to a control group.

Although learner backgrounds in the latter studies (e.g., Ross, 1983) were well-defined (education vs. medical), they are often unknown and much more diverse in real-life teaching situations. Accordingly, material that is potentially meaningful and motivating to one student may fail to be so for another given differences in backgrounds and current interests. Unfortunately, the individual teacher will normally lack sufficient time and resources to arrange appropriate individualized options. Recognizing these limitations, especially for elementary school students, Anand and Ross (1987) used microcomputers to personalize mathematical story problems for children by embedding information about each child (e.g., hobbies, friends' names) in the problem context. Children who received the personalized examples performed better and reacted to the lesson more positively than did those who received conventional problems (also see Ross & Anand, 1987). Despite these benefits, practical limitations of this strategy are the time needed to collect and input personalized data, and the questionable appeal of the personalized contexts over time, (i.e., after novelty effects have diminished).

An important goal for instructional technology research is to translate basic research findings into applied strategies that can be implemented in classroom and training settings (Clark, 1989; Winn, 1989). Accordingly, one purpose of the present research was to develop a more practical model for adapting context to learner interests. Our specific approach used CBI to make alternative contexts for statistics problems (i.e., sports, business, education, no-context) available for <u>selection</u> by individual learners. In this manner, adaptations were individualized, immediate, and applicable in feasibility and potential appeal to students at a wide range of grade levels. A second research interest was evaluating the context adaptation strategy when used both independently of and in combination with learner control (LC) of the number of practice examples. Although LC is a significantly more cost-effective individualization strategy than developing "program-control" models to make selections <u>for</u> students (e.g., Hansen, Ross, & Rakow, 1977; Tennyson & Rothen, 1977), the question has been raised whether the typical student possesses sufficient knowledge and interest to make effective decisions (see reviews by Hannafin, 1984; Ross & Morrison, 1989; Steinberg, 1977). Specifically, when a learning task is relatively difficult or ability is low, learners may be inclined to select less instructional support so they may exit earlier from the task (Carrier, Davidson, & Williams, 1985; Ross & Rakow, 1982; Tennyson, 1980). The present rationale was that if the examples were made more meaningful by conveying familiar contexts, motivation to use them as a learning resource should increase.

To investigate these questions, the present design involved the manipulation of standard (prescribed) contexts versus LC-context in combination with standard instructional support versus LC-instructional support. One hypothesis was that the LC-context would result in superior learning and more positive task attitudes relative to standard contexts as a result of allowing learners to choose more meaningful topics that make relevant problem information easier to translate. Second, it was predicted that when learners could choose preferred contexts, they would be more receptive to the material and thus increase their selection of instructional support. In addition to testing these assumptions, a primary focus of the study was analyzing the nature of LC decisions in relation to the types of instructional options made available and learner characteristics.

Method

Subjects and Design

Subjects consisted of 227 undergraduate students enrolled in required education courses at Memphis State University. They received credit toward their course grade for participating. Subjects were preassigned at random to 15 treatments formed by crossing 5 types of context (sports, education, business, no-context, and LC) with 3 conditions of instructional support (minimum, maximum, and LC). Absences by several subjects who were originally assigned to treatments resulted in slightly uneven group sizes, ranging from 13 to 17. Major dependent variables consisted of achievement on three types of posttest items (definition, calculation, and transfer) and attitudes toward the lesson. Achievement scores were analyzed via a 5(context) x 3(support) MANOVA. For attitude data, separate 5 x 3 ANOVAs were performed on individual items scores and on the composite score.

Instructional Material and Treatments

All subjects completed the identical introductory statistics unit presented by computer. The unit, which was adapted from materials developed by Morrison, Ross, and O'Dell (1988), teaches principles of central tendency in eight separate lessons: (1) computing the mean from simple data, (2) computing the mean from frequency distributions, (3) computing the median with an odd number of scores, (4) computing the median with an even number of scores, (5) determining the mode, (6) selecting the median over the mean (Case I: open-ended), (7) selecting the median over the mean (Case II: extreme scores), and (8) relative positions of the mean and the median in skewed and symmetrical distributions. Each unit contained an instructional section that presented an explanation for the particular topic, followed by four practice examples. The explanatory sections were identical for all treatments, but the practice examples were intentionally constructed to convey one of four context variations, as described below.

Education contexts described situations involving teachers and students in school settings, such as scores on a national spelling test, number of absences from school, years of experience of "Master Teachers," and IQ scores. Sports contexts involved situations such as free-throw accuracy in basketball, strike-outs in a softball game, rushing yards in football, times in a 440-yard dash, and so on. Business contexts mainly involved sales and marketing of products, such as the number of magazines sold per week, number of dresses sold in a four-day period, repair rates for appliances, prices of coffee beans, etc. No-context problems presented only the numerical values needed to solve the problem, without a supporting verbal context. Parallel problems comprising the four context sets were identical in structure, numerical values, and in the resultant numerical solution. Subjects assigned to the four standard context treatments received the same context on all examples. At the beginning of each lesson, LC-context subjects selected the one they preferred from the four options. The selected context was then presented on all lesson examples.

Instructional support variations involved the presentation of four examples on each lesson in the "maximum" condition and one example on each lesson in the "minimum" condition. In the LC condition, subjects were presented with the first example and, after viewing it, were asked whether they wanted to receive another. This LC option was then repeated after the second and third examples, but not the fourth, thus allowing a range of one to four examples on each of the eight lessons. The various example prototypes were presented in the same sequence in all treatment variations.

Instructions encouraged students to try to work the problems on their own. When ready, they could press the space bar to see the solution steps and final answer. They could then back page to study the problem again or progress to the next problem or segment. To increase experimental control over learning activities, the lessons and associated problems were administered sequentially with no opportunity to skip any content or to review old examples.

Instrumentation

Instruments used in the experiment are described below in the order in which they were administered. The first four measures consisting of the pretask attitude survey, reading test, computer attitude test, and unit pretest, were administered prior to the experimental session.

Nelson-Denney Reading Test. Subjects took the "comprehension and rate" section of Form D of the Nelson-Denny Reading Test (Brown, 1976). Comprehension was measured by having them read eight paragraphs and answer multiple-choice questions on each. Reading rate was measured by asking them to record the number of the line they had reached following the initial 60 seconds of reading.

Unit pretest. The unit pretest (paper-and-pencil mode) contained 10 items on material to be covered in the instructional unit. Five of the items assessed definitional knowledge, three assessed problem solving (calculations), and two assessed applications. The problems were parallel forms of those used on the posttest, with approximately one-fourth to one-third of each type represented. The KR-20 internal-consistency reliability of the pretest was determined to be .76.

An independent pretest item asked subjects to assume that they were about to take a mathematics lesson in which they could study examples relating to different themes (i.e., education, sports, business, no-context). They were then asked to rank the four contexts in order of preference ("1"= most desirable).

Unit posttest. A printed unit posttest, adapted from Morrison et al. (1988), contained 34 items (total points = 43) organized into three subtests. The knowledge subtest (17 items) assesses recognition or recall of definitional information exactly as it appeared in the text. The calculation subtest contained six problems requiring computation of central tendency measures from new data not used in lesson examples. The transfer subtest consisted of seven problems that involved interpreting and explaining the rationale for how central tendency would vary with changes in distributions or individual scores. Items of this type were not included in the lesson, nor were the underlying principles explicitly stated. On all transfer items, there was essentially one correct explanation for the effect in question. Scoring, which was done by two of the authors, was therefore straightforward in nearly all cases. Where an answer was ambiguous or partially correct, the two scorers examined it jointly and reached a mutual scoring decision.

Scoring rules on objective items and calculation problems awarded one point for a correct answer. On interpretative items, one point was awarded for a correct answer and an additional point for a correct explanation. The total test KR-20 reliability was .90. Transfer subtest reliability was .84.

Task attitude survey. A survey consisting of six Likert-type items was used to assess subjects' reactions to the task and materials. Internal-consistency reliability was .54. LC-context subjects reacted to two additional items, one asking whether examples with familiar themes were easier to learn, and the other whether receiving a mixture of themes is preferable to experiencing only one theme. They were also asked open-ended questions, regarding the desirability of being able to select contexts and to learn from a computer.

Results

Achievement

Posttest achievement was analyzed via a 5(context) x 3(instructional support) MANOVA with the knowledge, calculation, and conceptual subtests as dependent variables. None of the sources of variance was significant. Examination of means, as shown in Table 1, showed little difference between treatments, with 10 out of the 15 treatment means being within 1.5 points of the overall sample mean of 27.45 (64% correct).

Insert Table 1 about here

Attitudes and completion time. Analyses of individual attitude items on the follow-up survey and total score showed only one effect. As might be expected, subjects who received minimum support found the lesson faster moving ($p < .04$) than those who received maximum support. Overall, most items evoked fairly mixed reactions with the median response falling between "undecided" and "agree." The lowest mean ratings on the six core items (items received by all subjects) were for "the lesson moved quickly" and "I prefer this method of learning over lecture." The highest mean ratings were for "sufficiency of instruction" and the "readability of the layout." Interestingly, the most favorable reactions on the entire survey occurred on the LC item concerning the desirability of learning from familiar themes ($M = 4.11$), with 89% of the sample indicating either strong agreement (25%) or agreement (64%). Only 41% agreed or strongly agreed, however, that they would prefer a mixture of themes rather than the same theme throughout, but this response did not correlate with actual tendencies to change themes during instruction. Finally, the two-way ANOVA on completion time showed the instructional support main effect to be the only significant result ($p < .05$). As would be expected, the ordering of treatments from most to least time was maximum ($M = 30.0$ min.), learner-control ($M = 26.7$), and minimum ($M = 25.4$).

Open-Ended Attitude Responses

Qualitative analyses of open-ended responses regarding the desirability of selecting problem themes showed 92% to be positive, 5% neutral, and only 3% negative. Follow-up analyses of the positive responses indicated that the most frequently given rationale (38%) specifically mentioned the advantages of context selection for relating the material to existing knowledge or experiences. Examples were: "Wonderful, I was able to relate it (the materials) to something I understood," and "It was good to see that central tendency can be applied to everyday living situations." Other, lesser used response categories consisted of "General" (37%; "I liked it"), "Interest" (16%; "The context made the problems more interesting"), "Familiarity" (11%; "I am sports minded, so I felt more comfortable with sports"), and "Variety" (5%; "I liked choosing the themes because I was able to add variety").

In response to the question about the desirability of learning math by computer, the responses were mixed, with 58% classified as positive, 14% as neutral, and 28% as negative. The most frequently mentioned positive aspects were the self-pacing and feedback components. Most frequently mentioned as a negative factor was the lack of interaction with a human teacher.

Learner Control Outcomes

Additional analyses examined LC-context and LC-instructional support outcomes and their relationship with individual difference variables consisting of gender, pretest score, task attitude score, reading ability, and total posttest score.

Context rankings and preferences. On the pretest, subjects were asked to rank the four contexts in order of preference. As shown in Table 2, the ordering of mean rankings (lower mean = higher preference) and of frequencies with which the contexts were ranked first was education highest, followed by sports, business, and no-context. Statistical comparison of number one rankings across contexts indicated a highly significant difference, ($p < .001$). Gender differences were also highly significant, ($p < .001$): males were more likely to rank sports highest (66%) than were females (14%), while the converse occurred for education (17% vs. 52%).

Insert Table 2 about here

Also, as shown in Table 2, the relative frequencies with which contexts were actually selected across the eight lessons were ordered similarly to initial rankings with the most popular choice, education, being selected on almost half of the eight trials ($M = 3.66$), followed by sports ($M = 1.88$), no-context ($M = 1.61$), and business ($\bar{M} = .91$). Comparison of the four context selection scores, using the nonparametric Freidman ANOVA By Rank test (Hays, 1981), were significant, (3) = 19.86, $p < .001$, thus confirming the observed preference differential. Analyses of gender differences were significant on three of the contexts: males were more likely than females to select sports ($p < .05$), but less likely to select no-context ($p < .01$) and education ($p < .001$). Correlations between pretest scores and selection totals further revealed that higher prior achievement was associated with a greater tendency to select the no-context option, r (44) = .32, $p < .05$, and a lesser tendency to select the education context, r (44) = -.47, $p < .001$.

Context selection patterns. Variations in context preferences during learning were examined by tabulating the number of times selections were changed across adjacent lessons (maximum score = 7). Results showed that 39% of the subjects selected the same context on all lessons, 25% made 1 or 2 changes, and 36% made 3 or more changes. Fourteen percent of the total group sampled all four options, and 25% examined at least three out of four. Change scores were not found to be correlated with any of the individual difference variables.

Other results revealed that differences in the relative frequencies with which the four contexts were selected early (Lesson 1) compared to late (Lesson 8) in the task were not significant. Students who selected the no-context option had significantly higher pretest scores than those who selected the education context on both Lesson 1 [M = 64% correct vs. M = 21% correct, $t(25) = 3.72$, $p < .001$] and Lesson 8 [M = 45% vs. M = 19%, $t(27) = 2.54$, $p < .05$].

Instructional support selections. The total quantity of examples selected across the 8 lessons ranged from 8 to 32, with a standard deviation of 6.5. The distribution was positively skewed, with a mean of 15.5 (1.9 per lesson), median of 13.5, and mode of 11.0. As expected, total quantity selected was negatively correlated with pretest scores, r (75) = -.26, $p < .05$.

Examination of the total quantity of examples selected by each context group showed that the means were ordered in the predicted direction with the no-context mean lowest (M = 12.0) and the LC mean (M = 18.5) highest. Fairly comparable means were obtained for the three thematic contexts, education (M = 16.0), sports (M = 16.7), and business (M = 14.6). For purposes of analysis, the data for the three thematic context groups were pooled, resulting in a three treatment group ANOVA design: standard thematic context, no-context, and LC. The treatment effect was significant, $F(2,72) = 4.21$, $p < .02$. Follow-up comparison of means, using the Tukey-HSD procedure, showed that LC subjects selected significantly more ($p < .05$) examples than did no-context subjects, but not more than subjects reviewing thematic contexts.

Support selection patterns. Tabulations of the number of times subjects varied their selections of examples across adjacent lessons (maximum score = 7.0) revealed an overall mean of 2.63 (a 38% rate). Overall, 91% of the sample varied their support selections at least one time. Three individual difference variables were related to these tendencies. Selection changes were more frequent for females (M = 2.87) than for males (M = 1.33), $t(73) = 3.08$, $p < .001$; for slower readers than for faster readers, r (75) = -.24, $p < .05$; and for higher posttest performers, r (75) = .24, $p < .02$.

Correlations Between Learner Variables and Experimental Outcomes

Correlations between learner characteristics and task outcomes generally revealed the expected tendencies for learners with higher prior achievement (pretest scores) and reading ability to complete the task faster, score higher on the posttest, and view the task more favorably. To examine these relations from a multivariate perspective, separate multiple regression analyses, using step-wise entry of variables, were conducted on each of the three criterion variables: posttest, attitudes, and time. Each criterion variable was entered as a predictor for the other two, along with pretest score, total number of examples received, reading rate, and reading comprehension. Results for the posttest showed significant predictors, in order of entry, to be pretest, mathematics attitudes, and reading comprehension ($R^2 = .35$, $p < .001$); for task attitudes, predictors were pretest and reading rate ($R^2 = .08$, $p < .001$); for completion time, they were number of examples, pretest, and reading comprehension ($R^2 = .15$, $p < .001$).

Discussion

The achievement results of this study failed to support the hypothesized benefits for learning of allowing learners to select preferred contexts for practice examples. However, findings regarding selections of instructional support and context in LC conditions provided some interesting insights into how learner control is used by different types of students as well as suggestions for increasing its effectiveness as a CBI strategy. Also, compared to earlier applications (Ross, 1983; Anand & Ross, 1987), a practical model for incorporating contextual adaptation in CBI was developed and demonstrated.

With regard to achievement, the instructional material appears to have been somewhat difficult for students given the scope and conditions of the learning task. In the regular self-paced statistics course from which the present lesson was adapted, students generally take two or three days (presumably involving at least several hours of self-study) to complete essentially the same unit of material and average approximately 89% on a comparable test compared to the present average of 64%. Accordingly, as suggested by the multiple regression data, achievement was strongly related to subjects' abilities and prior learning (pretest, math attitudes, reading ability), but generally independent of task variables. Even the amount of instructional support received, a highly influential variable in most learning situations (Carrier & Williams, 1988; Ross & Rakow, 1982; Tennyson & Rothen, 1977), had no impact on performance. An additional factor that might have attenuated contextual effects compared to previous studies (Ross, 1983; Ross, et al., 1986) was the restriction of the contextual manipulations to practice examples only, after the relevant principles and operations had been taught. Also, the simplicity of the contexts with regard to length and detail probably reduced the meaningfulness and thus the interest value of the applications conveyed.

Despite the absence of performance effects, the learner control outcomes were revealing regarding common selection strategies employed and their relationship to learner differences. Consistent with previous studies (Carrier et al., 1985; Ross & Rakow, 1982; Tennyson, 1980), there was a general tendency by subjects to select minimal instructional support (less than two examples per rule). Given the generally low posttest scores, this tendency may reflect subjects' inability to gain an adequate understanding of the content from the examples. As Clark (1984) suggests, students tend to avoid high support options (and the extra effort entailed) when they expect to fail anyway. Another possible explanation is that, as a result of working in an experimental rather than actual learning setting, subjects may have had low motivation to prolong the task by selecting additional support.

Identifying effective uses of learner control has relevance to the practical problem of making CBI more adaptive for learners. Program-controlled adaptive strategies that systematically select learning resources <u>for</u> students can provide powerful instructional adaptations (e.g., Tennyson & Rothen, 1977; Park & Tennyson, 1986), but are very costly to develop due to the sophistication of the executive models needed to analyze performance and generate individualized prescriptions oriented to the learning task concerned. Another alternative is "advisement" or "coaching" in which students are given direction by the program about what resources to select, but are ultimately free to make their own choices (Tennyson & Buttrey, 1980). But to provide such advice, the program must somehow determine what is "adaptive" for the individual, a process that carries similar executive modeling requirements (and associated development costs) as program control.

A third, more practical alternative is to identify strategies that facilitate independent adaptive decision-making by learners. Suggestive evidence from the present study is that when learners could select problems themes that interested them, the number of examples they elected to examine significantly increased compared to the no-context group (a 54% increase) and was directionally higher compared to the combined thematic context groups (a 17% increase). This basic idea is consistent with current theoretical views regarding uses of interesting displays and subject matter to increase motivation and attention in CBI (Keller & Suzuki, 1988). It was also supported by subjects' attitude ratings and open-ended survey responses, with approximately 90% of the LC sample commenting on the motivational and/or learning advantages of choosing preferred problem themes. Such personalized properties can increase the motivational effects that learner control in general seems to have for students as a CBI design component (Kinzie & Sullivan, 1989).

The number of shifts in the quantity of examples selected across lessons was the only task outcome variable to relate significantly to posttest achievement. This correlational outcome could have been influenced by numerous intervening variables. One possiblity, however, is that subjects who varied their selections more frequently were making greater use of metacognitive strategies in assessing their needs on the lesson (Tobias, 1987). This interpretation suggests the possible benefits of orienting LC strategies to help students to gain greater awareness of their needs and appropriate study behaviors. An exemplary approach is to require LC students to repeat formative test items that they initially answer incorrectly (Kinzie, Sullivan, & Berdel, 1988). Consequently, they receive immediate confirmation of their errors, while knowing that they will be held accountable for learning the correct information before progressing on the task. As an alternative, explicit on-task advisement (e.g., Carrier, Davidson, Williams, & Kalweit, 1986) might be used to prompt students to reflect on their degree of understanding and to vary their selection of LC resources accordingly (e.g., "Are you understanding this section? Consider selecting additional examples if you are having any difficulty."). This type of advisement, though requiring additional empirical validation, constitutes a highly practical means of providing adaptive coaching in CBI lessons.

The present study is also one of several recent CBI studies (i.e., Carrier & Williams, 1988; Kinzie et al., 1988; Ross, Morrison, & O'Dell, 1988) that have identified reading ability as a relatively strong predictor of achievement. Although reading skills should certainly affect text comprehension from any presentation medium, the unique conditions and constraints of CBI text displays (the small display area, keypressing requirements, special formats, back- and forward-paging limitations, etc.) may exacerbate attentional or comprehension problems for the low-ability reader (see Hepner, Anderson, Farstrup, & Weiderman, 1985). Further research should focus on this issue and the possibility of designing practical LC options that allow individuals to vary text formats or content (e.g., as in Morrison et al., 1988) according to preferences or needs.

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Table 1

Total Posttest Mean Percentage Correct for Context x Instructional Support Treatments

	Instructional Support		
Context	Minimum	Maximum	Learner-Control
Education	30.6	24.4	25.9
Sports	24.0	28.8	28.1
Business	26.3	24.2	28.4
No-Context	27.5	27.5	27.0
Learner-Control	23.8	27.0	27.8

Note: Possible range of scores was 0-43

Table 2

Summary of Learner Control Context Rankings and Selections

	Initial Rankings		Lesson Selections		
			Overall	Male	Female
Contexts	M	Rf1	M	M	M
Education	1.70	.55	3.66	1.00	4.07
Sports	2.56	.24	1.88	4.33	1.42
Business	2.74	.11	.91	2.38	.68
No-Context	2.99	.11	1.61	.33	1.82

[a] Relative frequencies of #1 rankings.
[b] Means indicate average number of selections across the 8 lessons.