DOCUMENT RESUME

ED 295 647 IR 013 357

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TITLE Cooperative Learning at the Computer: Ability Based Strategies for Implementation.
PUB DATE Jan 88
NOTE 16p.; In: Proceedings of Selected Research Papers presented at the Annual Meeting of the Association for Educational Communications and Technology (New Orleans, LA, January 14-19, 1988). For the complete proceedings, see IR 013 331.
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Academic Achievement; Analysis of Variance; Aptitude Treatment Interaction; *Computer Assisted Instruction; Elementary Education; Elementary School Students; *Group Dynamics; *Grouping (Instructional Purposes); Group Instruction; *Intermode Differences; *Low Achievement
IDENTIFIERS *Cooperative Learning

ABSTRACT

This study compared the achievement of low and high ability eighth grade students working cooperatively during computer-based instruction. Students were grouped either homogeneously or heterogeneously on ability, and received identical instruction on a fictitious rule-based arithmetic number system. No significant differences in achievement were found between the two grouping methods. However, the achievement of low ability students in the mixed ability treatment improved substantially without an accompanying significant reduction in the achievement of the high ability students. The results indicate that designers and teachers have little to risk in terms of achievement, but potentially much to gain in socialization and interaction, by cooperative heterogeneous grouping during computer-based instruction. The text is supplemented by tables, figures, and 23 references. (EW)

Cooperative Learning at the Computer: Ability Based Strategies for Implementation

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Abstract

This study compares the achievement of high and low ability eighth grade students working cooperatively during computer-based instruction. Students were grouped either homogeneously or heterogeneously on ability, and received identical instruction on a fictitious rule-based arithmetic number system. No significant differences in achievement were found between the two grouping methods. However, the mixed ability treatment substantially improved the achievement of the low ability students without an accompanying significant reduction in the achievement of the high ability students. The results indicate that designers and teachers may have little to risk in terms of achievement, but potentially much to gain in socialization and interaction, by cooperative heterogeneous grouping during computer based instruction.

Cooperative Learning at the Computer: Ability Based Strategies for Implementation

Educators interested in the implementation of computers in education are concerned with identifying models that maximize learning. One model that has gained much recent attention involves the use of cooperative learning (e.g. Carrier & Sales, 1987; Johnson & Johnson, 1986; Johnson, Johnson, & Stanne, 1985; Mevarech, Stern, & Levita, 1987; Webb, Ender, & Lewis, 1986).

To many, cooperative learning has both strong intuitive appeal and compelling practical significance. The limited availability of computers in the classroom often mandates the use of group models (Hannafin, Dalton, & Hooper, 1987). Further, studies have generally indicated that students often work better in small groups than individually (Peterson & Janicki, 1979; Peterson, Janicki, & Swing, 1981; Swing & Peterson, 1982; Slavin, 1983). Consequently, assigning a computer to each student may be both unnecessary and unwise (Dalton & Hannafin, 1987).

Cooperative learning involves the selection of a number of students (usually between three and five) to work together in groups. Once selected, the degree of cooperation within groups can be manipulated by methods that control rewards. Group members can, for example, work toward cooperative, competitive, or individual incentives (Slavin, 1983). With a cooperative incentive all group members are rewarded identically, although the method of assessing group achievement may vary. Group members may receive either the score of the lowest achiever in the group, the average score of all the group members, or some other similar group reward. Competitive incentives involve comparison of all team members' scores, and rewards commensurate with success. Thus students may work together in the knowledge that helping other group members may actually reduce their own personal chances of success. Individual incentives may be offered to individual group members regardless of others' achievements.

Of particular interest are the relationships between student interaction and achievement and the effects of different grouping methods on resulting interaction. As part of an investigation into the influence of cooperative learning on achievement, Webb (1982) examined the effects of giving and receiving help during small group learning. She found that students who were active in the learning process, and who gave explanations to other students, showed higher levels of achievement than those students who were not actively involved in group interaction. Giving explanations involves forming associations between new and existing information, and also requires the learner to form elaborations (Webb, 1985). Elaborations, in turn, aid retrieval by forming alternative pathways for the construction of answers (Gagne, 1985). Webb also found that students who sought and then received help showed significant improvements in learning. Receiving help may engender an atmosphere of caring within the group which may in turn result in greater personal effort (Slavin, 1978).

How should cooperative groups be formed? How should learners of varying abilities be grouped to maximize the benefits of cooperative grouping? A description of the learning phases, proposed by Rummelhart and Norman (1978), may help to predict effective models of cooperative learning. They characterized learning as a process during which the learner passes through three stages of understanding. In the first stage, accretion, the learner is able to discriminate between examples and non-examples but is unable to apply knowledge to new situations, or to provide in-depth explanations. During the second stage, restructuring, the learner is still unable to provide deep explanations but can now transfer some learning. Finally the learner enters the highest level of learning, tuning, and is at last able to solve novel problems, to work effectively under stress, and to provide deep explanations.

This model suggests that low ability students working together in small groups are likely to flounder in an environment that requires group members to explain cognitively complex information: They are unlikely to reach the tuning stage for difficult tasks. Consequently, they would be unable to provide adequate explanations of the learning process to fellow group members. However, the model also suggests that students in both mixed and high ability groups may benefit from cooperative learning. High ability students may better organize information within their own cognitive structures by giving in-depth explanations (Bargh & Schul, 1980). This improved organization is likely to deepen understanding (Mayer,1984). Further, low ability students, grouped with high ability team members, are likely to receive more individualized and in-depth explanations than possible from the classroom teacher. The extra instruction is likely to increase learning for low students without corresponding decrements for high students.

One aspect of cooperative learning that has received little attention concerns the influence of grouping on the learning of increasingly complex tasks. While low level information generally does not require meaningful encoding, higher order skills, such as rule application and problem solving, often require deeper cognitive processing. While more able learners may impart strategies to less able students to learn simple information, it is unlikely that higher level learning will be achieved through a limited exposure to cooperative learning: Low students may simply lack the cognitive structures required for complex learning. Consequently, as the complexity of the learning task increases, the positive effects of heterogeneous ability grouping for low students will likely dissipate.

The purpose of this study was to extend research into computer-based cooperative learning by examining the effects of two methods of ability grouping, homogeneous and heterogeneous, on the learning of increasingly complex concepts.

Methods

Subjects

The subjects were 40 eighth grade students selected from a junior high school in a rural area. The students comprised approximately equal numbers of mainstreamed males and females from both the top and bottom ability levels of pre-algebra and general math.

Materials

Participants, working in small groups of three or four students, received a computer driven tutorial. To avoid the confounding effects of prior knowledge, the content was designed to be as content and culture free as possible. The content was based on basic arithmetic concepts that all students of this grade level should have mastered.

The tutorial comprised four sections. In the first section students were shown four different sets of novel symbols, corresponding to the arithmetic operations of addition, di :sion, multiplication, and doubling and adding, as shown in Figure 1. Each set included three identical constants (1, 2, and 4), resulting in the following operations; divide by 1, divide by 2, and divide by 4; double and add 1, double and add 2, double and add 4. Multiple choice questions, as shown in Figure 2a, were then presented concerning the meaning of the symbols. After 10 successive correct questions students began the second section.

Insert Figures 1 and 2 about here

In the second section, four examples were presented that involved evaluating the combined values of two symbols. For example, add 2 followed by double and add 4 (answer 8). Students were then required to correctly evaluate five successive pairs of symbols, such as shown in Figure 2b, before beginning the third section.

In the third section, (see Figure 2c), students were required to evaluate strings of three symbols. Three successive correct answers were required to complete this section.

In the final section, students were given strings of five symbols to evaluate. Examples of these strings are shown in Figure 2d. Four successive correct answers were required to complete this section. Students could check the symbol meanings at any time by selecting a help screen that displayed all 12 symbols with their corresponding values. In all four sections, immediate feedback was given concerning the correctness of each response. Further, in the second, third, and fourth sections incorrect responses were followed by display of the correct answer.

To promote cooperation between group members, the tutorial contained an embedded strategy that required students to alternate roles after approximately every five questions. Each student received a card numbered 1, 2, 3, or 4. Each card specified the role to be played by the card-holder; decision-maker, advisor, or typist/advisor. Roles rotated when cards were exchanged among group members.

Treatments

There were three cooperative groupings: homogeneous high, homogeneous low, and heterogeneous. High ability subjects were defined as those from the pre-algebra math class, and low ability subjects were defined as those from general math. In the homogeneous high group, four high ability subjects were assigned to each of three groups; in the homogeneous low group, four low ability subjects were assigned to each of three groups; in the heterogeneous group, two high and two low ability subjects were assigned to each of six groups.

Posttest

To avoid the influence of recency, students received a delayed posttest: This was administered one week after the initial treatment. The posttest included 16 questions at three different levels: factual recall, application, and problem solving. Sample posttest items are shown in Figure 3.

Insert Figure 3 about here

Factual recall There were four questions which required recall of the meanings of the symbols. Three points were awarded for the correct operation and two points for the corresponding constant. The K-R 20 subscale reliability was .70 .

Application There were six questions which required calculation of strings of two, three, and five symbols. Five points were awarded for the correct answer but no partial credit was awarded. The K-R 20 subscale reliability was .76 .

Problem solving There were six questions at this level. To test problem solving, subjects were asked to generate strings of two, three, and five symbols that together formed a given number. Five points were awarded for each correct answer. Two partial credit points were awarded if the given answer was equivalent to the question, but contained no more than one too many, or too few, symbols. The K-R 20 subscale reliability was .84 .

The overall K-R 20 posttest reliability was .90 and the individual item difficulty ranged from .20 to .79 .

Design and Data Analysis

The study employed a 2X2(X3) mixed factorial design featuring two levels of ability (high and low), two levels of grouping (homogeneous and heterogeneous), and three types of learning (factual recall, application, and problem solving). Posttest scores were analyzed through mixed effects ANOVA procedures.

Procedures

Within the high and low ability groupings, students were randomly assigned to treatment groups. Students were told that they would be tested individually one week after receiving instruction: The treatment was then administered as prescribed. Students has one class period (approximately 45 minutes) to complete the treatment. One week after the instruction, subjects received a written posttest.

Results

Posttest Scores

The means and standard deviations for each level of the posttest are found in Table 1 and the results of the corresponding ANOVA are found in Table 2.

Insert Tables 1 & 2 about here

As expected, the overall posttest means of the high ability (61.9) and low ability (30.5) groups were significantly different, $F(1,36)=17.59$, $p<.001$. Though no significant differences were found for either grouping method or for the ability X grouping method interaction, the predicted patterns were obtained. As shown in Figure 4, the low ability subjects, grouped heterogeneously, consistently scored higher than their low ability counterparts grouped homogeneously. Further, although the high ability subjects, grouped homogeneously, achieved greater overall success than the other high ability group, the pattern was inconsistent over levels of questioning. In fact, the high heterogeneous group outscored its counterpart on the problem solving questions.

Insert Figure 4 about here

As expected, significant differences were found for both levels of questioning, $F(2,72)=72.50$, $p<.001$, and ability X levels of questioning, $F(2,72)=4.17$, $p<.05$. Post hoc analyses of the interaction of ability and levels of questioning, using Tukey tests, indicated significant ($p<.05$) pairwise comparisons between factual and both application and problem solving questions: Increasing the complexity of the learning task resulted in differences in group achievement. Specifically, as the complexity of the learning task increased, scores of both high and low ability groups were reduced. However, although the high ability group indicated significant reductions in achievement, the low ability group demonstrated performance scores that suggest a floor effect for higher levels of learning.

Discussion

This study examined two methods of ability grouping for cooperative learning. Although the interaction between ability and grouping method was statistically insignificant, the predicted pattern was found between the two treatments. Further analysis of these factors revealed that low ability students in the heterogeneous treatment showed a 51% improvement in learning over the other low ability group, while the high ability students in the heterogeneous group showed a 9% decrease in learning compared to the other high ability group. Stated differently, the low ability students in mixed groups showed improvement in achievement over the other low ability students, without a negative effect on the achievement of the high ability students in mixed groups. These findings tend to support previous cooperative learning studies which suggest that cooperative learning poses little risk to the more able tutors.

While the overall effect of grouping strategies appears to have little influence on high ability students, low ability students grouped heterogeneously appear to perform at higher levels than their homogeneously grouped counterparts. Further investigation of the scores of the low ability students revealed that while only marginal differences were found between the groups for problem solving, much greater variability was found at both the factual and application levels. Low ability students, with poorly developed learning and problem solving skills, may quickly model superficial strategies that enhance learning of lower level information through heterogeneous cooperative learning. However, developing more complex learning skills to assist problem solving is likely to be a much more difficult task. While learning simple information is a relatively well defined process achievable through a number of strategies, learning the skills necessary to improve problem solving is much less well understood: These skills cannot be easily trained and require gradual development (Derry & Murphy, 1986). Consequently, the development of problem solving skills is unlikely to take place as a result of limited exposure to heterogeneous cooperative learning.

No significant differences were found between the two grouping methods: This in itself may be noteworthy. There are many goals of education, other than academic achievement, that may be fostered by cooperative education such as concern for other students' well being, positive attitudes for students of different ability levels (Slavin, 1983), improved race relations (Stallings & Stipek, 1986), and enhanced self esteem for low ability students (Slavin & Karweit, 1984). Grouping strategies that promote important social objectives through mixed ability grouping, without significant decrements in academic achievement may be preferable to competitive strategies.

Several potential limitations of this study warrant discussion. One limitation may have been the lack of control over intra-group cooperation. This study included individual incentives as a means of encouraging cooperation. Some have suggested that students in cooperative learning environments perform best if given group versus individual incentives (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Slavin, 1983). If so, group incentives might have promoted greater cooperation between group members. Although the procedures of this study encouraged cooperation, group incentives were not used to mediate cooperation among group members.

Increased incentives to cooperate are likely most critical for heterogeneous ability groups where differences in learner needs are most pronounced. In a study of ability based grouping methods, students in heterogeneous groups showed greater levels of interaction than homogeneously grouped students (Nijhof & Kommers, 1985). Group rewards may encourage higher ability students to invest more effort in advising less able students and, simultaneously, less able students may invest more effort in the process of receiving help. The resulting deeper processing would likely manifest itself in improved test scores if the incentives to cooperate are appealing.

In summary, this study supports the notion that heterogeneous ability grouping may have few negative consequences and significant potential for both academic and social outcomes. In addition, cooperative grouping may help to ameliorate logistical problems associated with the dearth of computers in the schools. Precisely the degree to which the potential of heterogeneous grouping is realized, however, is likely to depend more on internal group dynamics than on learning from the computer per se.

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Table 1. Posttest means and standard deviations.

Grouping strategy		Facts	Applications	Problem solving	Totals
Homogeneous					
Hi (n=10)					
	M	86.00	59.90	55.00	64.59
	SD	17.92	39.42	41.48	33.13
Lo (n=8)					
	M	57.50	8.38	16.75	23.80
	SD	26.99	12.57	19.90	14.25
Total	M	73.33	37.00	38.00	46.46
	SD	26.12	39.77	38.16	33.16
Heterogeneous					
Hi (n=12)					
	M	84.58	44.42	58.17	59.62
	SD	15.15	28.68	35.85	25.19
Lo (n=10)					
	M	77.50	25.00	19.00	35.88
	SD	20.72	17.90	21.51	15.69
Total	M	81.36	35.59	40.36	48.82
	SD	17.81	25.81	35.63	24.18
Ability					
Hi (n=22)	M	85.23	51.46	56.73	61.88
	SD	16.07	34.05	37.59	28.45
Lo (n=18)	M	68.61	17.61	18.00	30.51
	SD	25.14	17.52	20.23	15.88

Table 2. ANOVA performed on posttest scores.

Effect	df	MS	F	P
Group	1	516.00	.33	.57
Ability	1	27,620.03	17.59	.0001*
Group X Ability	1	2,259.30	1.44	.24
Error	36	1,570.25		
Levels of questioning	2	21,574.72	72.50	.0001*
Group X Levels of questioning	2	202.39	.68	.51
Ability X Levels of questioning	2	1,241.70	4.17	.02*
Group X Ability X Levels of questioning	2	695.40	2.34	.10
Error	72	297.57		

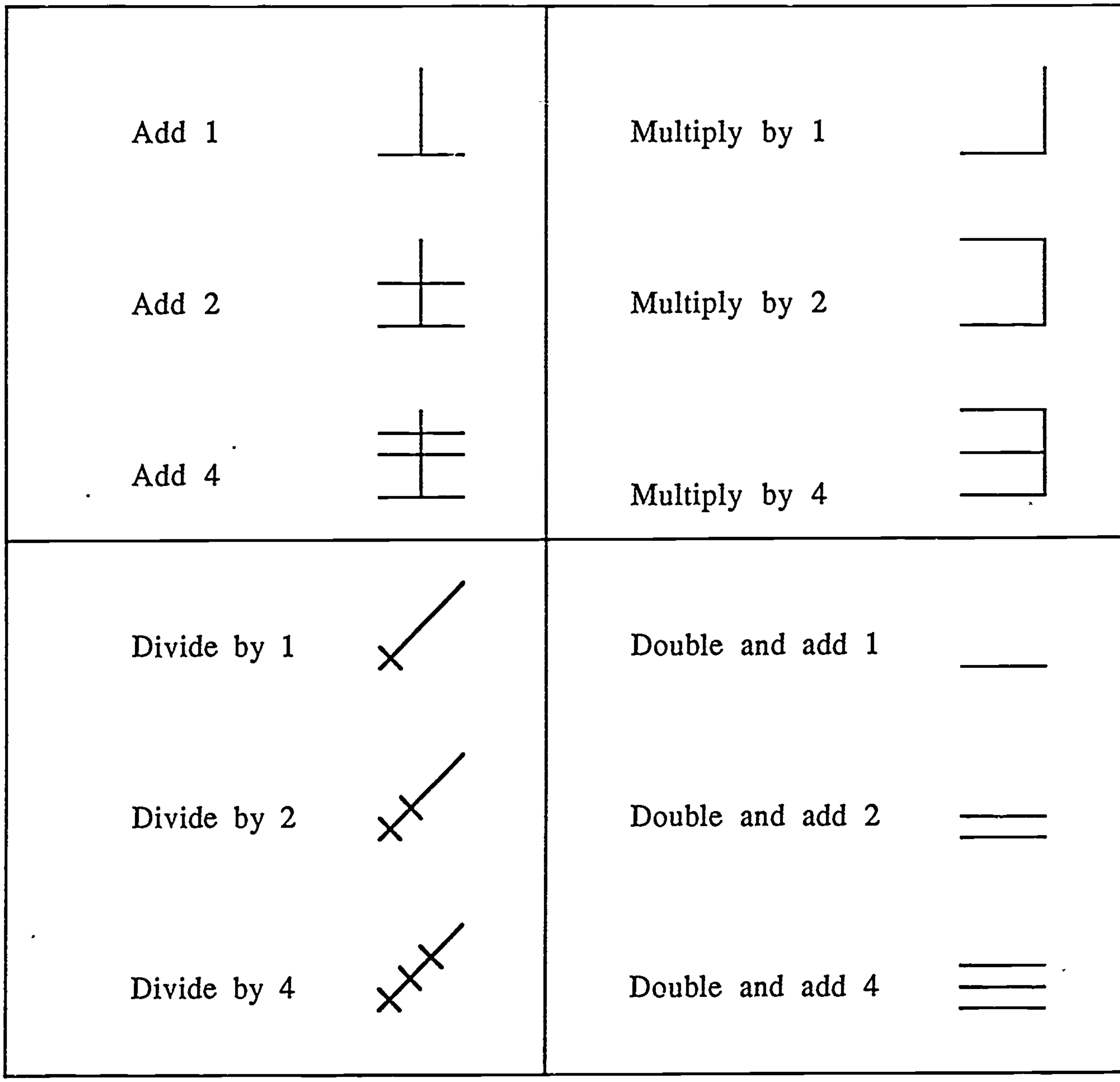
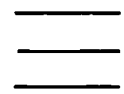
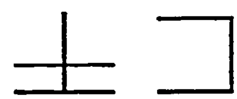


Figure 1. Function symbols.

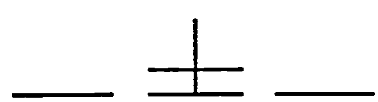
What does the symbol  mean?

a] Add
b] Divide
c] Multiply
d] Double and add.

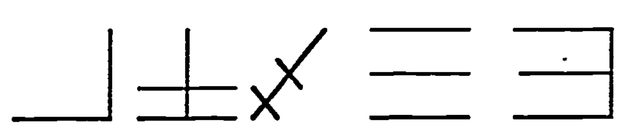
Answer: d

Evaluate the string 

Answer: 4

Evaluate the string 

Answer: 7

Evaluate the string 

Answer: 24

Figure 2.(a-d). Examples of questions embedded in the tutorial.

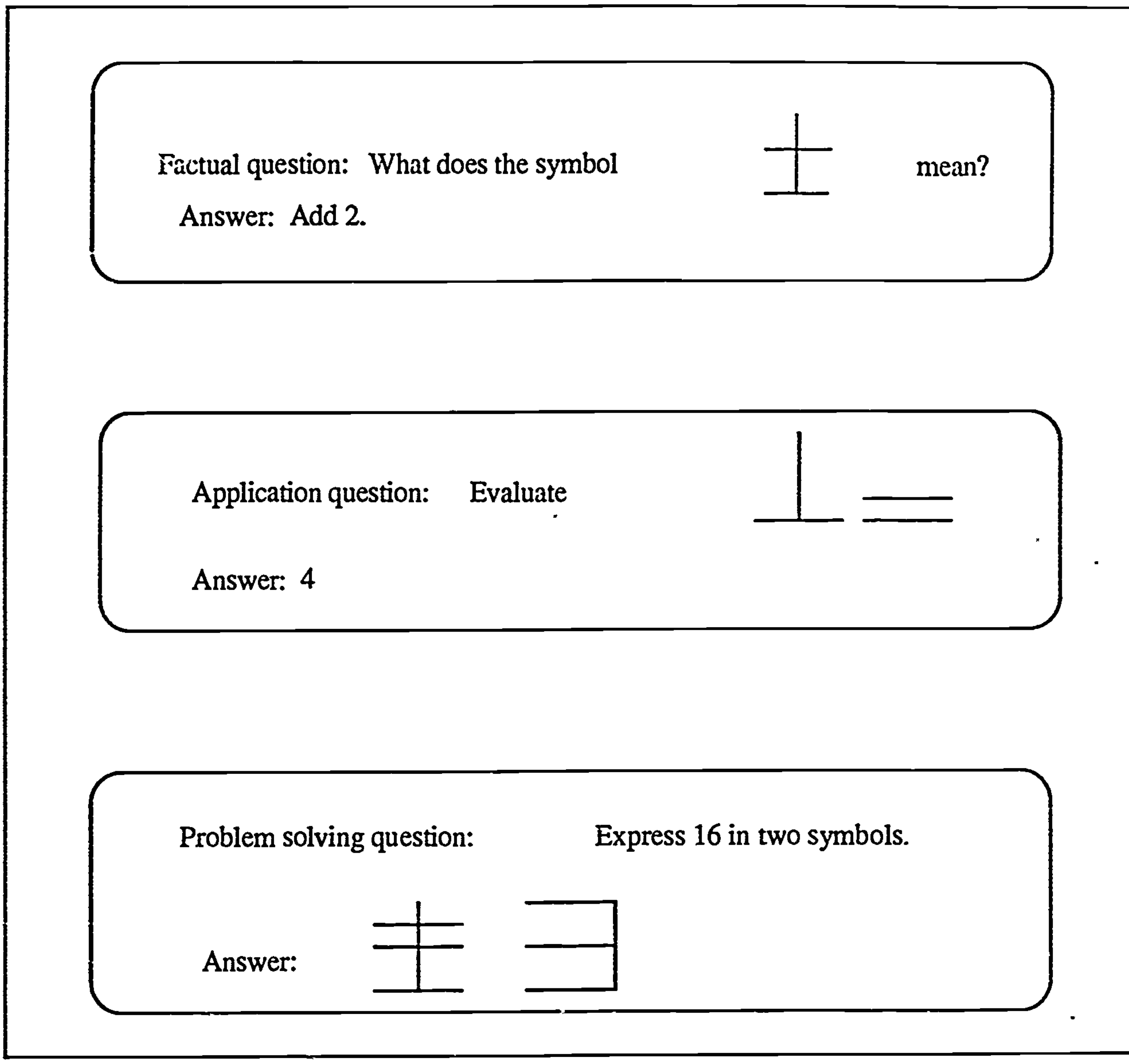


Figure 3. Examples of posttest questions.

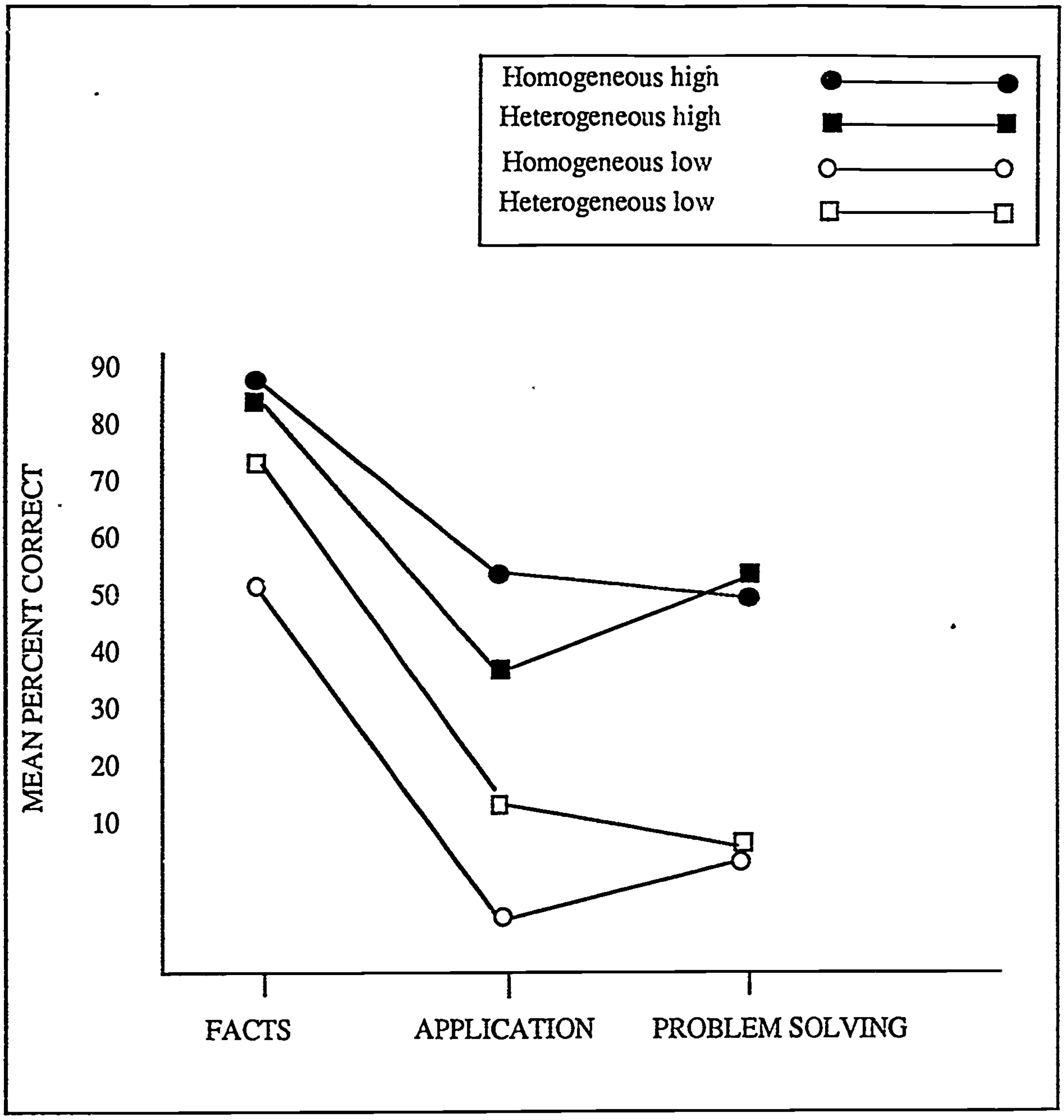


Figure 4. Percent correct for facts, applications, and problem solving.