DOCUMENT RESUME

ED 214 614 JC 820 171

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TITLE Factors Related to Problem Solving by College Students in Developmental Algebra.
PUB DATE Mar 82
NOTE 34p.; Paper presented at the Annual Meeting of the American Educational Research Association (New York, NY, March 19-23, 1982).

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Algebra; *Basic Skills; Cognitive Ability; Cognitive Style; *College Students; Community Colleges; Developmental Stages; Females; Males; Postsecondary Education; *Problem Solving; *Remedial Mathematics; Spatial Ability; *Student Characteristics; Two Year College Students; Universities
IDENTIFIERS *Mathematics Skills; *University of Maine Orono

ABSTRACT

A study was conducted to contrast the characteristics of three groups of college students who completed a developmental algebra course at the University of Maine at Orono during 1980-81. On the basis of a two-part final examination, involving a multiple-choice test of algebraic concepts and skills and a free-response test of problem-solving abilities, 16 four-year college students and 75 community college students were assigned to one of three categories. Group 1 was the low algebra skills, high problem-solving ability group; Group 2 was the high algebra skills, low problem-solving ability group; and Group 3 scored high on both measures. Comparisons among the groups were made on the basis of student test scores in the areas of visual spatial ability, abstract reasoning ability, cognitive style, learning style, and Piagetian developmental level. In addition, gender differences were analyzed. The study revealed that: (1) students in Group 3 were older and entered the class with better arithmetic skills than the other two groups; (2) that Group 2 students started the course with greater knowledge of algebra than the other two groups and were less field independent; and (3) Group 1 students were more field dependent than Group 2 students, were predominantly male, and may have had more spatial ability and more intuitive problem-solving methods. However, the groups were generally similar in more ways than they differed. Sample test items and data analyses are appended. (HB)

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Factors Related to Problem Solving by College Students in Developmental Algebra

Background

As George Polya wrote in 1962, "solving problems can be regarded as the most characteristically human activity." If our society continues to change as quickly in the next 20 years as in the past, new demands for competence and flexibility in problem solving will be made on students now in college as they enter the job market and function as citizens, parents and consumers. Mathematics educators have assumed a sizable part of the responsibility for teaching problem solving and have made learning to solve nonroutine verbal problems one of the most important objectives of mathematics instruction. However, bridging the gap between knowledge of concepts and skills and the ability to apply them in problem situations remains difficult.

To be more specific, over the nine semesters the author has taught developmental algebra with a problem solving component she has noticed two kinds of discrepant students. One does well on algebraic skills and manipulation but can not apply them to solving verbal problems for which they do not immediately recall a specific procedure. The other group can solve problems adequately, and sometimes very well, despite the fact that their algebra skills are mediocre. Then there is the important group of students who do well at both. It seemed that problem solving instruction in a developmental, college setting could ultimately be improved by a better understanding of the

Paper presented at the annual meeting of the American Educational Research Association, New York, March, 1982.

other ways in which these three groups of students differ. Some research of this type has been done by Meyer (1981) which suggests variables to pursue and statistical techniques to use. However, its usefulness is limited because the subjects were in fourth grade and the only variables studied were cognitive abilities. Other research on older students has identified variables which have been associated with differences in problem solving performance. Discussion of those variables which show the most promise of discriminating among the groups follows.

Piagetian Stage of Intellectual Development. Formal operational thought, in the Piagetian sense, which involves the ability to reason abstractly about propositions in hypothetical situations, seems to be important to success in mathematics at the early college level (Carpenter, 1980). Also students at this level appear to have problem solving processes available to them not available to students at lower levels (Days, Wheatley and Kulm, 1979; Watson, 1980). Although secondary school students should reach this level of thinking, according to Piaget and his followers, there is evidence that not all college students function at this level (Adi, 1978; Adi and Pulos, 1980; Silverman, 1978).

Visual Spatial Abilities. The use of diagrams and graphs in solving many types of mathematic problems argues for the logic of connecting the two abilities. These connections have been empirically demonstrated, especially for three-dimensional tests of spatial visualization, in a number of secondary school studies reviewed by the author (Schonberger, 1979). However, with a few exceptions (Elmore and Vasu, 1980; Sweeney, 1953), research on the college population, especially those in developmental courses, has yet to be done.

Abstract Reasoning Ability. One of the difficulties of establishing the mechanism of the relationship between solving spatial and mathematical problems is that subjects report both visual-movement and verbal-logical methods of solving spatial items (Barrett, 1953; French, 1965, Werdelin, 1961). There are cognitive abilities tests presenting figural stimuli with no movement implied which measure what has been called figural, nonverbal, or abstract reasoning ability. There is limited evidence that this ability is more closely related to solving mathematical problems than spatial ability is (Schonberger, 1979), but there is much less research in this area than in the spatial area.

Cognitive Style or Learning Style. The novel or nonroutine nature of verbal problems suggests that competent problem solvers are more independent in some way than people who are not good problem solvers. Two types of independence suggest themselves. One is at one end of the cognitive style quality called field independence/dependence. According to Witkin and Goodenough (1977), field independent students tend to do better in mathematics and science and are more successful at imposing structure on an unstructured setting than students at the other end of the continuum who are usually better at interpersonal skills. That this is a cognitive ability of a spatial nature rather than a cognitive style, has been convincingly argued by Sherman (1967). In any case, there is empirical evidence of its relationship to problem solving ability in college students (Berry, 1958, 1959; Blake, 1978; Moore, 1980). On the other hand, an independent learning style may be more important, especially since college courses often have sizable self-instruction components.

Gender. The generalization has been made that while females may do better at computation, males excel at problem solving. Much of the research on which this generalization was based can be criticized on methodological grounds, and more recent studies show few, if any, gender-related differences in problem solving performance (Fennema and Sherman, 1978; Schonberger, 1978). However, there is some evidence to the contrary in high school students (Armstrong, 1980; Swafford, 1980) and community college students taking developmental math courses (Moore, 1980). Another reason to include this variable is that gender-related differences have been noted in some studies for most of the other variables listed above.

Method

Subjects

Subjects for this study (n=91) were all those who finished a developmental algebra course taught by the author at the University of Maine at Orono in the 1980-1981 academic year. Most of these students were required to take the course because they had low scores on an admissions placement test or because they had failed a higher level course. A very few students simply chose to take the course. All had either taken or tested out of a developmental arithmetic course. Of the 91, 16 were enrolled in four-year programs at the University; the remaining 75 were enrolled in two-year programs, mostly at the Community College of the University. For reasons to be discussed later, separate data analyses were performed on the group of 91 and the subgroup of 75. Both the whole group and the subgroup had a female-male ratio of 36-64 percent. This ratio was the same as the female-male ratio of students entering the course or persisting past midterm. Their ages ranged from 17 to 41 but 70 percent of the whole group and 75 percent of the subgroup were 21 or younger.

Instruments

All participants in the study took a two-part, teacher-constructed final exam: a multiple choice test of algebraic concepts and skills (each problem scored right or wrong), and a free response test of problem solving (each problem scored from 0 to 3). Because the final exam was offered several times during exam week each semester, two parallel forms of each test were used. To adjust for possible differences in the tests, scores were standardized with a mean of 50 and a standard deviation of 10 and the results pooled. In addition, pretest scores on a twenty-four-item arithmetic test and a twenty-item algebra test like the concepts and skills part of the final exam were available for about 65 percent of the subjects. (See Appendix A and Table 10.)

Besides providing data from the mathematics measures, the students took the following paper and pencil tests during the algebra class to provide measures of the variables discussed in the previous section.

Visual Spatial Ability: Space Relations from the Differential Aptitude Test (Bennett, Seashore, and Wesman, 1973).

Abstract Reasoning Ability: Abstract Reasoning from the Differential Aptitude Test.

Cognitive Style: Gottschaldt Figures Test modified for group administration (Crutchfield, 1975).

Learning Style: Student Learning Style Questionnaire (Pare, 1972). (See Appendix A.)

Piagetian Developmental Level: Equilibrium in a Balance Test (Adi, 1976). (See Appendix A).

The last is a fifteen-item multiple choice test based on Piaget's balance tasks and designed to measure developmental level of reasoning about proportions. Adi considered it to be closely related to solving equations, an important tool used in solving algebra problems. This author derived five scales from Adi's instrument. The test is divided into three five-item parts (Equilibrium in a Balance 1, 2 and 3) with items at the late concrete, transitional and early formal levels of reasoning. Passing scores at the three levels are 4/5, 4/5 and 3/5 respectively. Adi's directions place a subject at a developmental level if (s)he passes that level and all those before it; this author placed the subject at the highest level passed, period. Equilibrium in a Balance Levels were assigned values from 1 (no levels passed) to 4 (the top level passed). In addition, Equilibrium in a Balance Total recorded the total number of items answered correctly from the three parts.

Analyses

The plan of this study was to see how groups discrepant on skills or concepts and problem solving differed from each other and from the group high on both dimensions. The job of identifying the groups presented a dilemma, given the relatively small number of subjects in the study. In order to maximize the differences between the discrepant groups, a middle band should be removed on each dimension. However, that could leave groups so small that differences did not reach statistical significance. This dilemma was resolved by doing the division three ways: using a 50-50 split, removing a middle band of about half a standard deviation, and removing a middle band of about one standard deviation. (See Figure 1.)

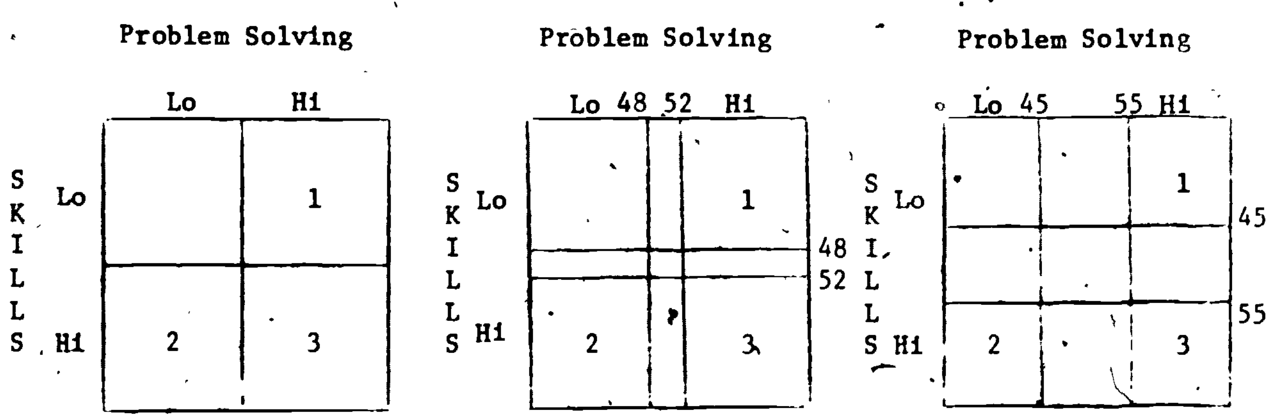

Figure 1

In each division Group 1 was Low Skills - High Problem Solving, Group 2 was High Skills - Low Problem Solving and Group 3 was High Skills - High Problem Solving.

When looking at the lists of students that fell into each group, the author noted that about 50 percent of Group 3 (High-High), were students in four-year programs. In order to remove this variable as a source of bias, the subgroup of 75 students in two-year programs wes studied separately. The standard scores were recomputed using this group and new groups were formed using the three methods described above.

Descriptive statistics (Table 1) and Pearson r correlation coefficients (Tables 2 and 3) were computed for the whole group of 91 and the two-year program subgroup of 75. One-way ANOVAs were performed on the three groups generated by each of the three splits of the whole group of 91 and the subgroup of 75. The criterion variables were sex, age, and scores from the instruments described earlier. In addition, each form of the problem solving test was analyzed, item by item, to see on which, if any, specific problems the three groups differed as evidenced by t-tests. Because of the small numbers here, only the 50-50 split was used.

Results and Discussion

Tables 4 through 9 list the results of the one-way ANOVAs for both the whole group of 91 and the two-year program subgroup of 75, each split by the three different methods described in the last section. In general, group means and standard deviations were listed only if the F-ratio's probability was less than .05 for that criterion variable on at least one of the six tables.

The first important result was that there were sizable numbers of discrepant students. In the 50-50 split of the 91 subjects Group 1 (low skills - high problem solving) had 23, Group 2 (high skills - low problem solving) had 17, and Group 3 (high skills - high problem solving) had 21; with the same split of the 75 two-year program students Group 1 had 21, Group 2 had 21 and Group 3 had 14. Although the discrepant groups decreased faster than Group 3 as the size of the excluded middle band increased, there were still distinct groups even with the split of one standard deviation. For the 91 subjects Group 1 had 11, Group 2 had 6, Group 3 had 15; for the 75 students Group 1 had 6, Group 2 had 7 and Group 3 had 9. (See the footnotes to Tables 4-9.) This result was expected, given the size of the correlations between the Algebra Skills Posttest and the Algebra Problem Solving Test: for the whole group $r = .353$; for the subgroup $r = .250$ (Tables 2 and 3).

One of the most outstanding results of the analyses is that the Group 3 students were older than those in the other two groups. This was only a trend for the 50-50 splits of both groups but was significant at the .01 level or below in the analyses with middle bands removed. Another characteristic which differentiated Group 3 from the two discrepant groups is that they entered the course with better arithmetic skills. While it should be noted that pretest data were missing for 25 to 30 percent of the subjects, the F-ratios for this difference were significant at the .02 level or below on all six analyses. There were two sources of the Arithmetic Skills Pretest scores: one, if the student tested above 14/24 on admission and was excused from Developmental Arithmetic and two, if the student took the arithmetic course and was successful on an equivalent 24-item test used as part of the final exam. The picture that these results give of the Group 3 students is that they are motivated adults who either entered college with good computational skills or else learned how to learn mathematics in the previous developmental math course.

The other result that involved skills on entry to the course were the Algebra Skills Pretest analyses. On all three splits of the whole group and the middle split of the two-year program subgroup, Group 2 students entered with significantly ($p < .05$) better algebra skills than Group 1 students. Since the Algebra Skills Pretest and Posttest (on which the groups were divided) were designed to be equivalent, this is probably to be expected. One possible interpretation is that for the Group 2 students the course served to remind them of what they had already learned without increasing their problem solving ability.

Another variable on which there were some differences between the groups was cognitive style. The instrument used, the Gottschaldt Figures Test, has two separate, timed parts which were used as separate scales as well as the total. The F-ratios were the most significant for the largest split (one standard deviation) of both groups on Part 2 of the test. The F-ratio for the total test was also significant ($p = .01$) for the whole group and suggestive ($p = .08$) for the two-year program subgroup. T-test results indicated that Group 3 outperformed Group 2 in all cases where the F-ratio was significant and in some cases where it was between .05 and .10. The first part of the Gottschaldt Figures test showed no significant differences which might seem surprising given the differences on Part 2. Despite the fact that a pilot tryout of this measure had indicated that similar students understood the directions, in the actual study some subjects appeared to have difficulty knowing what to do on the first part. The second part was probably a better measure of their field independence or dependence. The confusion on Part 1 probably diluted the usefulness of the total score, explaining why the results were more significant on Part 2. Inspection of the means on Part 2 and the total test shows that the Group 1 means were much closer to the Group 3 means than to those of Group 2 although the difference between Groups 1 and 2 was statistically significant only on Table 6. This suggests that field independence is a cognitive style or ability that good problem solvers have in common despite their level of algebra skills. Without the measurement problems this might have shown up more clearly.

Results related to gender were also interesting. Another analysis of this data (Schonberger, 1981) had indicated that both in the whole group ($p = .002$) and in the two-year program subgroup ($p = .005$) the males did better on the Algebra Problem Solving test although there were no differences on the Algebra Skills Posttest. Given the male-female ratio of 36 to 64 and the fact that males were scored 1 and females 2 on the gender variable, the means for gender would have been 1.36 if the males and females had been distributed evenly among the three groups. The mean was exactly that for Group 3 of the two-year program subgroup, split 50-50, and a little more than that (1.43) for Group 2; Group 2 was significantly ($p = .05$) more female than Group 1 in this division of the 75 students (Table 7). The Group 2 mean for the 50-50 split of the whole group was 1.35, but other than those, the group means showed that there were fewer females than expected in all the remaining groups. In other words, as soon as any middle band was removed, all groups were predominantly male and Group 1 was almost exclusively so. The higher male means on Algebra Problem Solving would explain the predominance of males in Groups 1 and 3 but not in Group 2. This may be an example of the hypothesized "greater variability" of males in quantitative areas (Maccoby and Jacklin, 1974). In this group the male standard deviation was 12% higher than that of females on Algebra Problem Solving.

On the rest of the measures there was little of significance. On the Equilibrium in a Balance scales, there were a few cases when the t-test results indicated that Group 3 excelled Group 1, but these are probably not important because the significance of the F-ratios hovered around .10. While Equilibrium in a Balance 1 and 3 scales were not expected to be good discriminators because they lacked variability, the author had great hopes for the other Piagetian scales. This test had been given early enough in the semester to be used to predict who would or would not complete the course. The cross-tabulation of the Equilibrium in a Balance Levels by course completion indicated that the higher the student's level of reasoning the more likely (s)he was to complete the course (significance of chi square = .01, of Kendall's tau c = .001). However, crosstabulations of level of algebra problem solving by level of algebra skills by Piagetian developmental level and of each algebra variable separately by Piagetian level produced no significant results.

Although there were significant correlations between Algebra Problem Solving and DAT Space Relations ($p \leq .01$) as well as between Algebra Problem Solving and DAT Abstract Reasoning ($p < .05$), the results of the ANOVAs on these variables were disappointing. In Meyer's (1981) study the abstract or figural reasoning test was the best discriminator between the high skills - low problem solving and high skills - high problem solving groups. The test chosen for this ability in this study has a good psychometric reputation and should have picked up differences if they existed. One possible reason that it did not is lack of variability. Although the means for Grade 12 students published in the DAT Administrator's Handbook were similar to those found in this study, their standard deviations were about 10 and those in this study were about 5. This is less likely to be the explanation for the lack of usefulness of DAT Space Relations where the standard deviations were less than, but close to, the published norms. The means for the DAT Space Relations test were included in Tables 4 through 9 even though none of the F-ratios were significant because this was the only scale on which the Group 1 means were always higher than those for the other two groups (although not significantly so). If significant, those results would have supported a popular hypothesis that good problem solvers are intuitive, global, spatial, right-hemisphere thinkers.

By doing the item analysis of Algebra Problem Solving separately by groups, the author had hoped to find that Groups 1 and 3 solved different kinds of problems despite the fact that their overall means were high. In general this was not the case. Only on the car radiator problem (3B) was there a significant difference with the Group 3 students doing better. Not only did this problem involve percents, but the answer was 6 2/3. Intuition would probably be much less useful in solving 3B than having learned the methods of solving mixture problems taught in class. On another mixture problem (4B) whose answers were 52¢ and 34¢ Group 3 students also did better than Group 1 but the p-value was only .09. By contrast the cube problem (2B) on which Group 1 really excelled was the one judged by the author to differ most from those dealt with in class or in the book. It is also the only geometry problem which is three dimensional which may be correlated with the hint of higher performance of Group 1 on the three dimensional DAT Space Relations. By far the most differences were found between the good problem solvers (Groups 1 and 3) and the poor ones (Group 2). Two of the best examples are 2A, a geometry problem, and 6B, a coin problem. The differences in the means indicate that subjects either got the problems right or did not understand them at all and could not connect those with any types learned before. The author's observations during the testing sessions support this generalization.

Significance

The number of statistically significant results of this study was disappointingly small. Still, profiles of the three groups emerged from the statistically significant results and the author's knowledge of the students. Group 3, the high skills - high problem solving group, had a substantial number of the 16 students from four-year programs (with their higher math entrance requirements). With or without these students, Group 3 was older and entered with better arithmetic skills, although not better algebra skills. They appeared to be more field independent than Group 2 which was high on skills but low on problem solving. They may have been at a higher developmental level of reasoning but that evidence is only suggestive.

The Group 2 students started the course with more knowledge of algebra skills than either of the other two groups, and were less field independent. This information plus the author's personal knowledge of the students suggests that there were two kinds in this group. One came in knowing quite a bit of algebra, refreshed their memories on the rest of the skills and coasted. The other worked hard and mastered the skills but never got the hang of transferring those skills to new situations. Their performance on the problems most different from those taught in the course supports this latter description.

Group 1, those able to solve problems competently despite mediocre algebra skills, were the group of most interest to the author. Their field independence was closer to that of the other good problem solvers (Group 3), and there was a hint that they may have had the best spatial ability of the three groups. Their problem solving methods may have been more intuitive than those of Group 3. While all the groups were disproportionately male, Group 1 was almost exclusively male. The author also noticed that, with a very few exceptions, these students were very quiet and rarely interacted with the other students in the class.

What implications do these profiles have for teaching problem solving to students in developmental algebra? Instructors rarely have much control over student maturity or entry level skills. If field independence is indeed a cognitive style rather than a cognitive ability, there is probably nothing that can be done in the classroom to develop it. However, there is a study of varying methods of instructing college students that indicated that field dependent students learn more with a high level of guidance whereas field independent students learn better in minimal guidance settings (McLeod, Carpenter, McCormack and Skvarcius, 1978). On the other hand, a similar study showed no aptitude-treatment interaction (McLeod and Adams, 1979). Interestingly, the author thinks that although there was a sizable self-instructional component to the rest of the course, the students received maximal guidance on the problem solving sections. This should have benefitted the field dependent students more, but it appeared not to. Teaching problem solving in a more social setting is another instructional strategy which might benefit the more field dependent students. Perhaps an optimal instructional strategy would be to have Group 1 students sharing their problem solving techniques with Group 2 students in small groups. The analysis and rationalization of their intuitive methods necessary to communicate them to someone else might help the Group 1 students integrate skills and intuition as well as help the Group 2 students learn to make enough sense out of problems to be.

able to apply their algebra skills. On the other hand, given the observed social skills of Group 1, this might not be successful.

In summary, it can be said that groups discrepant on algebra skills and problem solving do exist. They and the most able group differ in some ways that can help characterize them and suggest how to teach them. However, it should also be said that they are similar in many more ways than they differ.

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Appendix A

Sample Items from Tests Not Copywrited

Arithmetic Skills Pretest

A. Subtract 21.55 from 42.

a. 21.13

b. -21.13

c. 21.45

d. 20.55

e. 20.45

B. Which of the following equals $\frac{4}{15} + \frac{3}{7}$?

a. $\frac{4}{35}$

b. $\frac{28}{45}$

c. $\frac{1}{8}$

d. $\frac{12}{35}$

e. $2\frac{11}{25}$

Algebra Skills Pretest and Posttest

A. $(5m - 2)^2$ equals which of these?

a. $25m^2 - 10m + 4$

b. $25m^2 - 4$

c. $5m^2 - 10m + 2$

d. $25m^2 - 20m + 4$

e. $25m^2 - 20m - 4$

B. Find the pair of numbers which simultaneously solves $x + y = 7$ and $3x - y = 5$.

a. (6,1)

b. (-1,-2)

c. (3,4)

d. (4,3)

e. None of these

Student Learning Style Questionnaire

A. When you have a complicated problem, it is best to . . .

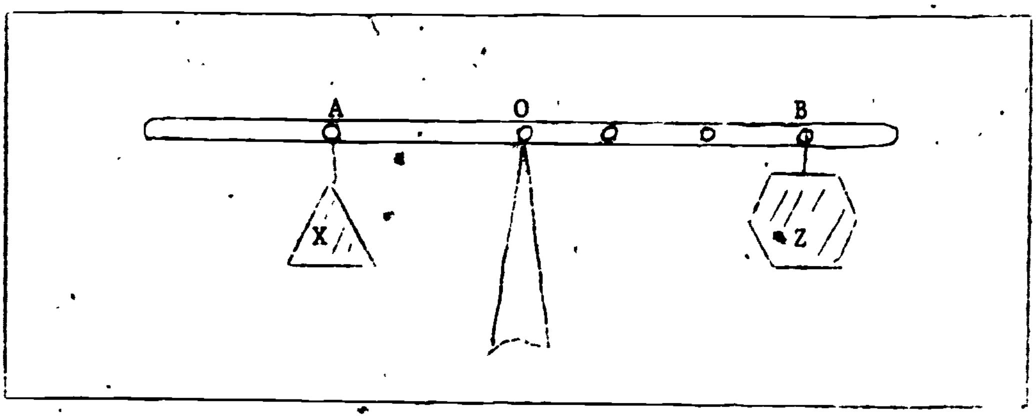
a. seek someone to remedy the situation.
b. consult with others but make up my own solution.
c. work the problem out myself without consulting anyone else.

B. When working in situations that require me to work in a team or group . . .

a. I pretty much follow the way the group wants to go.
b. my partner(s) and I share the work.
c. I do most of the work, or I work alone, because I prefer it.

Equilibrium in a Balance (A Transitional Item)

8. Given a system at equilibrium:



The length of $\overline{OA}$ is shorter than the length of $\overline{OB}$. If we double the weight of X, then we should ________ the weight of Z, to maintain the equilibrium of the system.

a) take half

b) keep as given

c) double

d) can't tell without knowing the original weights of both objects

Table 1

Descriptive Statistics

	Whole Group n=91		Two-Year Program Sub Group n=75	
	Mean	S.D.	Mean	S.D.
Algebra Problem Solving	50.97	9.69	50.05	9.88
Algebra Skills Posttest	49.37	10.18	50.15	9.76
Algebra Skills Pretest	5.58[a]	2.39	5.58[a]	2.39
Arithmetic Skills Pretest	18.88[b]	2.91	18.88[b]	2.91
DAT Abstract Reasoning	36.76	5.19	36.97	5.07
DAT Space Relations	36.46	10.23	36.64	10.12
Gottschaldt Figures (part 1)	3.30	3.01	3.13	2.96
Gottschaldt Figures (part 2)	3.90	2.87	3.75	2.71
Gottschaldt Figures Total	7.20	5.51	6.88	5.25
Equilibrium in a Balance 1	4.33	.72	4.31	.75
Equilibrium in a Balance 2	3.02	1.55	3.00	1.55
Equilibrium in a Balance 3	1.48	1.32	1.37	1.24
Equilibrium in a Balance Total	8.84	2.69	8.67	2.60
Learning Style	53.32	5.00	53.56	5.25

a n=57
b n=59

Table 2

Correlation Coefficients
Whole Group (n=91)

	1	2	3	4	5	6	7	8	9	10	11
1. Algebra Problem Solving											
2. Arithmetic Skills Pretest	.216*										
3. Algebra Skills Pretest	-.094	-.083									
4. Algebra Skills Posttest	.370***	.994*	.305***								
5. Space Relations	.371***	-.004	-.032	.103							
6. Abstract Reasoning	.244**	-.179*	.075	.124	.579***						
7. Gottschaldt Figures	.406***	.091	-.060	.120	.455***	.306***					
8. Learning Style	.030	.121	-.190*	.006	.013	-.110	-.064				
9. Equilibrium in a Balance 1	.152*	-.065	.088	.044	.034	.116	.009	-.058			
10. Equilibrium in a Balance 2	.199**	.017	.276**	.245***	.353***	.372***	.125	.011	.244***		
11. Equilibrium in a Balance 3	.232**	.072	.201*	.254***	.214**	.142*	.242***	.008	-.053	.527***	
12. Equilibrium in a Balance Total	.269***	.026	.299**	.277***	.317***	.311***	.193**	-.005	.380	.899***	.779***

* p < .10
** p < .05
*** p < .01

Table 3

Correlation Coefficients
Two-Year Program Subgroup (n=75)

	1	2	3	4	5	6	7	8	9	10	11
1. Algrbra Problem Solving											
2. Arithmetic Skills Pretest	.209*										
3. Algebra Skills Pretest	-.078	.083*									
4. Algebra Skills Posttest	.250**	.188*	.305***								
5. Space Relations	.325***	-.004	-.032	.072							
6. Abstract Reasoning	.300**	-.179*	.075	.213**	.557***						
7. Gottschaldt Figures	.327***	.091	-.060	.094	.412***	.280***					
8. Learning Style	.007	.121	-.190*	.139	.051	-.066	-.155				
9. Equilibrium in a Balance 1	.201**	-.065	.088	.067	.041	.108	.006	-.061			
10. Equilibrium in a Balance 2	-.143	.017	.276**	.254**	.367***	.405***	.021	-.076	.281***		
11. Equilibrium in a Balance 3	.161*	.072	.201*	.236**	.170*	.113	.173*	-.097	-.110	.452***	
12. Equilibrium in a Balance Total	.221**	.026	.300**	.285***	.313***	.324***	.097	-.111	.407***	.898***	.717***

* $p < .10$
** $p < .05$
*** $p < .01$

Table 4

One Way ANOVA for the Whole Group (n=91)
50-50 Split (No Middle Band)

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			.831	.4406	NSD
Gp1[a]	1.17	.388			
Gp2[b]	1.35	.493			
Gp3[c]	1.24	.436			
Age			2.326	.1068	NSD
Gp1	21.0	3.33			
Gp2	21.1	5.27			
Gp3	23.8	5.47			
DAT Abstract Reasoning			.333	.7179	NSD
Arithmetic Skills Pretest			13.683	.0001	
Gp1 (n=15)	18.4	2.23			Gp3> Gp1[d]
Gp2 (n=10)	18.0	2.11			Gp3> Gp2[d]
Gp3 (n=7)	22.7	1.11			
Algebra Skills Pretest			3.867	.0324	
Gp1 (n=14)	4.79	1.53			Gp2> Gp1[d]
Gp2 (n=11)	7.18	2.89			
Gp3 (n=7)	6.42	2.07			
Equilibrium in a Balance 1			.367	.6944	NSD
Equilibrium in a Balance 2			.579	.5635	NSD
Equilibrium in a Balance 3			.783	.4619	NSD
Equilibrium in a Balance Total			.844	.4354	NSD
DAT Space Relations			1.656	.2005	NSD
Gp1	41.0	9.23			
Gp2	34.9	11.54			
Gp3	38.5	9.17			
Gottschaldt Figures 1			1.610	.2087	NSD
Gottschaldt Figures 2			2.695	.0760	
Gp1	4.52	2.86			
Gp2	3.06	2.82			Gp3> Gp2[e]
Gp3	5.19	2.87			
Gottschaldt Figures Total			2.361	.1033	
Gp1	8.26	5.19			Gp3> Gp2[e]
Gp2	5.88	5.56			
Gp3	9.86	6.09			
Learning Style			.627	.5379	NSD

a Group 1 = Low Skills - High Problem Solving (n=23 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=17 unless stated differently)
c Group 3 = High Skills - High Problem Solving (n=21 unless stated differently)
d Significant at the .05 level on both *t*-tests
e Significant at the .05 level on the less strict *t*-test

Table 5

One Way ANOVA for the Whole Group (n=91)
Split with Middle Band of Half a Standard Deviation

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			.731	.4871	NSD
Gp1[a]	1.11	.315			
Gp2[b]	1.27	.467			
Gp3[c]	1.22	.428			
Age			6.025	.0048	
Gp1	20.8	2.68			Gp3 > Gp1[d]
Gp2	19.4	1.29			Gp3 > Gp2[d]
Gp3	23.2	3.91			
DAT Abstract Reasoning			.050	.9510	NSD
Arithmetic Skills Pretest			12.022	.0002	
Gp1 (n=11)	18.3	2.45			Gp3 > Gp1[d]
Gp2 (n=9)	18.2	2.11			Gp3 > Gp2[d]
Gp3 (n=7)	22.7	1.11			
Algebra Skills Pretest			4.639	.0198	
Gp1 (n=11)	4.82	1.60			Gp2 > Gp1[d]
Gp2 (n=9)	7.67	2.60			
Gp3 (n=7)	6.43	2.07			
Equilibrium in a Balance 1			.703	.5005	NSD
Equilibrium in a Balance 2			.288	.7512	NSD
Equilibrium in a Balance 3			.238	.7896	NSD
Equilibrium in a Balance Total			.460	.6345	NSD
DAT Space Relations			.960	.3912	NSD
Gp1	40.9	8.67			
Gp2	36.7	12.42			
Gp3	36.9	8.88			
Gottschaldt Figures 1			.645	.5294	NSD
Gottschaldt Figures 2			1.632	.2068	NSD
Gp1	4.68	2.71			
Gp2	3.36	3.04			
Gp3	5.33	2.89			
Gottschaldt Figures Total			1.150	.3258	NSD
Gp1	8.68	5.11			
Gp2	6.82	6.55			
Gp3	10.17	5.98			
Learning Style			1.218	.3060	NSD

a Group 1 = Low Skills - High Problem Solving (n=19 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=11 unless stated differently)
c Group 3 = High Skills - High Problem Solving (n=18 unless stated differently)
d Significant at the .05 level on both *t*-tests
e Significant at the .05 level on the less strict *t*-tests

Table 6

One Way ANOVA for the Whole Group (n=91)
Split with Middle Band of One Standard Deviation

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			.101	.9042	NSD
Gp1[a]	1.09	.302			
Gp2[b]	1.17	.408			
Gp3[c]	1.13	.352			
Age			8.460	.0013	
Gp1	19.6	.92			Gp3> Gp1[d]
Gp2	19.0	1.26			Gp3> Gp2[d]
Gp3	23.0	3.40			
DAT Abstract Reasoning			1.455	.2511	NSD
Arithmetic Skills Pretest			14.187	.0009	
Gp1 (n=5)	17.0	2.35			Gp3> Gp1[d]
Gp2 (n=4)	19.0	1.83			Gp3> Gp2[d]
Gp3 (n=5)	23.0	1.00			
Algebra Skills Pretest			4.622	.0349	
Gp1 (n=5)	5.2	.48			Gp2> Gp1[d]
Gp2 (n=4)	9.2	2.50			
Gp3 (n=5)	6.4	2.51			
Equilibrium in a Balance 1			.100	.9055	NSD
Equilibrium in a Balance 2			2.281	.1202	NSD
Equilibrium in a Balance 3			.814	.4531	NSD
Equilibrium in a Balance Total			2.337	.1145	Gp3> Gp1[e]
DAT Space Relations			1.765	.1904	
Gp1	42.1	6.01			
Gp2	33.8	14.61			
Gp3	39.7	6.44			
Gottschaldt Figures 1			2.922	.0698	Gp3> Gp2[e]
Gottschaldt Figures 2			6.467	.0048	
Gp1	4.64	2.11			Gp1> Gp2[e]
Gp2	2.00	2.10			Gp3> Gp2[d]
Gp3	6.00	2.51			
Gottschaldt Figures Total			5.078	.0129	
Gp1	8.64	4.30			Gp3> Gp2[d]
Gp2	4.00	4.73			
Gp3	11.47	5.32			
Learning Style			1.712	.1989	

a Group 1 = Low Skills - High Problem Solving (n=11 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=6 unless stated differently)
c Group 3 = High Skills - High Problem solving (n=15 unless stated differently)
d Significant at the .05 level on both t-tests
e Significant at the .05 level on the less strict t-test

Table 7

One Way ANOVA for Two-Year Program Subgroup (n=75)
50-50 Split (No Middle Band)

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			3.289	.0450	Gp2 > Gp1
Gp1[a]	1.10	.301			
Gp2[b]	1.43	.507			
Gp3[c]	1.36	.497			
Age			2.039	.1402	
Gp1	20.8	2.62			
Gp2	20.6	4.55			
Gp3	23.1	4.20			
DAT Abstract Reasoning			.873	.4237	NSD
Arithmetic Skills Pretest			5.383	.0089	
Gp1 (n=14)	18.9	2.57			Gp3 > Gp1[e]
Gp2 (n=17)	18.2	2.53			Gp3 > Gp2[d]
Gp3 (n=9)	22.6	2.50			
Algebra Skills Pretest			2.331	.1121	NSD
Gp1 (n=14)	4.71	1.49			
Gp2 (n=16)	6.31	2.82			
Gp3 (n=8)	6.38	1.92			
Equilibrium in a Balance 1			1.038	.3614	NSD
Equilibrium in a Balance 2			1.244	.2965	NSD
Equilibrium in a Balance 3			.632	.5352	NSD
Equilibrium in a Balance Total			1.866	.1648	NSD
DAT Space Relations			.819	.4466	NSD
Gp1	39.7	8.87			
Gp2	35.7	10.10			
Gp3	38.4	10.51			
Gottschaldt Figures 1			1.245	.2962	NSD
Gottschaldt Figures 2			1.457	.2422	NSD
Gp1	4.43	2.91			
Gp2	3.14	2.67			
Gp3	4.50	2.77			
Gottschaldt Figures Total			1.534	.2250	NSD
Gp1	8.10	5.32			
Gp2	5.67	5.30			
Gp3	8.57	5.94			
Learning Style			2.737	.0745	Gp3 > Gp1[e]

a Group 1 = Low Skills - High Problem Solving (n=21 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=21 unless stated differently)
c Group 3 = High Skills - High Problem Solving (n=14 unless stated differently)
d Significant at the .05 level on both *t*-tests
e Significant at the .05 level on the less strict *t*-test

Table 8

One Way ANOVA for Two-Year Program Subgroup (n=75) Split with Middle Band of Half a Standard Deviation

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			1.148	.3282	NSD
Gp1[a]	1.06	.250			
Gp2[b]	1.25	.452			
Gp3[c]	1.25	.452			
Age			8.119	.0012	
Gp1	19.8	1.28			Gp3 > Gp1[d]
Gp2	19.6	1.44			Gp3 > Gp2[d]
Gp3	22.8	3.56			
DAT Abstract Reasoning			.370	.6936	NSD
Arithmetic Skills Pretest			12.913	.0002	
Gp1 (n=10)	18.0	2.45			Gp3 > Gp1[d]
Gp2 (n=9)	18.2	2.10			Gp3 > Gp2[d]
Gp3 (n=7)	22.7	1.11			
Algebra Skills Pretest			5.672	.0099	
Gp1 (n=10)	4.50	1.43			Gp2 > Gp1[d]
Gp2 (n=9)	7.67	2.60			
Gp3 (n=7)	6.43	2.07			
Equilibrium in a Balance 1			.369	.6940	NSD
Equilibrium in a Balance 2			1.835	.1739	NSD
Equilibrium in a Balance 3			1.206	.3109	NSD
Eqilibrium in a Balance Total			2.377	.1068	Gp3 > Gp1[e]
DAT Space Relations			.336	.7172	NSD
Gp1	39.6	8.64			
Gp2	37.2	11.88			
Gp3	36.7	9.42			
Gottschaldt Figures 1			.403	.6714	NSD
Gottschaldt Figures 2			.786	.4629	NSD
Gp1	4.63	2.66			
Gp2	3.50	2.94			
Gp3	4.75	2.63			
Gottschaldt Figures Total			.631	.5379	NSD
Gp1	8.69	4.73			
Gp2	6.83	6.25			
Gp3	9.25	5.88			
Learning Style			2.958	.0654	Gp3 > Gp1[e]

a Group 1 = Low Skills - High Problem Solving (n=16 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=12 unless stated differently)
c Group 3 = High Skills - High Problem Solving (n=12 unless stated differently)
d Significant at the .05 level on both *t*-tests
e Significant at the .05 level on the less strict *t*-tests

Table 9

One Way ANOVA for Two-Year Program Subgroup (n=75) Split with Middle Band of One Standard Deviation

Variable	Mean	SD	F-ratio	Probability	T-test results
Gender			.702	.5081	NSD
Gp1[a]	1.00	.000			
Gp2[b]	1.14	.378			
Gp3[c]	1.22	.441			
Age			5.155	.0163	
Gp1[a]	20.0	.89			Gp3> Gp1[e]
Gp2[b]	19.4	1.61			Gp3> Gp2[d]
Gp3[c]	23.4	3.88			
DAT Abstract Reasoning			2.108	.1521	
Arithmetic Skills Pretest			6.568	.0205	
Gp1 (n=2)	18.0	4.24			Gp3> Gp1[e]
Gp2 (n=4)	19.0	1.83			Gp3> Gp2[e]
Gp3 (n=5)	23.0	1.00			
Algebra Skills Pretest			2.702	.1269	
Gp1 (n=2)	5.0	.00			
Gp2 (n=4)	9.3	2.50			
Gp3 (n=5)	6.4	2.51			
Equilibrium in a Balance 1			.189	.8291	NSD
Equilibrium in a Balance 2			2.671	.0950	Gp3> Gp1[e]
Equilibrium in a Balance 3			.299	.7450	NSD
Equilibrium in a Balance Total			2.255	.1322	NSD
DAT Space Relations			1.077	.3628	NSD
Gp1	43.8	3.77			
Gp2	35.0	13.67			
Gp3	38.2	6.81			
Gottschaldt Figures 1			2.151	.1438	NSD
Gottschaldt Figures 2			3.311	.0584	
Gp1	4.17	2.14			Gp3> Gp2[e]
Gp2	2.43	2.23			
Gp3	5.44	2.51			
Gottschaldt Figures Total			2.917	.0786	
Gp1	8.33	5.42			Gp3> Gp2[e]
Gp2	4.43	4.47			
Gp3	10.78	5.61			
Learning Style			1.244	.3118	NSD

a Group 1 = Low Skills - High Problem Solving (n=6 unless stated differently)
b Group 2 = High Skills - Low Problem Solving (n=7 unless stated differently)
c Group 3 = High Skills - High Problem Solving (n=9 unless stated differently)
d Significant at the .05 level on both *t*-tests
e Significant at the .05 level on the less strict *t*-test

Table 10

Algebra Problem Solving A
Item Analysis

1. *A man and woman can paddle a canoe at a speed of 5 mph in still water. They make a trip up the river and then back down in a total of 10 hours when the river is flowing at 2 mph. How far up the river do they go before turning back?*

	Means	Standard Deviations	
Gp1	1.67	1.00	
Gp2	1.88	.99	NSD
Gp3	2.40	.97	

2. *A rectangular plot of ground is 20 feet wide and 30 feet long. Across one of the shorter ends it is necessary to put a 5-foot walk. How much must the shorter dimension (the width) be increased in order to maintain the original area?*

	Means	Standard Deviations	
Gp1	2.67	.71	Gp1 > Gp2**
Gp2	.50	.55	Gp3 > Gp2**
Gp3	2.10	1.29	

3. *A man is able to invest part of his $10,000 savings at 8 1/2% annual interest and the remaining amount at 6%. If his total earnings in one year are $700 how much was invested at each rate?*

	Means	Standard Deviations	
Gp1	1.33	.87	
Gp2	1.00	.76	NSD
Gp3	1.10	1.10	

4. *The hypotenuse (longest side) of a right triangle is 13 meters long. One leg is 7 meters longer than the other. Find the lengths of the legs (shorter sides). Then find the area of the triangle.*

	Means	Standard Deviations	
Gp1	2.78	.67	
Gp2	2.63	.74	NSD
Gp3	2.90	.32	

5. *A woman and her Little League team went to a drive-in restaurant. She ordered 6 hamburgers and 4 hot dogs and paid $7.50. Two of the kids who had wanted hamburgers changed their minds and wanted hot dogs. The waiter changed the order and gave her $.50 more in change. What was the price for each sandwich?*

	Means	Standard Deviations	
Gp1	1.67	.71	Gp1 > Gp2**
Gp2	.75	.46	Gp3 > Gp2**
Gp3	2.00	.82	

6. *On balance scales, a gold bar weighs as much as one third of a bar together with a one-pound weight. How much does the gold bar weigh?*

	Means	Standard Deviations	
Gp1	2.00	1.32	
Gp2	1.26	1.13	Gp3 > Gp2*
Gp3	2.30	1.16	

Items scored from 0 to 3 points each   * $p < .05$
Reliability: Alpha = .57   ** $p < .01$

Algebra Problem Solving B
Item Analysis

1. *A train leaves a station and travels at 45 mph. Three hours later an express train leaves the same station traveling 75 mph. How far from the station will the second train overtake the first?*

	Means	Standard Deviations	
Gp1	2.23	1.09	Gp1 > Gp2**
Gp2	.67	.50	Gp3 > Gp2**
Gp3	1.91	1.14	

2. *A cube has a surface area of 600 square cm. What is its volume?* (A picture of an unmarked cube accompanied this problem.)

	Means	Standard Deviations	
Gp1	2.69	.63	Gp1 > Gp2**
Gp2	1.11	1.17	Gp3 > Gp2*
Gp3	2.09	1.14	

3. *If a radiator is filled with a 40% solution of antifreeze solution, how much must be drained off and replaced by pure antifreeze in order to get a concentration of 60%, assuming that the radiator holds 20 quarts when full?*

	Means	Standard Deviations	
Gp1	.77	.93	Gp3 > Gp1*
Gp2	.67	.71	Gp3 > Gp2**
Gp3	1.82	1.25	

4. *Papa Baldacci went to the store to get 5 cans of tomatoes and 3 cans of tomato paste for his famous spaghetti sauce recipe. When he got there he found that the cost would be $3.62. Since he had only $3.50 in his pocket he changed the recipe. He bought 4 cans of each, and paid $3.44. How much did each can cost?*

	Means	Standard Deviations	
Gp1	1.00	.71	
Gp2	1.67	1.12	NSD
Gp3	1.64	1.03	

5. *A park, 100 yds by 100 yds, is designed to have a road around the entire inside perimeter. How wide should the road be to preserve 6400 sq. yds of area for the park?*

	Means	Standard Deviations	
Gp1	2.85	.38	Gp1 > Gp2**
Gp2	1.22	1.20	Gp3 > Gp2*
Gp3	2.27	1.28	

6. *A collection of nickels, dimes and quarters is worth $4.20. If there are twice as many nickels as quarters, and the total number of coins is 37, how many nickels, how many dimes and how many quarters are there in this collection?*

	Means	Standard Deviations	
Gp1	2.00	1.23	Gp1 > Gp2**
Gp2	.22	.44	Gp3 > Gp2**
Gp3	2.27	1.19	

Items scored from 0 to 3 points each — * $p < .05$
Reliability; Alpha = .70 — ** $p < .01$