THE RELATIONSHIP BETWEEN SELECTED VARIABLES AND ARITHMETIC PROBLEM SOLVING AMONG COMMUNITY COLLEGE STUDENTS

by

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Chapter 1

INTRODUCTION

Experience and research suggest that students have difficulty solving mathematical verbal problems. This difficulty is not confined to the underprepared mathematics students. In fact, at all age levels and all levels of academic preparation, performance on activities requiring problem solving is usually low (Carpenter, Corbitt, Kepner, Lindquist & Reys, 1980b). Generally, problem solving activities require basic skill in reasoning and thinking. Such skill may be elusive for many of the developmental mathematics students who make up a significant portion of the community college population. Some studies have indicated that as many as 50 percent of the total community college population are enrolled in developmental mathematics students (Baldwin, 1975).

A report, submitted by the New Jersey Basic Skills Council on the New Jersey College Basic Skills Placement Test, indicated that of the 51,135 students tested in 1982, a very small percentage demonstrated proficiency in the basic skills. The report noted among the students entering college, 31% lacked proficiency in verbal skills; 46% lacked proficiency in computation; and 61% lacked proficiency in elementary algebra (New Jersey Basic Skills Council, 1982). This report suggested that remediation continues to be a function that all segments of postsecondary education must address.

Many developmental students do not have the mathematical experience to feel comfortable with problem solving activities. Problem solving requires computational skill and technique, and to develop competence in this activity might necessitate practice and dedication. Developmental students, however, may be so mathematically immature that they simply lack the sheer dedication that is required to be good problem solvers (Hecht & Akst, 1980). Although the number of developmental students has increased during the past two decades, only a few studies (e.g. Bellile, 1980; Gimmestad, 1977; Moore, 1980) have considered the problem solving difficulties of this population. With the increased technological demands placed on the average citizen, basic mathematical problem solving competencies become a must. The fact is that these demands place a tremendous burden on developmental students (Pearlman, 1977). With a steady increase in the number of community college students who are forced to enroll in developmental mathematics courses, it becomes a must that developmental educators devote greater attention to preparing developmental students not only to move into mainstream curricula, but also to prepare developmental students to meet the challenges of a technological society.

Despite the importance of problem solving, little time is devoted to teaching this skill in developmental mathematics. Many instructors indicate that developmental students have such acute skill deficiencies that problem solving activity is simply not a realistic objective. One essential component for enhancing problem solving in an educational setting is to understand the factors which inhibit effective problem solving.

For developmental students, there is inconclusive research data concerning both cognitive and affective variables which affect problem solving performance. In the last two decades much has been written about the community college developmental student, but most of the literature has focused on the demographic characteristics of the community college student. There have been very few research efforts which have specifically linked any of these characteristics to successful problem solving performance.

According to the literature, there appear to be several reasons why developmental students experience more difficulty with problem solving than the nondevelopmental student. First, developmental students show differences in their approach to problem solving. That is, students who are enrolled in developmental mathematics will typically attempt to solve a verbal problem using trial and error strategies. Rarely will these students utilize any systematic or heuristic approach to obtain the solution. This approach to obtaining solutions to verbal problems may be indicative of the student's lack of mathematical knowledge or the student's inexperience with verbal problems. In addition, many students in this group have avoided taking formal mathematics courses (Richardson, Martens, & Fisk, 1981).

Supporting this same assertion is the fact that students enrolled in developmental mathematics score in the lowest third on tests of mathematical ability (Cross, 1972). Consequently, these students lack proficiency with the fundamental skills, and they often lack conceptual understanding; both factors are essential in verbal problem solving. Developmental students are selected for remediation on the basis of test scores, information gained through interviews, or other evidence indicating poor academic preparation (Sanchez, 1977). As indicated by previous academic experience, these students may suffer from not only an inadequate mathematics background, but also from poor study habits, low self concept (Cross, 1972; Moore, 1980; Pearlman, 1977), and poor language skills (Bittinger, 1972).

Presumably, successful problem solving is contingent upon several factors, both affective and cognitive, in which developmental students are deficient. According to Suydam (1980), good problem solvers possess the ability a) to understand mathematical concepts, b) to think critically, c) to estimate and analyze, d) to score high on measures of self-esteem, e) to score high on measures of reasoning and f) to score high on measures of reading comprehension. The literature indicates that there are certain variables which consistently denote variance in verbal problem solving among developmental students (Schonberger, 1982). These variables are: (a) mathematical achievement, (b) logical reasoning, (c) verbal skills and (d) the utilization of problem solving strategies (see also, Hollander, 1978; Kantowski, 1977).

In view of the increased numbers of developmental mathematics students in community colleges, this research was undertaken to enhance the understanding of the factors which affect problem solving performance.

From the literature review and from experience, it was hypothesized here that there are three major aptitudes that contribute most to problem solving success. These aptitudes are (a) the ability to read and comprehend the problem, (b) the ability to think critically in assessing the data given in the problem, and (c) the ability to utilize certain mathematical concepts and applications that are necessary in performing the appropriate computations which lead to the correct answer to the problem.

Statement of Problem

It is well documented that verbal problem solving is an extremely difficult activity for countless students. Based on both experience and a review of the literature, it appears that three significant factors contribute consistently to problem solving performance at all age and academic levels. The most frequently documented variables are: (a) level of mathematics achievement, (b) critical thinking ability, and (c) reading ability. These selected factors were investigated to establish to what extent they contribute to the variance in problem solving performance for a sample of community college students.

Purpose and Rationale

The community college developmental student experiences immense difficulty with mathematics in general and verbal problem solving in particular. Many developmental students either avoid such activities or become so frustrated during such activities that they develop a phobia about problem solving. Kilpatrick (1969) and Kantowski (1977) suggested that researchers give close attention to assessing the components of the problem solving process. According to Gross (1983), one method of assessing the particular components of the problem solving process is through paper and pencil tests which allow the researchers to identify whether the difficulty is in reading, understanding or some aspect associated with computation. Polya (1971) proposed the most widely used four-stage problem solving model. Polya limited his problem solving model to the following steps: understanding the problem, devising a plan, carrying out the plan and looking back. According to Carpenter, Corbitt, Kepner, Lindquist and Reys (1980b), students ignore three of these stages: understanding the problem, devising a plan and looking back. Too often students even fail to attempt a systematic approach that will enhance their understanding of the problem.

The specific purposes of the study were:

1. To assess the problem solving performance of a sample of community college students who were identified as either developmental or nondevelopmental (using the Iowa Problem Solving Project test). The IPSP test utilizes stages 1, 3 and 4 of the Polya model.
2. To describe the correlation between problem solving performances and selected variables (mathematics achievement, critical thinking and reading comprehension).
3. To identify the contribution of six variables (three stages of the problem solving process denoted as PS1 {Subtest 1, IPSP}, PS2 {Subtest 2, IPSP}, PS3 {Subtest 3, IPSP}, mathematics achievement, critical thinking, and reading

comprehension) to the difference between developmental and nondevelopmental students.

4. To identify which of three selected variables (mathematics achievement, critical thinking or reading comprehension) is the best predictor of problem solving success among developmental students and nondevelopmental students.

Research Questions

In an attempt to investigate the sources of variance in problem solving performance among subjects in this study, the following questions provided direction for the study:

1. What is the contribution of six variables (three aspects of problem solving, mathematics achievement, critical thinking, and reading comprehension) to the difference between students classified as developmental or nondevelopmental?

2. Which of three selected variables, mathematics achievement, reading comprehension and critical thinking, is the best predictor of problem solving performance among developmental and nondevelopmental students?

Significance of the Study

Since Bellile's work (1980), no study has been conducted to determine the performance of developmental college students on an instrument such as the Iowa Problem Solving Project Test. Although Bellile described a sample of remedial college students, many questions concerning this population still remain unanswered.

There are several suggestions from Bellile's study that give impetus to the current study. Her research as well as others (e.g., Moore, 1980) suggest certain important considerations for future research. These considerations are that some problem solvers, particularly those from the population of developmental students, find poor reading comprehension a hindrance, some developmental students are unable to "carry out the plan," most developmental students are unable to "look back" at the solution and, perhaps overall the problem solving performance of developmental students differs significantly from nondevelopmental students. The latter consideration is the primary difference between Bellile's study and this study.

Since problem solving is at the heart of learning mathematics, it seems appropriate to consider this activity as a realistic part of community college developmental mathematics programs. While developmental students often have specific academic deficiencies, all students, developmental and otherwise, look to the educational environment to foster the transmission of subject matter, as well as to develop the ability to solve problems.

Ultimately, this research and future research will add to the body of knowledge which seeks to examine the relationships between knowledge and problem solving. As more instructional personnel develop a more holistic approach to teaching, it will become increasingly important that students be taught not only the fundamentals, but also those problem solving strategies that enhance an understanding of basic concepts and lead to the attainment of higher order concepts. In addition, this study will contribute to the body of knowledge that is considered when creating an effective problem solving environment for community college students. Despite the importance of problem solving, there has been little research involving community college students or adults which investigates the relative effects certain cognitive variables have on the utilization of different stages of the problem solving process (i.e., IPSP Model). From the early 1900s until the early 1960s, research in arithmetic problem solving was almost exclusively focused on factors associated with the difficulty which children have in solving arithmetic word problems. While a few recent studies have concentrated on adults, this area of research is still virtually unexplored.

Limitations of the Study

This study had several limitations. The study was limited to a single multi-campus Virginia community college; this college was comprehensive in nature and featured a broad-based population of both developmental and nondevelopmental students, however, it was a single institution study. Another limitation was that the study did not incorporate the second step, "Choosing what to do," of Polya's model. No valid means of assessing this step through multiple choice testing has been found.

A third limitation of this study was the procedure used for classification of a subject as either developmental or nondevelopmental. Primarily the basis for this classification is the placement in the course identified as developmental or nondevelopmental. A basic assumption is that this procedure of classification is accurate and consistent with other community colleges. Further discussion of this classification will take place in the Subjects section of Chapter 3, where limitations associated with methodology will be discussed.

Definition of Terms

Critical thinking ability is the score on the Watson-Glaser Critical Thinking Appraisal, Form A.

Developmental student (Remedial and developmental are used interchangeably here) is a student enrolled in a developmental mathematics course at J. Sargeant Reynolds Community College. Generally, a developmental mathematics student implies a student who is mathematically underprepared. Through counseling and testing the student was placed in a noncredit preparatory mathematics course. A student was placed in a developmental course because of the results obtained on a mathematics placement test. At the Downtown Campus, the nationally normed Descriptive Test of Mathematics Skills was used. Generally, local cut-offs have been decided upon, and students were assigned to developmental mathematics courses when they score less than 70 percent on the intermediate Algebra content area. There were three content areas of the test, arithmetic, elementary algebra and intermediate algebra. If the student did not demonstrate 70% proficiency or better in any given content area, that student is then placed in that content area developmental course. In addition to placement testing, some students are placed into developmental mathematics because of self-selection.

Mathematics achievement is the score on the mathematics subtest of the Stanford Test of Academic Skills, Form E.

Nondevelopmental student is a student enrolled in a nondevelopmental or credit mathematics course at J. Sargeant Reynolds Community College. Typically, a nondevelopmental student is enrolled in an occupational-technical or college transfer mathematics course. If a student is enrolled in a nondevelopmental mathematics course, then that individual has completed the placement test with a 70 percent proficiency or better in the intermediate algebra content or the person has satisfactorily completed a developmental mathematics course or its equivalent. The nondevelopmental courses used in this study require various degrees of mathematics proficiency. That is, some courses require only proficiency in elementary algebra. It should be noted here that students often volunteer for nondevelopmental mathematics courses. That is, the student may, through personal choice, opt to take a nondevelopmental course. In some cases, the student might possess fewer than the required prerequisites for the course.

Problem solving performance is the score on the Iowa Problem Solving Project Test, Form 781.

Reading comprehension is the score on the Reading Comprehension subtest of the Stanford Test of Academic Skills, Form E.

Organization of the Remaining Chapters

The remainder of this study is organized in four chapters. Chapter 2 consists of a review of related research and literature dealing with (a) the theoretical background of problem solving, (b) profiles of the developmental student, and (c) findings from research related to the selected variables, mathematics achievement, critical thinking and reading comprehension.

The research methodology, population, sample, instrumentation and data analysis are described in Chapter 3. Chapter 4 describes the findings of the study, and Chapter 5 includes a discussion of findings, summary, conclusions and recommendations.

Chapter 2

RELATED LITERATURE REVIEW

Theoretical Background of Problem Solving

There is no consensus on a definition of problem solving. Although this phenomenon has been studied for decades, it continues to be a little understood activity. Numerous authors have attempted to describe problem solving both as a cognitive process and as an operational skill. Problem solving definitions come from basically two schools of psychology: behaviorism and information processing. Behaviorists view problem solving as the association of a stimulus with a response. During the problem solving situation, the stimulus (information or data) promotes certain behavior which results in the actual act of solving or attempting to solve the problem. Skinner (1975) described this activity as follows: "The behavior which brings about the change is called problem solving and the response promotes a solution. A question for which there is no immediate answer is a problem" (p. 225). Skinner claims that there is no behavioral process which is not relevant to the solution of some problem. He further notes that a stimulus-response situation must be followed by a reinforcing consequence, thus reducing the complexities associated with solving similar problems.

The information processing approach to problem solving is based upon the utilization of the language of computers. According to Rubenstein (1975), the emphasis here is on the process that intervenes between input and output and eventually promotes the solution of the problem. That is, this process seeks to provide information concerned with the pattern of thinking utilized by the problem solver.

Similarly, Wickelgren (1974) advocated an information processing approach in describing problem solving. He noted that all problems are composed of three types of information: information concerning givens, information concerning operations, and information concerning goals. Although many problems are concerned with physical objects, the problem itself is a compilation of information, usually in the abstract, which must be cognitively represented in order for the problem solver to reach a desired solution. It appears that Wickelgren was suggesting that the problem solver must possess certain cognitive aptitudes in order to accept a problem in its "given state" and conceptualize the "route" that leads to the "goal state" or solution.

In contrast, Skemp (1979) related problem solving to the psychology of learning mathematics. Calling this process reflective problem solving, he claimed that the innate state must be the awareness of a problem; that is, there must be a conceptualization of the goal state, a state which one cannot routinely reach. In addition, Skemp noted that the prerequisite for this path to the goal state is a well organized body of knowledge.

One can readily see that the literature provides a variety of definitions of problem solving. Another supportive definition of problem solving is given by Polya (1980). Polya (1980) wrote:

> Solving a problem is finding the unknown means to a distinctly conceived end. If the end by its simple presence does not instantaneously suggest the means, if, therefore we have to search for means, reflecting consciously how to attain the end we have to solve a problem (p. 1).

The current study was based on several common elements that permeate the aforementioned definitions of problem solving. First, there must be an awareness of a problem. One of the necessary conditions for a problem is the existence of and the problem solver's awareness of a question (Henderson & Pingry, 1953). An individual's behavior (problem solving) is precipitated by one's ability to conceptualize the given data and to perceive how that data connects to the overall goal of the problem. Henderson and Pingry suggested that problem solving is not a reality unless the goal is clear to the individual, that is, it "directs, evokes and sustains the individual's behavior" (p. 229).

In verbal problem solving, foremost to obtaining a solution is one's knowledge of all the axioms, algorithms and concepts that must be assumed for the given problem situation. Along with knowledge, one has to understand the problem before a goal state can be perceived. Henderson and Pingry (1953) indicated that if the problem solver is lower in mathematical achievement, or perceives no conceptual relationship, then it is unlikely the problem will be seen as a "problem."

Obviously, there are individual differences in verbal problem solving, because what may be a "problem" for some is only an exercise for others (Henderson & Pingry, 1953). The level of difficulty of the problem depends to a large extent on the abilities of the problem solver, including the individual's utilization of the information in the problem. Wickelgren (1974) states, "usually, the implicit givens, operations and goals of a problem are clear to the problem solver, but sometimes they are not" (p. 14). This fact supplied the impetus for the current study. Although a general definition of problem solving has been cited, for this study, problem solving was specifically associated with one's acceptance of a "verbal" problem as a challenge to the extent that the goal or solution is not readily attainable. The assessment of some of the variables that increase the variance in verbal problem solving was the primary goal of this study.

Assessing Problem Solving

One of the difficulties in an investigation involving problem solving is that because problem solving is a mental process it is extremely difficult to assess one's competence or efficiency in obtaining a solution to a given problem. Many problem solving studies during the last fifty years have focused on problem solving as a product; however, during the last decade, considerable attention has been given to problem solving as a process (Suydam, 1980). Product researchers usually sought to study problem solving by having the subject solve a set of problems. By producing only a percentage of correct responses, this technique of investigating problem solving added little to the discovery of the sources of difficulty or the extent to which certain factors contributed to the problem solving performance.

Researchers during the past decade have focused almost exclusively on processes involved in solving problems. It is well documented that the processes a problem solver might utilize while solving a problem are both varied and complicated. According to Lester (1980) these "processes include all thinking done during problem solving and range over such diverse behaviors as working backward, simplifying and deducing to drawing pictures, solving equations and using trial and error" (p. 300).

At this point it is important that several terms associated with processes be clarified. According to Polya (1971), the act of solving a problem involves utilizing a series of planned actions which he describes as heuristics. Many researchers have associated actions such as making a table or solving an equation with the word "heuristic" (Lester, 1980). For this research, the aforementioned actions as noted by Lester (1980) were associated with the term strategy. Polya (1971) incorporated most of these strategies into his four-step problem solving model.

In studying the processes of problem solving, Polya (1971) laid the foundation for studies concerned with investigating most aspects of the problem solving process. He advances the notion that there is some degree of homogeneity among successful problem solvers. That is, most problem solvers explicitly or implicitly incorporate the stages of his model. For this study, a reference to strategies is a reference to Polya's model, because at every stage of the model, specific strategies are utilized.

The model utilized in this study was a model developed by the Iowa Problem Solving Project, which in general is a version of the model by Polya (1971). Schoen and Oehmke (1980) described the IPSP model as (p. 217):

1. Getting to know the problem. The problem solver is engaged in reading and discerning the meanings of the words in the problem, comprehending the problem setting, determining the relevant facts, perceiving the implied relationships and understanding the nature of the question being asked.

2. Choosing what to do. The problem solver is developing or choosing a plan of attack that she or he hopes will lead to the solution. The plan could include, making a table, graph or diagram, using an equation, systematic trial and error, and so on.

3. Doing it. The problem solver is carrying out his or her strategy to a solution.

4. Looking back. The problem solver reflects on the solution in light of the conditions of the problem and attempts to answer questions such as the following: Does the solution make sense given the conditions of the problem? Can other problems like this one now be solved? Is the solution still correct if certain conditions are varied in the problem? Is there another way to solve the problem?

It should be noted here that the aforementioned model is the model developed by the Iowa Problem Solving Project, but the IPSP test only assesses steps 1, 3 and 4. "After two years of effort, the IPSP team has not been able to find a valid machine-scorable way to test a student's ability to choose a problem-solving strategy, step 2 of the four-step model" (Schoen & Oehmke, 1980, p. 218).

Problem Solving Performance Variables

There appear to be a few common characteristics among successful problem solvers; however, there is no clear consensus as to the set of factors that affect problem solving in general. The list of factors can be drawn from several literature sources (Hollander, 1978; Kantowski, 1977; Suydam, 1980). The factors which most often appear in the literature to show promise in denoting the sources of variance in verbal problem solving among community college students are: (1) mathematical achievement, (2) logical reasoning, (3) verbal skills and (4) problem solving strategies (Gimmestad, 1977, Hollander, 1978; Kantowski, 1977; Moore, 1980).

Mathematical Achievement. One of the primary prerequisites for problem solving is a well organized knowledge structure of the subject matter (Ausubel, Novak & Hanesian, 1978; Resnick & Ford, 1981). Some researchers would posit that this factor is the most important reason associated with the difficulty developmental students experience while attempting to solve verbal problems.

Although it is generally agreed that knowledge is an important ingredient for successful problem solving, many developmental students simply fail to demonstrate mastery of specific skills and concepts (Whitesitt, 1982). Whereas mathematical knowledge is a necessary condition for problem solving, it is not sufficient because it may be shown that mathematical knowledge alone does not always result in successful problem solving (Carpenter, Corbitt, Kepner, Lindquist & Reys, 1980a; Meyer, 1978).

In a study involving 40 high school students, Webb (1979) found that mathematics achievement, represented by conceptual knowledge, accounted for approximately 50 percent of the variance in problem solving performance. Similarly, using a sample of 175 fourth grade students, Zalewski (1978) found that the variables mathematical concepts, computation, number sentence selection and reading comprehension accounted for most of the variance in mathematical word problem performance. She observed that the two best predictors of word problem solving success were mathematical concepts and computation.

Dodson (1971) studied students who were identified as insightful problem solvers. He found that mathematical achievement contributed most significantly to the variance in problem solving success. Meyer (1978) investigated intellectual abilities associated with verbal problem solving. She found that the strongest predictor of problem solving performance was mathematical ability. Meyer (1981) presented a further analyses of her earlier work (Meyer, 1978). She selected good and poor problem solvers from among 179 fourth-graders. The results of the study indicated that verbal, numerical and induction abilities are significantly related to problem solving success.

In a study determining the relative importance of reading and computation ability to problem solving success among 1,400 sixth graders, Balow (1964) found that both reading and computation ability have a significant effect on problem solving ability. Balow further stated "that for any given level of reading ability, problem solving increases as computation ability increases" (p. 22).

Other authors have reported similar results. Martin (1963) concluded that for a sample consisting of 523 fourth-graders and 584 eighth graders there was a considerable correlation between problem solving and abstract verbal reasoning, reading, arithmetic concepts and computation. The highest correlation was found between arithmetic concepts and problem solving.

Sprungin (1981) studied the relative effect the factors problem comprehension, problem application, attitude toward solving mathematical problems, mathematics anxiety, mathematics ability, and number of years of high school mathematics completed had on the problem solving success of 71 female prospective teachers. The results of the study indicated that mathematics ability as measured by the Scholastic Aptitude Test — Mathematics was the best predictor of problem solving performance. It accounted for 36.7% of the variance in problem solving as indicated by the six predictors. Gimmestad (1977) studied the processes used by sixty community college mathematics students. The most popular processes were found to be deduction, trial and error, and algebraic equations. In addition, a significant correlation ($P < .05$) of .35 was found between mathematics achievement and mathematical problem solving.

Mathematics achievement has consistently been a factor in successful problem solving among elementary school subjects. With a few exceptions (e.g., Gimmestad, 1977), most researchers have failed to ascertain a definitive position regarding the relative importance of mathematics achievement or problem solving among older and mathematically experienced subjects.

Critical Thinking. Another factor which contributes to individual differences in problem solving ability can be found by examining the relationship between problem solving performance and a general reasoning ability called critical thinking (Craven, 1966; Ennis, 1962; Fisher, 1972). For this research, critical thinking was defined as the correct assessing of statements (Ennis, 1962). It was believed that this ability was essential in the solution of mathematical problems (Ennis, 1962; Johnson, 1944).

Closely tied to the subskills associated with the problem-solving model utilized in this study are the competencies associated with critical thinking ability. According to Ennis (1962, p. 84), there are several basic aspects of critical thinking. He notes that there are twelve aspects of critical thinking. These aspects are listed below:

1. Grasping the meaning of a statement.
2. Judging whether there is ambiguity in a line of reasoning.
3. Judging whether certain statements contradict each other.
4. Judging whether conclusion follows necessarily.
5. Judging whether a statement is specific enough.
6. Judging whether a statement is actually the application of a certain principle.

7. Judging whether an observation statement is reliable.
8. Judging whether an inductive conclusion is warranted.
9. Judging whether the problem has been identified.
10. Judging whether something is an assumption.
11. Judging whether a definition is adequate.
12. Judging whether a statement made by an alleged authority is acceptable.

Several researchers have investigated the relationship of critical thinking ability to problem solving performance and have obtained mixed results (e.g., Brown, 1967; Craven, 1966; Fisher, 1972; Loveless, 1970). For example, Fisher (1972) examined the relationship between problem solving ability and critical thinking ability. Results of the study showed that critical thinking correlated moderately with a problem-solving skill involving the ability to translate a "real-world" problem into a mathematical expression.

Tate and Stanier (1964) studied the kinds of errors made by good and poor problem solvers. The sample consisted of 234 seventh and eighth grade pupils who were measured on tests of critical thinking and practical judgment. With I.Q. controlled, the critical thinking scores for the good problem solvers were significantly higher than those for the poor problem solvers. On the critical thinking tests, the poor problem solvers tended to avoid utilizing the alternative "not enough facts," that is, good problem solvers, not knowing the right answer tended to answer "not enough facts," whereas poor problem solvers, not knowing the correct answer, tended to reject the answer, "not enough facts".

If critical thinking can be considered akin to reasoning, then there can be little disagreement as to its importance in problem solving success. Suydam (1980) reported that one of the abilities usually associated with good problem solvers is high reasoning ability. Studies have shown a positive correlation between certain types of reasoning ability and problem solving success (Martin, 1963; Meyer, 1981).

Although the correlation was not very high, Gimmestad (1976) did find that one of the more frequent processes used by community college students during problem solving was some form of deductive reasoning. Similarly, Hansen (1944) found that reasoning and numerical ability contributed significantly to problem solving ability.

Bellile (1980) advocated that there is a link between problem solving ability and what she calls "mathematical thinking." According to Bellile, mathematical thinking consists of abilities presented by Hiatt (1971). These abilities are listed below:

1. An ability to comprehend mathematical statements and diagrams
2. An ability to originate a line of reasoning
3. An ability to detect a line of reasoning
4. An ability to differentiate between possible and necessary conclusions
5. An ability to solve locus problems
6. An ability to recognize all possible cases of a situation
7. An ability to visualize
8. An ability to apply theorems
9. An ability to carry out computation or algorithmic manipulation
10. An ability to recall theorems
11. A knowledge of terminology and notation
12. An ability to discriminate between relevant and irrelevant data
13. An ability to recognize solvability of a problem.

These abilities are closely related to critical thinking. In addition, it appears that critical thinking is related to creative thinking (Gibson, Kibler & Barker, 1968). Gibson, et al. (1968) studied 100 college undergraduates to assess relationships between creativity and critical thinking. Scores from creative thinking tests (Object Synthesis Test, Alternative User Test, Apparatus Test: Drastic and Minor, and Symbol Production Test) and the Watson-Glaser Critical Thinking Appraisal were obtained. The authors reported the following:

> "the appraisal of an individual's ability to evaluate ideas critically (and particularly, to recognize unstated assumptions) and his ability to behave in an adaptive-flexible manner apparently involves somewhat similar processes in the hierarchy of intellectual factors. Perhaps one can neither solve existing problems effectively nor develop new ideas or solutions without the ability to move freely from situation to situation" (p. 712).

In a study involving 506 freshmen and sophomore college students, Chang (1969) assessed correlates of the Watson-Glaser Critical Thinking Appraisal and selected variables. Using only black students, he found that (1) with academic status held constant, males received significantly higher means in critical thinking than females in both remedial and nonremedial groups, and (2) with sex held constant, nonremedial students received significantly higher means in critical thinking than remedial students of both sexes.

Although critical thinking seems to be a very complex cognitive ability, there appears to be a correlation between this ability and the creative activity involved in solving a mathematical problem. However, critical thinking has rarely been investigated as a correlate of problem solving ability.

Reading Comprehension. In addition to the variables mathematics achievement and critical thinking, reading ability or more particularly, reading comprehension, has shown a positive relationship to the ability to solve verbal arithmetic problems (Aiken, 1971; Balow, 1964; Chase, 1960).

In general, the ability to understand and translate word problems into symbolic representation reflects a student's ability to read the problem statement and comprehend the essential question and facts of the problem (Stover, 1980; Webb, 1975). This fact underscores the importance of reading in learning mathematics. In reading mathematics the speed may be low, but the material must be read very critically, that is, one must pay close attention to detail, relevant information, and irrelevant information.

Skillman (1973) found that for college algebra students, emphasis on reading techniques improved mathematical achievement. Similarly, it has been found that mathematical vocabulary is a factor in both arithmetic and algebra problem solving (Johnson, 1944; Vanderlinde, 1964).

In a study similar to the study conducted by this author, Moore (1980) found that reading ability did contribute to problem solving success among community college students. He found that poor readers had lower problem solving scores than good problem solvers (among those using a heuristic method of instruction).

Using sixth graders as subjects, Ballew and Cunningham (1982) suggested that the inability to read problems is a major problem solving obstacle. Their study was concerned with "identifying those students who had difficulty in setting up a problem if they had to read it . . ." (p. 209). Ballew and Cunningham reported that 12 percent of the subjects (N = 217) could read and set up problems correctly at a higher level than they could compute.

Similar results were reported by Blankston (1975) who concluded that the readability of mathematics materials is significantly related to mathematics achievement. Using 58 community college students, she found that the group who received materials written at the lowest reading level scored highest on the mathematics achievement test.

According to Dunlap and McKnight (1978), students at all academic levels have difficulty with the reading-thinking processes involved in solving word problems. They report that the ability to solve word problems involves, (1) translating general, technical and symbolic language, and (2) conceptualizing by making use of mental images while forming symbolic representation.

According to Chase (1960), knowledge of general vocabulary is not significantly associated with problem solving performance, however, Treacy (1944) reported that good problem solvers have a significantly greater knowledge of the meaning of mathematical vocabulary than do poor problem solvers (cited in O'Mara, 1981). Cottrell (1967) concludes that reading is more crucial to poor problem solvers than to good problem solvers (cited in O'Mara, 1981). According to Riley and Pachtman (1978), the skill of simply reading may not be sufficient in problem solving because the language of word problems may be abstract in that the relationships and concepts might not be readily apparent to the reader. It is assumed that reading in mathematics may be quite different from reading ordinary English.

Balow (1964) advanced the same notion that reading, in mathematics and particularly in the area of problem solving, is extremely important. He notes that in considering problem solving activities, "the subject must determine the question being asked, the information given, the arithmetical operations required, and must find this information through reading" (p. 18). Further, Balow (1964) suggested that "general reading ability does have an effect on problem-solving ability" (p. 21). He tested 1,400 sixth-grade students, using the Stanford Achievement Tests, Reading and Arithmetic. The Reasoning subtest was used to measure problem-solving ability. While controlling for intelligence, the results indicated that higher reading ability scores did result in higher problem solving scores; however, computation was shown to be the most significant factor in problem solving. O'Mara (1981) reported the following:

> Good readers are not necessarily good problem solvers and poor readers are not necessarily poor problem solvers (Harvin & Gilchrist, 1970). There is no linear relationship; good problem solvers are characterized by a variety of reading levels (Cottrell, 1967), although poor problem solvers are generally characterized by low reading levels (Cottrell, 1967; Treacy, 1944).

Although the aforementioned results seem to suggest that poor reading ability may not cause verbal problem difficulty, it can be a significant hindrance to problem solving success for some remedial students (Moore, 1980; O'Mara, 1981).

In describing the relative importance of the aforementioned factors, Chase stated

> ". . . in predicting a student's ability to solve verbal problems in arithmetic, as sources of basic data one may turn with considerable confidence to that pupil's ability in the mechanics of computation, his comprehension of principles which underlie the number system, and the extent to which he notices specific items of information when he reads" (p. 10).

Developmental/Nondevelopmental Student

It should be noted that the definition of developmental or nondevelopmental student pertains to specific trait variables which are associated with the student.

According to Kilpatrick (1975), trait variables refer to abilities, attitudes, perceptual styles, self-concept, anxiety and need for achievement. It is generally accepted that many students are lacking many of these abilities identified by Kilpatrick. Developmental programs have historically focused on remediating academic deficiencies, so that the developmental student can reach an academic level which enhances successful college level course work.

Basically, there are two types of students who constitute the developmental mathematics program. Some of these students need serious remediation, while others need minor review. Whereas, some writers have labeled developmental students as "high risk," "low achievers," or "marginal," many developmental students can be considered as mathematical underachievers because of other variables such as mathematics anxiety, low self-concept, and an inadequate mathematics background (Cross, 1972).

Since the individual characteristics of developmental students are varied, their success with problem solving activities would appear to be just as varied. Those students who have been out of high school for several years, but are strong in mathematical ability, might perform problem solving tasks quite well. There are many developmental students, however, who are characterized by low reading ability, low mathematics achievement scores and poor reasoning ability. With such acute deficiencies, these students cannot be assured of problem solving success.

To provide the most appropriate mathematics course for each entering student at J. Sargeant Reynolds Community College, a mathematics placement test was administered through the Testing office at the Downtown Campus. This test, the nationally normed Descriptive Test of Mathematics Skills, was administered using local cut-offs. Generally, if an individual scores less than 70% on the intermediate algebra content area of the Descriptive Test of Mathematics Skills, they will be placed in a developmental course. Further testing will reveal the appropriate level of developmental mathematics. However, students occasionally request a certain developmental mathematics course without any further testing.

There is general agreement that most developmental or remedial students have difficulty solving typical textbook word problems. Although their difficulty might be compounded by numerous academic deficiencies, developmental students are older and for the most part have become quite proficient at solving complex "real world" problems. However, according to the literature, there appeared to be several reasons why developmental students might have more difficulty with problem solving than nondevelopmental students.

First, both research and theory indicate that developmental mathematics students show characteristic differences in their approach to solving problems. Many approaches appear to be quite unorganized, with little prior thought and logic. Although problem solving is an extremely complex area of human behavior, most authors agree that this activity involves the utilization of certain strategies which can be capsulized into a specific problem solving model.

Early descriptions of the developmental population suggest that this group included first generation college students; students with low socio-economic backgrounds; students with low career aspirations; students with self-doubt; students classified low achievers (Cross, 1972; Roueche & Kirk, 1973); and students who classified themselves as "dumb in math" (Hecht & Akst, 1980). A more current review of developmental programs would reveal that there is wider diversity among this clientele. Many of these students are underprepared mathematically, but they do show considerable skill and achievement in their mathematics courses.

Emerging within this population are at least two distinct groups of students: returning adults and recent high school graduates. Further, within each group, there are those students who need assistance in developing certain basic skills, and those students who need assistance in remediating certain deficiencies (Clowes, 1979).

A student characterized as developmental may be mathematically immature rather than deficient in specific mathematical or skills. Implicit in this distinction is that person who has been away from an educational setting for a number of years. This person often needs to review and sharpen basic skills and build self-confidence. Efforts to utilize problem solving activities with such clientele is appropriate only when a proper diagnosis of strengths and weaknesses has been made.

The list is fairly extensive of literature which has identified the characteristics of the developmental student, however, the literature is almost nonexistent where a comparison has been done to articulate the differences between developmental and nondevelopmental students. There is a notion among the professional developmental educators that a definite difference does exist between these two populations. Pollard, Benton and Hinz (1983), hypothesized that there was a distinguishable difference between developmental and nondevelopmental students. The hypothesis in their study was that beside the common developmental student characteristic of low educational skills, developmental students would be inferior to nondevelopmental students at resolving developmental tasks. Using the Student Developmental Task Inventory - 2, the author assessed the personal development of 93 developmental and 37 nondevelopmental or "regular" students. Regular students had significantly higher scores in development of the subtask "Appropriate Educational Plans" than did developmental students, however, overall there were fewer differences between the two groups than the author had expected.

Baker (1982) conducted a study to compare the efficiency and effectiveness of regular college English classes with developmental English classes. He compared 48 developmental English students with 24 regular English students. The subjects were compared on three subtests of the McGraw-Hill Writing Test. The results revealed that statistically significant gains were made by developmental students on two of the criterion measured, but the gains were not significantly different from the gains made by the regular students. When a random sample of student essays was analyzed, no significant differences were found. Baker reported that the attrition rate was higher in the remedial courses than the regular courses.

Dumont and Jones (1983) conducted a discriminant analysis in an effort to determine student characteristics that discriminate between successful developmental and those who are not successful. For mathematics courses, three predictive variables were revealed, mathematics pretest score, perceived usefulness of the course, and race. For the composition course, the most powerful predictive variables were age, pretest score, perceived usefulness of the course, and race.

In addressing the issue of differences between developmental and nondevelopmental students, Hartman-Hass (1981) focused on this issue in concluding that students in developmental programs (in the sample investigated) were in transition between concrete and formal operations. She maintained that programs can be developed to improve students' cognitive skills. One such program about which the author reported is based at Rockland Community College in Suffern, New York. One important assumption that formed the basis of this program is that although some students in college may function below concrete operations, many can perform formal operational thinking tasks if such functions are demanded by the tasks. Because of a poor academic background, developmental students often are distinguished from nondevelopmental students by skill deficiencies not only in reading, writing, and mathematics, but also in required listening and thinking skills (Hartman-Hass, 1981).

Additionally, Redmon (1982) described certain competencies that all college-bound students should possess; reading, writing, speaking and listening, mathematics, reasoning, and studying. Generally, authors suggest that these are the competencies that distinguish developmental students from nondevelopmental students.

A literature search revealed very few studies which specifically address the issue of statistical comparisons between developmental and nondevelopmental students. The vast amount of research pertains to student profiles in developmental studies programs. However, a study that focused on differences between developmental students and nondevelopmental students was conducted by Cartledge, Walls, and Henderson (1985). Their work compared 88 developmental, 69 undergraduate, and 62 graduate students on the variable locus of control. The study utilized Rotter's Internal-External locus of control scale which differentiates individuals on the basis of the person's perceptions of the outcomes in life which are due to forces either within one's control (internal) or beyond one's control (external). The study utilized two and three factor analysis of variance. The results indicated that the most significant difference in locus of control occurred between graduate and developmental students.

In a similar study, Wright and DuCette (1976) reported that when community college students from a population identified as "alternative instructional environment" were compared to those from the "traditional" environment, no difference in personality measure was found. However, the authors concluded that the variable "locus of control" can predict achievement where there is a clear distinction of "openness" between the two instructional settings. In this study, the term "alternative settings" followed an open format where the students participate in a contract form of evaluation.

In another study, Alvarez, Cooper, Risko and Hall (1983) found very few differences between teacher education students and developmental reading students. Their study involved 92 developmental and 74 nondevelopmental undergraduate students. The survey indicated that students in both groups spent more time reading than watching television. In addition, students in both groups could identify types of visual aids used in their textbook, however, the developmental groups did tend to show less accuracy. The students from both groups indicated that they utilized similar reading techniques, such as, rereading, paraphrasing, and visualizing.

Developmental studies programs historically have focused on the task of elevating students to a certain academic standard that would enhance their success in regular college parallel courses, and it has been the assumption of many developmental educators that there are clear distinctions between developmental students and nondevelopmental students. Bellile (1980) hinted at this distinction when she stated that remedial students "differ from samples of students at other age levels and from typical students at this level (p. 147)." The literature review revealed that the research which addresses these differences is lacking, and particularly absent is that literature which focuses on differences in cognitive skills, such as problem solving. Again this void gave impetus to the present study.

Problem Solving Models

While only a few studies have addressed the problem solving strategies of postsecondary developmental students (e.g., Bellile, 1980; Gimmestad, 1977; Moore, 1980), several studies have delineated the strategies which characterize good problem solvers in general (e.g., Kilpatrick, 1967; Robinson, 1973). Generally, the dominant method of describing problem solving strategies has been through problem solving models.

Schoenfeld (1980) advocated that the use of certain strategies will enhance problem solving performance. His strategies are included in the following model:

Analyzing and Understanding a Problem

1. Draw a diagram
2. Examine special cases
3. Try to simplify it by using symmetry

Planning

1. Plan solutions hierarchially
2. Be able to explain what you are to do and why

Exploring Similar Problems

1. Consider equivalent problems
2. Consider slightly modified problems.

Verify the Solution

1. Ask the following questions:
   a. Does it use all of the data?
   b. Does it answer the questions?
2. Can the answer be obtained differently?

There are several strategy models which are appropriate for problem solving activity. First, Dewey (1933) provides a process which he calls reflective thought which may be an essential part of problem solving. The five phases of reflective thought are: (1) suggestion, (2) intellectualization, (3) hypothesizing, (4) reasoning, and (5) testing the hypothesis by action (cited in Lester, 1978). According to Lester (1978), Johnson (1955) provides the following model of problem solving which includes three stages: (1) preparation and orientation, (2) production-consideration of approaches, and (3) judgment-determination of the adequacy of the solution (cited in Lester, 1978).

In addition, Lester (1978) suggested that problem solving activity could be described by the following model: (1) problem awareness, (2) problem comprehension, (3) goal analysis, (4) plan development, (5) plan implementation, and (6) procedure and solution evaluation. Each stage of the model would invoke certain actions on the part of the problem solver.

There are a plethora of problem solving models. It is quite clear, however, that most strategy models can be directly linked to the model proposed by Polya (1971). Polya limited his problem solving model to the following stages: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back.

It should be noted that Polya's model can best be described as a model which delineates a hierarchical set of stages in the problem solving process. Polya's model incorporates within each stage many problem solving strategies such as drawing a figure, pattern finding, working backward and checking.

As the model indicates, the first step in solving any problem is to "understand the problem." For example, many subjects experience difficulty with problem solving activities because they have failed to develop skill in analyzing the data, conditions, and relations given in the problem. The problem solver must synthesize the given information to the extent that the problem is clearly comprehended. One cannot get started in solving a problem unless this step is fully instituted. Likewise, Polya (1971) suggested that good problem solvers consciously or unconsciously decide on a specific plan or approach to solving a problem. After obtaining an answer, good problem solvers will usually decide on the reasonableness of the solution.

Inherent in the Polya model is the implication that the problem solver must possess certain aptitudes. For example, the first step of his model, "understanding the problem" implies that there is a significant role that verbal reasoning must play

(Oehmke, 1979). At this stage of solving a problem, one must critically assess the data in order to "get to know the problem." Additionally, it is hypothesized that the ability to comprehend verbal passages is utilized at this same step. The aptitude that is necessary at the third step of Polya's model, "doing it," is the ability to utilize the concepts and computational skills necessary in the achievement of a solution.

Most of the studies seeking to identify strategies utilized during problem solving have employed the "thinking aloud" technique, whereby problem solvers attempt to verbalize their actions. This technique appears to be a valid procedure, but it suffers from a major weakness because many developmental students simply have difficulty verbalizing their thought processes. It seems that the most promising problem solving research with developmental students is in an investigation which seeks to identify strategies in a quantitative analysis.

One method of studying the problem solving performance of developmental students in a quantitative approach is to assess their performance within a specific problem solving model. That is, considering the verbal deficiencies of developmental students, perhaps, a paper-pencil verbal problem solving test which seeks to identify essential problem solving strategies is appropriate for this population.

One such test was developed by the Iowa Problem Solving Project. In general, this test utilizes the problem solving model introduced by Polya (1971). However, where Polya considers four phases in problem solving: (1) understanding the problem, (2) devising a plan to solve the problem, (3) carrying out the plan, and (4) looking back, the Iowa Problem Solving Project test considers only phases 1, 3 and 4 (the IPSP model is defined in Chapter 3). As part of the Iowa Problem Solving Project, a multiple choice test was developed to assess the performance of grades five through eight at each phase of the Iowa Problem Solving Project model (Oehmke, 1979).

Oehmke (1979) validated this test for grades five through eight. However, she stated that one "limitation of the Iowa Problem Solving Project was that it was administered to an Iowa population" (p. 82). Oehmke (1979) further suggests that researchers should explore the difference in performance across various samples. Bellile (1980) obtained reliable results when this instrument was administered to a sample of remedial college students. This test was deemed appropriate because (1) the content was valid, and (2) the results compared favorably with results obtained when the test was administered to another similar sample of college students (Bellile, 1980). The reliability estimate for the IPSP test was .90 when administered to the pilot study sample of college students.

Closely related to the present study is the descriptive study conducted by Bellile (1980) who investigated the problem solving performance of a sample (N = 30) of remedial college mathematics students. Her study used scores on cognitive measures assessed prior to the study. These measures included American College Testing (ACT) scores and high school mathematics grades. To further describe this sample, Bellile compared these measures with scores on the IPSP tests, along with performance scores on individual interviews which assessed the processes students used while solving verbal problems. In addition, the investigator obtained measures of mathematics anxiety and cognitive development.

After conducting a pilot study of the IPSP test, Bellile used means, standard deviation, and correlation coefficients to summarize the data. Bellile concluded that subjects in her current study, who were more able verbally than the subjects in the pilot study, showed superiority with Subtest 1, (Getting to know the problem), and Subtest 3, (Looking back) of the IPSP test. Concurring with Oehmke (1979) Bellile concluded that there is a strong verbal reasoning component in subtest 1 and 3.

Further, the IPSP test results showed that this sample did as well or better than the other two samples (Oehmke, 1979 and Bellile's Pilot Study).

In Bellile's study, relationships among the variables were sought by computing Pearson Product Moment Correlation coefficients. The results indicated no significant correlation between background information, such as ACT scores or high mathematics scores, and the IPSP test scores. The anxiety variable correlated significantly ($p < .05$) with the subtest 3, "looking back" (.35). Finally, she found no significant correlation between the cognitive development scores (Piagetian tasks) and the IPSP scores.

Summary

The review of mathematical problem solving literature gives support to the notion that there are several factors which might affect word problem solving. The importance of this phenomenon is consistent with the widespread attention that it has been given in the literature. There are several important aspects about the literature. The chart on page 36a provides a good overview of the literature identified.

Much of the earlier research utilized elementary school subjects. At this level, the problem solving activity usually focused on the subject's proficiency with solving rather routine problems. Some researchers would argue that solving textbook problems is as Suydam (1980) states ... "exercises rather than problems" (p. 35). There does appear to be a shift in the research identified here. Contrary to the earlier studies, the focus now appears to be on the student characteristics which discriminate good problem solvers from poor ones (e.g. Dodson, 1971; Robinson, 1973). Although community colleges typically enroll large numbers of students who are academically deficient, research at this level is quite scarce. This trend is understandable because it has been assumed that many community college students possess characteristics which hinder efficient problem solving.

Suydam (1980) provided a review of the literature on problem solving at the elementary level. The author presented a list of characteristics applicable to the good problem solver. From this source and others (e.g. Balow, 1964; Robinson, 1973) there was evidence that reading comprehension is a factor in discriminating good and poor problem solvers. A closer review of the identified literature shows that at all academic levels three general areas of competence influence problem solving performance: reading, mathematics achievement, and reasoning.

Problem Solving Studies by Author, Level and Variables Studied

Author/Year	Level	Variable(s) Studied	Category*
Aiken, 1971	elementary/ secondary	review of many	R, M
Baldwin, 1975	elementary	survey of course	——
Ballew & Cunningham, 1982	elementary	reading	R
Balow, 1964	elementary	reading & comprehension	R, M
Blankston, 1975	college	reading	R
Bittinger, 1972	college	instructional strategies	——
Chase, 1960	secondary	reading & computation	R, M
Dodson, 1971	secondary	student characteristics	M
Dunlap & McKnight, 1978	multiple	reading	R
Fisher, 1972	college	achievement, attitude & critical thinking	M, T
Gimmestad, 1977	college	processes	M, T
Hansen, 1944	elementary	selected factors	M, T
Hiatt, 1971	secondary	mathematical thinking	T
Johnson, 1944	elementary	mathematical vocabulary	R
Kantowski, 1977	secondary	processes	T
Kilpatrick, 1967	secondary	processes	T
Martin, 1963	elementary	critical thinking, reasoning & computation	R, M, T
Meyer, 1981	elementary	student characteristics	R, M, T
Moore, 1980	college	selected factors	R, M, T
Robinson, 1983	elementary	selected factors	R, M
Schonberger, 1982	college	selected factors	R, M
Sprungin, 1981	college	anxiety, attitude	T

Author/Year	Level	Variable(s) Studied	Category*
Tate & Stanier, 1964	secondary	error analysis	T
Treacy, 1944	elementary	reading	R
Vanderline, 1964	elementary	vocabulary	R
Webb, 1979	secondary	processes & conceptual knowledge	M, T
Zalewski, 1978	elementary	selected factors	R,, M, T

*Variable category identified for this study.

R = Reading
M = Mathematics Achievement
T = Thinking

In an effort to understand the factors that influence sources of variance in problem solving among community college students, and to be consistent with the literature, it was hypothesized that three major aptitudes contribute most to problem solving success. These aptitudes are identified in this study as (1) the ability to read and comprehend the information conveyed by the problem, (2) the ability to think critically in assessing the data given in the problem, and (3) the ability to utilize certain mathematical concepts, algorithms, and applications that are necessary in performing the appropriate computations that lead to the correct solution.

Further, the literature revealed that most individuals will solve problems according to a problem solving model (i.e. IPSP model). If this is true, then one important objective of this research was to further the study of the problem solving process by investigating the primary source of difficulty at each stage of the IPSP model. That is, the present study sought to assess which independent variable best predicted success at a given stage in the IPSP model.

Chapter 3

RESEARCH METHODOLOGY AND PROCEDURES

This chapter describes the method and procedures used to gather and analyze the data. The primary purpose of this study was to assess the correlation between problem solving and mathematics achievement, reading comprehension and critical thinking. The chapter is divided into the following sections: (1) subjects, (2) instrumentation, (3) data collection and (4) statistical analysis.

Subjects

Two groups of subjects made up the sample. The sample consisted of 38 developmental subjects and 22 nondevelopmental subjects. The sample, consisting of students who took all four assessments, was selected from 152 students who participated in the testing. Data were gathered on the 60 subjects during three academic quarters, summer 1984, fall 1984, and winter 1985. A summary of data concerning the population and those subjects who took at least one assessment is shown in Table 1.

During the summer quarter, 1984, subjects were selected from all of the developmental students enrolled at the Downtown Campus of J. Sargeant Reynolds Community College. No nondevelopmental mathematics courses were offered during the summer quarter, therefore nondevelopmental subjects were selected during the fall quarter 1984 and the winter quarter, 1985. The sample from which data were analyzed contained those students in both day and night classes.

Data shown in Table 1 indicates 43.1% of the total population of nondevelopmental students were tested. There is certainty that this sample is representative of

Table 1

Number and Percentage of Subjects Available or Tested by Group

	Quarter											
	Summer, 1984			Fall, 1984			Winter, 1985			Total		
Group	P	T		P	T		P	T		P	T	
Developmental	121	55	(45.45)	387	34	(8.79)	428	13	(0.29)	936	102	(10.90)
Nondevelopmental	0	0	(0.00)	72	23	(31.94)	44	27	(61.36)	116	50	(43.10)
Total	121	55		459	57		472	40		1,052	152	(14.45)

P = Population
T = participated in the study by taking at least one test.

Note: Percentages in parenthesis.

the population. Special consideration was given to insure that a cross-section of the available classes were used in the study.

The developmental population was considerably larger than the nondevelopmental population, therefore Table 2 is used to show the breakdown in race and sex of this population. Consideration was given in test administration to insure that the best cross-section of the population was considered. Students enrolled in morning, afternoon, and evening classes, including lecture and self-paced laboratory classes, were included in this study.

Instrumentation

The four instruments used to gather the data for this study are described in the order of administration. The Iowa Problem Solving Project Test was used to obtain a measure of problem solving performance. This test measures a person's ability to (1) understand the problem, (2) apply certain problem solving strategies or skills, and (3) look back at the solution. The instrument consists of three subtests, where each subtest measures specific abilities. Subtest 1 measures the subject's ability to analyze the given information in an attempt to understand the problem. This subtest actually measures one's ability to incorporate Polya's first step, "understand the problem," of his four-step model. Subtest 2 measures the subject's ability to choose the appropriate computation, estimate or compute from a diagram or table, and subtest 3 measures the subject's ability to relate problems that can be solved in a similar way, and the subject's ability to check the solution. Subtests 2 and 3 are measures of Polya's third and fourth step "carrying out the plan" and "looking back," respectively. The subtests incorporate many of the skills and strategies that Polya suggests in his model (Polya, 1971). The IPSP test was validated for grades 5 through 8, but the content is reported to be appropriate for the community college population (Bellile, 1980). The test is considered appropriate for the community

Table 2

Developmental Population in Quarters Data Gathered

Race	Quarter	Sex: Male N	Sex: Female N	Total N	
White	Summer, 1984	11	22	33	(3.53)
	Fall, 1984	40	62	102	(10.90)
	Winter, 1985	38	65	103	(11.00)
	Subtotal	89	149	238	(25.43)
Non-white	Summer, 1984	27	61	88	(9.40)
	Fall, 1984	95	190	285	(30.45)
	Winter, 1985	102	223	325	(34.72)
	Subtotal	324	474	698	(74.57)
Grand Total		413	623	936	(100.00)

Percentage of total population in parenthesis.

college population because, in addition to assessing problem solving performance, the instrument actually determines a subject's utilization of three of the problem solving stages advocated by Polya (1971). There are 30 problems on the test, with each subtest consisting of 10 problems. Each individual was given an overall score as well as three subtest scores. This test had been used only twice, and has not been validated. However, the test was administered to a sample of 57 Westmar College (Iowa) students who were enrolled in elementary algebra. The Cronbach-reliability estimate for the IPSP test total score was .90 (Bellile, 1980). The Iowa Problem Solving Project Test was chosen because it contains the appropriate content area and because it is the only test found which assesses an individual's ability to utilize a specific problem solving model.

To assess mathematics achievement, the Mathematics subtest, Level 2, of the Stanford Test of Academic Skills (TASK) was used. This test is intended for grades 9 through 13. In addition, it is designed to measure numerical concepts, computation skills, application of these concepts, and skills used in problem solving. The content--algebra, geometry and measurement--is deemed appropriate because much of the content is an integral part of the content area of the IPSP test. The reported reliability for the mathematics subtest is .93 (KR-20, post-high school) (Gardner, Callis, Meriwin & Rudman, 1983).

The Reading Comprehension subtest of the Stanford Test of Academic Skills (TASK) was used to measure reading comprehension. This test seemed especially appropriate because of its content and its measurement objectives. The type of reading that is required in the test relates quite well to the reading that is required to comprehend a mathematical word problem. The test incorporates three types of passages. These are described as textual reading, functional reading and recreational reading. The test is designed to measure the subject's ability to understand what has been stated in the passage, and to make inferences, draw conclusions and predict outcomes. The reported reliability for the test is .92 (KR-20 post-high school) (Gardner, et al., 1983).

The Watson-Glaser Critical Thinking Appraisal (CTA) was used to assess critical thinking ability. It is designed to measure an individual's skill in five aspects of critical thinking: (1) inference (20 items) - ability to discriminate among degrees of truth or falsity in inferences drawn from data; (2) assumption - recognition (16 items) - ability to recognize unstated assumptions and presuppositions which are taken for granted in statements (3) deduction (25 items) - ability to reason in accord with principles of class and conditional logic; (4) interpretation (24 items) - ability to judge whether given generalizations are reasonably supported by the data; and (5) evaluation of arguments (15 items) — ability to discriminate between strong, relevant arguments and weak or irrelevant arguments (Stewart, 1979). The CTA has been validated for grades 9 through college. It is frequently used for research purposes to determine relationships between critical thinking ability and other measures of achievement. For example, Sorenson (1966) found that participants in laboratory-centered biology classes showed greater change in CTA scores than did members of a lecture dominated class (cited in Gardner, et al., 1983). This test was chosen because it is the most widely used assessment of critical thinking ability. It also has a reliability range from $r = .67$ (Split-Half, grade 9) to $r = .83$ (Split-Half, Community College).

Data Collection

The initial part of the data collection was done during the summer quarter, 1984. Data were collected on a total of 29 developmental students during two days by administering the Iowa Problem Solving Project Test (IPSP) and then the Stanford Test of Academic Skills (TASK), Reading Comprehension subtest on the first day. On the second day the order of administration was the Stanford Test of Academic Skills, Mathematics Subtest followed by the Watson-Glaser Critical Thinking Appraisal. The data consisted of a problem solving performance score, a reading comprehension score, a mathematics achievement score, and a critical thinking score. The test scores were obtained by administering the Iowa Problem Solving Project Test (IPSP), the Reading Comprehension subtest of the Stanford Test of Academic Skills (RC), the Mathematics subtest of the Stanford Test of Academic Skills (M), and the Watson-Glaser Critical Thinking Appraisal (WGCTA).

The second part of the data collection took place during the fall quarter, 1984, and winter quarter, 1985. All nondevelopmental mathematics students at the Downtown Campus of J. Sargeant Reynolds Community College were available; in addition, six classes of developmental students were used for data collection. All nondevelopmental students were enrolled in either Math 121, Math 108, Math 137, Math 181, or Math 161, where the developmental students were enrolled in Math 05, Math 06, or Math 07. All the nondevelopmental classes were traditional credit (A,B,C grades) classes. The fall and winter quarter data gathering sessions were administered in the same manner as the summer quarter session. Table 3 shows the reliability coefficients and other data for each of the instruments used in the study.

Statistical Analysis

Initial analysis of the data consisted of computing means, standard deviations and significance tests for each subtest of problem solving assessment, reading comprehension, mathematics achievement, critical thinking, and student characteristics, sex, classification (developmental or nondevelopmental), race, and age. The primary analysis of data was multivariate analysis of covariance (MANCOVA) with six dependent variables, denoted by PS1 (Subskill 1 - "get to know the problem"), PS2 (Subskill 2 - "do it"), PS3 (Subskill 3 - "look back"), RC (Reading Comprehension),

Table 3

Means, Standard Deviations and Reliability Coefficients for Instruments

Instrument	Mean	SD	Reliability
IPSP (Problem Solving)[a]	24.79	7.13	.90
TASK (Mathematics Achievement)[b]	26.2	11.2	.93
TASK (Reading Comprehension)[c]	37.0	9.2	.92
CTA (Critical Thinking Ability)[d]	53.2	9.4	.83

[a]Bellile (1980) for 57 algebra students at Westmar College in Iowa

[b]Nationally normed for post-high school students

[c]Nationally normed for post-high school students

[d]Reported nationally for 148 junior and community college students

MA (Mathematics Achievement) and CT (Critical Thinking), one independent variable, denoted by edlevel (developmental or nondevelopmental) and three covariates: race, sex and age. The major reason for using MANCOVA is that there may be multiple sources of influence which cause groups to differ. For this study, the multivariate model seemed appropriate because there were multiple criterion measures. The study sought to ascertain the equality of means of two groups (developmental and nondevelopmental), on six dependent variables. In addition, six univariate ANCOVAs were done with each of the dependent variables.

MANCOVA suggests that the test of significance is actually a test of a vectors of means where each element of the vector is a group's mean for a particular variable (Amick and Walberg, 1975). Two basic assumptions were made with MANCOVA: the dependent variables have a multivariate normal distribution and in creating a vector of deviation scores, the variance-covariance matrix is the same for each group. With these assumptions any differences discovered through data analysis can be attributable to the strength of the variables which discriminate between the group means.

The secondary analysis of data was multiple regression analysis with four dependent variables (overall problem solving, subtest 1, 2, and 3) and four independent variables (reading comprehension, mathematics achievement, critical thinking, and edlevel. The multiple linear regression equation is represented algebraically as:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_iX_i$$

where Y represents the predicted scores on the dependent variable (PS, PS1, PS2, and PS3), X_i represents scores on the independent variables, a (the y intercept) is the mean of the sample when all X_i equal zero.

The purpose of the multiple regression analysis is to show the relationship between overall problem solving and critical thinking, mathematics achievement, and reading comprehension, after controlling for the demographics (race, sex, age, and edlevel). This was done by comparing the full model (see Table 10) which includes the independent variables and the demographic characteristics with the restricted model (see Table 10) which contains the demographics. Four different regression models were run, one for each of the dependent variables; these variables were the three subtest of IPSP and the overall problem solving score.

With the use of multiple regression, more than one independent variable was incorporated into the equation; this procedure offered a more definitive explanation of the dependent variable (Lewis-Beck, 1980). Further, multiple regression analysis allows the investigation to refer to R^2 which indicates the proportion of the variation in the dependent variable, problem solving, explained by the independent variables. Finally, not only will regression analysis be useful in explaining the variable in problem solving, the regression equation enhances one's ability to select those variables which best predicts problem solving performance. Further explanation of the statistical methods will be included in Chapter 4.

Summary

This chapter has presented a discussion of the subjects used in the study, along with a discussion about the instruments, data collection and statistical design used to analyze the data. Data were collected at three different times, the summer and fall quarter, 1984, and the winter quarter, 1985. The sample consisted of 60 subjects. The analysis of data consisted of multivariate analysis of covariance and multiple regression analysis.

Chapter 4

DATA ANALYSIS

The purpose of this study was to answer the following questions:

1. What is the contribution of six variables (three aspects of problem solving, mathematics achievement, critical thinking, and reading comprehension) to the difference between students classified as developmental or nondevelopmental?

2. Which of three selected variables, mathematics achievement, reading comprehension and critical thinking, is the best predictor of problem solving performance among developmental and nondevelopmental?

This chapter contains a discussion of the primary analysis, the secondary analysis, comparisons of the demographic characteristics, and a summary. The primary analysis utilized was multiple analysis of covariance (MANCOVA) with six dependent variables, one independent variable and three covariates. The secondary analysis utilized multiple regression analysis to determine whether the independent variables, mathematics achievement, critical thinking, and reading comprehension, are significant predictors of the dependent variable, problem solving, after controlling for sex, race, age, and edlevel.

Group Descriptions

The study was conducted during three consecutive quarters, summer, 1984, fall, 1984, and winter, 1985. This section compares data using the demographic characteristics sex, race and age. This discussion includes all subjects who participated in the study. Data in Table 4 shows the number and percentage of males and females in the study. The study utilizes a larger percentage (60%) of females than males (40%).

Table 4

Number and Percentage of Developmental and Nondevelopmental Students in the Study, by Sex, Race, and Age

	Developmental		Nondevelopmental	
	Number	Percent	Number	Percent
Sex				
Male	16	26.67	9	15.00
Female	22	36.67	13	21.67
Race				
White	8	13.33	6	10.00
Non-white	30	50.00	16	26.67
Age*				
Less than or equal to 24	14	23.33	12	20.00
Greater than 24	24	40.00	10	16.67
Mean Age* 28.75 (8.34)				

Standard Deviation in parenthesis

Table 4 also shows that the study involved more non-white students than white students. There was a significantly larger percentage of older subjects. That is, subjects in the age group greater than 24 years exceeded the number of subjects in the age group less than or equal to 24 years.

Primary Analysis

Multivariate analysis of covariance (MANCOVA) was used in this study. The MANCOVA model consisted of six dependent variables, denoted by PS1 (problem solving subskill 1), PS2 (problem solving subskill 2), PS3 (problem solving subskill 3), RC (Reading Comprehension), MA (Mathematics Achievement), and CT (Critical Thinking). In this analysis there was one independent variable, denoted by edlevel, and identified as developmental or nondevelopmental subjects. The effect of edlevel will be referred to as the "group effect." The demographic characteristics, sex, age and race, were covariates. Six MANCOVAs were done to ascertain which variables were the most discriminating between the two groups. Table 5 shows the six different MANCOVA models utilized in this study.

The MANCOVA models were conducted to answer the following:

(A.) Do the criterion measures demonstrate a significant difference between developmental and nondevelopmental subjects?

(B.) Which of the six dependent variables, PS1, PS2, PS3, RC, CT or MA, contributes most to discriminating between developmental and nondevelopmental students?

Table 5 shows analyses A, B and C using six dependent variables, with edlevel (developmental/nondevelopmental) as a factor variable and the variables' race, age and sex as covariates. The multivariate model sought to ascertain whether there is a

Table 5

MANCOVA Analyses

Analysis	Dependent Variables	Factor**	Covariates
A	PS1, PS2, PS3, RC CT, MA	Edlevel	Race
B	PS1, PS2, PS3, RC, CT, MA	Edlevel	Age
C	PS1, PS2, PS3, RC, CT, MA	Edlevel	Sex
D	PS, RC, CT, MA	Edlevel	Race
E	PS, RC, CT, MA	Edlevel	Age
F	PS, RC, CT, MA	Edlevel	Sex

PS = Total Problem Solving
PS1 = Problem Solving Subskill 1
PS2 = Problem Solving Subskill 2
PS3 = Problem Solving Subskill 3
RC = Reading Comprehension
CT = Critical Thinking
MA = Mathematics Achievement
**Edlevel = Developmental/Nondevelopmental

significant difference in the means of the two groups while controlling for the effects of the demographic variables. The analyses A, B and C results produced no significant difference between developmental and nondevelopmental subjects after controlling for the covariates, race, age and sex. That is, after partialing out the demographic effects, there is no significant difference between developmental and nondevelopmental students as measured by the six criterion measures (Race, $F=1.92419$; Age, $F=1.71610$; Sex, $F=2.42519$, $P \quad 0.05$). This result specifically addresses the research question: what is the contribution of the six variables (three aspects of problem solving, mathematics achievement, critical thinking, and reading comprehension) to the difference between students classified as developmental or nondevelopmental?

Due to the exploratory nature of this study, the univariate tests were investigated using the 0.10 level of significance. The results of these univariate tests are shown in Table 6. These data indicate that, when race, age, and sex were controlled, there were differences between developmental and nondevelopmental students on the criterion measures, PS2 (problem solving subskill 2) and PS3 (problem solving subskill 3). More importantly the results show that nondevelopmental students were more adept at using the subskills "doing it" and "looking back," respectively, than were developmental students. This conclusion is consistent with the hypothesis that mathematics achievement distinguishes developmental students from nondevelopmental students. According to Immerzeel (1977), "students don't choose to "do it" unless they have some idea about how to "do it" (p. 26)." In addition, "looking back" skill tends to be prevalent in more experienced problem solvers because they use their knowledge to give attention to the method used to solve the problem as well as to the answer to the problem.

Table 6

Univariate Test of Significance of Variables by Group
After Controlling for Race, Age and Sex

	Developmental (n=38) Mean	S.D.	Nondevelopmental (n=22) Mean	S.D.
Variables				
PS1	6.18421	2.27626	7.00000	2.60037
PS2*	5.55263	2.03612	7.04545	1.83815
PS3*	6.23684	1.88069	7.18182	1.40192
RC	34.92105	7.95386	37.72727	7.45898
CT	42.23684	11.85141	41.27273	10.60180
MA	22.18421	10.43346	25.63636	8.81311

*$p < .10$ df = 1,57

Group Comparisons

Data in Table 7 indicates that white subjects scored higher on all criterion measures except PS3. It is important to emphasize that only 23.3% of the sample consisted of white subjects. Data in Table 8 indicates that male subjects were better problem solvers than female subjects and had significantly higher mathematics achievement scores. Male subjects scored significantly higher on PS1, PS2, and PS3 than female subjects. These findings are consistent with the literature which reveals that on measures of mathematics ability, males tend to score higher than females. Table 9 shows that younger subjects scored significantly higher on the subskills PS1, "getting to know the problem" and PS2, "doing it" than older subjects. The reasons for these findings are not very clear, however, the assumption is that the problem solving situations presented in the IPSP test were familiar to a degree which enhanced the younger subjects' understanding of the problem. The ability to demonstrate proficiency for subskill 2, "doing it" is consistent with one's mathematics achievement. Although younger students had higher mathematics achievement scores than older subjects, the difference was not significant. Additionally, younger subjects were significantly better readers than older subjects.

Secondary Analyses

The purpose of the secondary analysis was to answer the following questions:

(A) After controling for the demographic characteristcs, sex, race, age, and edlevel, do the independent variables, mathematics achievement, critical thinking, and reading comprehension, increase the predictive power of the dependent variable, problem solving?

Table 7

Means and Standard Deviations of All Criterion Variables, By Race With Significance Tests

	Maximum Possible Score	White		N	Non-white		N
		Mean	S.D.		Mean	S.D.	
Variables							
PS1*	10	7.50	1.99	14	6.17	2.46	46
PS2*	10	7.36	1.45	14	5.72	2.11	46
PS3	10	7.21	1.58	14	6.39	1.80	46
RC*	50	39.71	7.77	14	34.80	7.57	46
CT*	80	47.14	13.68	14	40.28	10.15	46
MA*	45	30.14	10.60	14	21.41	8.88	46

$^*p < .10$

PS1 = Problem Solving - Subskill 1

PS2 = Problem Solving - Subskill 2

PS3 = Problem Solving - Subskill 3

RC = Reading Comprehension

CT = Critical Thinking

MA = Mathematics Achievement

Table 8

Means and Standard Deviations of All Variables, By Sex With Significance Tests

	Maximum Possible Score	Male			Female		
		Mean	S.D.	N	Mean	S.D.	N
Variables							
PS1*	10	7.48	2.20	25	5.83	2.32	35
PS2*	10	6.76	1.99	25	5.67	2.03	35
PS3*	10	7.24	1.51	25	6.19	1.85	35
RC	50	36.84	8.69	25	35.31	7.12	35
CT	80	43.84	13.06	25	40.50	9.73	35
MA*	45	26.92	11.65	25	21.22	7.81	35

*$p < .10$

PS1 = Problem Solving - Subskill 1

PS2 = Problem Solving - Subskill 2

PS3 = Problem Solving - Subskill 3

RC = Reading Comprehension

CT = Critical Thinking

MA = Mathematics Achievement

Table 9

Means and Standard Deviations of All Variables, By Age With Significance Tests

Variables	Maximum Possible Score	≤ 24 Years Mean	≤ 24 Years S.D.	N	> 24 Years Mean	> 24 Years S.D.	N
PS1*	10	7.15	2.43	26	5.97	2.30	34
PS2*	10	6.35	1.88	26	5.91	2.23	34
PS3	10	6.69	1.76	26	6.50	1.80	34
RC*	50	37.54	8.88	26	34.74	6.81	34
CT	80	41.19	10.64	26	42.41	11.96	34
MA	45	24.00	9.18	26	23.03	10.60	34

*$p < .10$

PS1 = Problem Solving - Subskill 1

PS2 = Problem Solving - Subskill 2

PS3 = Problem Solving - Subskill 3

RC = Reading Comprehension

CT = Critical Thinking

MA = Mathematics Achievement

(B) Which of the selected criterion measures -- reading comprehension, critical thinking or mathematics achivement -- is the best predictor of problem performance among developmental and nondevelopmental students?

To answer the questions, the secondary data analysis utilized multiple regression with seven independent variables and four dependent variables. The seven independent variables were reading comprehension, critical thinking, mathematics achievement, edlevel, sex, age, and race. Therefore, x_1 = reading comprehension (RC); x_2 = critical thinking (CT); x_3 = mathematics achievement (MA); x_4 = educational level (edlevel); x_5 = sex; x_6 = age; and x_7 = race. The dependent variables were problem solving (PS); problem solving subskill 1 (PS1); problem solving subskill 2 (PS2); and problem solving subskill 3 (PS3).

To answer question A, Restricted Model (RM) and Full Models (FM) were developed to ascertain whether the variables, mathematics achievement, critical thinking, and reading comprehension, increased the predictive power of problem solving, after controlling for the demographic variables and edlevel. The RM model was a regression analysis of sex, age, race, and edlevel with each dependent variable, PS1, PS2, and PS3. The FM model was sex, age, race, edlevel, mathematics achievement, critical thinking, and reading comprehension with each dependent variable. In the regression analyses (Table 10) were done, each FM was tested against its corresponding RM (Analysis 1-Analysis 4; Analysis 2-Analysis 5, and Analysis 3-Analysis 6). The results indicate that there was a significant R^2 increase for each dependent variable. These results, shown in Table 11, indicate that there was an ($p < .05$) effect due to the predictors, critical thinking, reading comprehension, and mathematics achievement for each of the dependent variables, problem solving subskill 1, problem solving subskill 2, and problem solving subskill 3.

Table 10

Multiple Regression Analyses

Analysis	Dependent Variable	Predictors
Restricted (1)	PS1	Edlevel, Race, Sex, Age
Restricted (2)	PS2	Edlevel, Race, Sex, Age
Restricted (3)	PS3	Edlevel, Race, Sex, Age
Full (4)	PS1	Edlevel, Race, Sex, Age, CT, RC, MA
Full (5)	PS2	Edlevel, Race, Sex, Age, CT, RC, MA
Full (6)	PS3	Edlevel, Race, Sex, Age, CT, RC, MA

Table 11

R square values for Full and Restricted Model and
The F-ratios for the Change in the R square values

Criterion Variable	Model	R^2	R^2 Change	$1 - R^2$	F-Ratio
PS1	Full	.64043	---	.35957	---
	Restricted	.21953	.42090	---	30.38979*
PS2	Full	.58051	---	.41949	---
	Restricted	.21153	.36898	---	15.24626*
PS3	Full	.68670	---	.31330	---
	Restricted	.35680	.32990	---	18.25173*
PS	Full	.74062	---	.25938	32.38523*
	Restricted	.25600	.48462	---	

*$p < .05$ df = 3,52

To answer question B, the significance of the B coefficients for CT, RC, and MA were investigated with the FM model. The results, shown in Table 12, indicate that reading comprehension was a significant ($p < .001$) predictor of problem solving subskill 1 (PS1). In addition, Table 12 shows that reading comprehension was a significant ($p < .01$) predictor of the problem solving subskill 2. For the dependent variable, problem solving subskill 3 (PS3), mathematics achievement was a significant ($p < .01$) predictor. With the total problem solving score as the dependent variable, both reading comprehension (RC) and mathematics achievement (MA) were significant predictors. Mathematics achievement was significant at a lower level ($p < .05$) than reading comprehension ($p < .001$).

Summary

This chapter has presented the results from the data analysis of the discriminating effects of six criterion measures on two groups of subjects identified as developmental and nondevelopmental. The six criterion measures were three subskills of problem solving, critical thinking, reading comprehension and mathematics achievement. The secondary analysis presented results from the analysis of the effect of critical thinking, reading comprehension and mathematics achievement on problem solving. Also, this chapter presented results from analysis of data relative to student demographics. The results from the analyses indicated that:

MANCOVA - Nonsignificant

1. Collectively the six criterion measures were not significant discriminators of differences between developmental and nondevelopmental subjects.

Table 12

Unstandardized and Standardized Regression Coefficients and t-values for Critical Thinking, Reading Comprehension, and Mathematics Achievement in the Full Model

Variable	Predictor	B	Beta	t-Value
PS1	CT	.01349	.06336	.613
	RC	.20967	.68104	5.027*
	MA	.00203	.00836	.060
PS2	CT	-.00493	-.02683	-.240
	RC	.10866	.40901	2.795*
	MA	.05945	.28394	1.892
PS3	CT	-.00103	-.006670	-.053
	RC	.03625	.16052	.977
	MA	.08922	.50117	2.976*
PS	CT	.00753	.01608	.183
	RC	.35457	.52379	4.552*
	MA	.15070	.28244	2.394*

*P < .05

PS1 = Problem Solving Subskill 1
PS2 = Problem Solving Subskill 2
PS3 = Problem Solving Subskill 3
PS = Total Problem Solving

ANCOVA - See Table 6

2. After controlling for race, age, and sex, problem solving subskill 2, and problem solving subskill 3 were significant discriminators between developmental and nondevelopmental subjects. Nondevelopmental students showed a higher degree of proficiency in using the subskills 1 and 2.

Group differences - See Tables 7, 8 and 9.

3. Females had significantly lower problem solving subskill scores and mathematics achievement scores than males.
4. Whites scored higher on all criterion measures except problem solving subskill 3 than non-whites.
5. Younger subjects had higher problem solving subskill 1, problem solving subskill 2, and reading comprehension scores than older subjects.

Regression analysis

6. After controlling for the effect of race, age and sex, the three criterion measures entered together were significant predictors of each subskill of problem solving.
7. Reading comprehension was a significant predictor of both problem solving subskill 2 and total problem solving score.
8. For the problem solving subskill 3, and total problem solving score, mathematics achievement was a significant predictor.

Chapter 5

SUMMARY, CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

The number of students who are identified as those who need postsecondary developmental instruction continues to increase. Postsecondary developmental education has become a very sensitive issue, partly because of the constraints of funding, and also because there is some question whether this should be a postsecondary concern. However, it is probable that the number of developmental students in the nation's colleges will continue to increase. How best to educate these students continues to be a very complex issue. This research was conceived and carried out with hopes of adding to the body of knowledge which describes developmental education in general, and describes the students who make up this population in particular. An additional objective was to investigate the predictive power of selected variables on problem solving performance.

Summary

Purpose. The purpose of the study was twofold: first, the study sought to investigate the differences between developmental and nondevelopmental subjects as measured by selected variables; and second, to investigate which selected variables are the best predictors of problem solving performance.

The study sought to answer the following questions:

1. Are there significant differences between developmental and nondevelopmental students as measured by the selected criterion measures?
2. Are the criterion measures significant predictors of problem solving performance?

3. Are there significant differences among criterion measures for subjects according to sex, race, age?

Methods. Criterion measures for 60 subjects identified as developmental or nondevelopmental mathematics students were analyzed. Four nationally normed tests were administered to students in selected developmental and nondevelopmental mathematics classes.

Twenty-two (22) students were in the nondevelopmental group. The developmental group consisted of 38 subjects. Each subject was administered the criterion tests in the order problem solving, reading comprehension, mathematics achievement, and critical thinking. The entire testing was completed in two days.

The primary analysis of data utilized multiple analysis of covariance with six dependent variables, one factor variable, and three covariates. Essentially, the primary analysis sought to determine if there was a significant difference between developmental and nondevelopmental students, considering multiple criterion measures. The secondary analysis employed multiple regression analysis with three criterion measures as predictors and three dependent variables. The secondary analysis sought to ascertain which criterion measure was the best predictor of problem solving, after controlling for effects due to demographic characteristics.

Findings. The results of the data analyses can be summarized under three headings: multivariate analysis, univariate analysis, and regression analysis.

Multivariate Analysis

The major finding of the study was that the multivariate analysis produced no significant difference between developmental and nondevelopmental subjects when all six criterion measures were considered. The primary research hypothesis--one for which the literature is not conclusive--was that the two groups would be significantly different. It should be noted here that one of the reasons for the multivariate design is to ensure that the observed results may be attributed to experimentation and no other cause, thus, reducing the possibility of committing a type 1 error. With the multivariate analysis, more stringent criteria for declaring a difference between the two groups significant must be met, and therefore, a difference must be larger to be identified as a true difference (Norusis, 1983). The hypothesis that there is no difference between developmental students and nondevelopmental students was accepted on the basis of this analysis.

A second multivariate analysis was done to investigate the effect of the covariates: race, sex and age. After controlling for the effect of the differences between developmental and nondevelopmental students, the results indicate that sex is significantly related to the criterion measures, three subskills of problem solving, reading comprehension, mathematics achievement, and critical thinking. As revealed by the univariate tests, females scored significantly lower on all aspects of problem solving, and mathematics achievement than male subjects.

When the total problem solving score was included as a criterion measure along with critical thinking, reading comprehension and mathematics achievement, the results were quite similar. Again the multivariate test produced no significant difference between the two groups.

Univariate Analysis

When individual criterion measures were tested there were significant differences between developmental and nondevelopmental students. The problem solving proficiency of nondevelopmental students was greater when utilizing the problem solving subskill 2 which is identified as the skill "doing it," and problem subskill 3, "looking back," respectively. This result is consistent with the assumption that nondevelopmental students would out perform developmental students when activities require knowledge and experience. The problem solving subskill 2, "doing it," requires that the student choose the correct computation procedure needed to obtain the answer. In addition to adding, subtracting, multiplying, or dividing, the student may decide to guess and check or make a table or diagram. The requisite skills which are tied to the skill, "doing it," are related to one's knowledge or achievement in mathematics. Higher mathematics achievement scores yield greater proficiency in utilizing the skill "doing it."

With higher scores on the problem solving subskill 3 (PS3), nondevelopmental students had a greater propensity for not stopping because they had the answer. This skill reflects on the nondevelopmental student's ability to understand the conditions of the problem and to assess how those conditions actually relate to the answer. Such practice builds confidence for similar problems in the future (Immerzeel, 1977). In general, it is assumed that nondevelopmental students have more mathematical experience than developmental students. Consequently, a key disadvantage for most developmental students appears to be inexperience with formal problem solving activities.

When the total problem solving score was included as a criterion measure, the results were similar. Taken as a single criterion measure, total problem solving was a significant discriminator between developmental and nondevelopmental students. Nondevelopmental students had significantly higher total problem solving scores than developmental students.

When the differences between developmental and nondevelopmental were controlled, there were significant differences among certain criterion measures due to race. White subjects had higher scores than non-white students on the criterion measures, problem solving subskill 2, "do it," reading comprehension, critical thinking and mathematics achievement.

A similar investigation was done with age as the covariate. When the group effect (developmental - nondevelopmental) was controlled there was no significant differences among the criterion measures due to age.

Regression Analysis

There were significant predictors for problem solving performance. Reading comprehension was a significant predictor for both problem solving subskill 1 and problem solving subskill 2. Mathematics achievement was the only significant predictor for problem solving subskill 3. When the total problem solving score was the dependent variable, both mathematics achievement and reading comprehension were significant predictors.

Conclusions

The conclusions include those from the primary analyses and those from the secondary analyses. This study was limited to a single community college. It was intended to provide distinguishing characteristics of a sample of developmental and nondevelopmental students. The caveat of this study is the method used to designate a student as developmental or nondevelopmental. The contextual view of this selection process involves institutional academic requirements and individual self-selection. Given this contextual setting, a certain caution must be used in applying these findings to general population, however, under similar conditions using similar selection processes, these findings may be relevant.

Primary Analyses. The findings from the primary analyses support the conclusion that the group effect was not significant. There was no significant difference between the group means of developmental and nondevelopmental students based upon the groups' scores on the set of dependent variables, which were described as problem solving subskill 1, problem solving subskill 2, problem solving subskill 3, critical thinking, reading comprehension, and mathematics achievement.

When the dependent variables were considered individually (univariate test) and the covariates, sex, race, and age were controlled; there was a significant statistical difference between developmental and nondevelopmental students. Although the multivariate test produced no significant difference, the univariate test produced differences on the problem solving criterion measure. Developmental students scored significantly lower on problem solving subskill 2 (sex, age, race controlled), and problem solving subskill 3 (sex controlled) than nondevelopmental students. It is important to note that none of the other factors were discriminating factors between developmental and nondevelopmental subjects. Apparently the skills of computing, estimation, and use of tables, which underlie problem solving subskill 2, and the skill of looking back at the solution, which underlies subskill 3, require more specialized student aptitudes or characteristics. According to other research (Oehmke, 1979), looking back strategies were infrequently used during interview problem solving sessions. Oehmke reported that only the brighter students actually utilized subskill 3 (looking back). This skill is defined as the ability to have the solution checked against the conditions of the problem.

It was hypothesized that the criterion measures for nondevelopmental students would be higher than the scores for developmental students. The literature suggests the same. According to Suydam (1980) and taken from several sources good and poor problem solvers differ in IQ, reasoning ability, reading comprehension, quantitative ability and spatial aptitude. There is general agreement that successful problem solving is enhanced by higher scores on the aforementioned criterion measures.

For this study, the single factor which distinguishes developmental mathematics students from nondevelopmental mathematics students is mathematics achievement. Nondevelopmental students are classified as such by their higher scores on the mathematics placement test. The literature clearly suggests that there are other factors that could distinguish these two groups of subjects. Pollard, et al (1983) hypothesized that there was a distinguishable difference between developmental and nondevelopmental students as measured by certain developmental tasks, however, the authors found that the group differed significantly on only one task, "appropriate educational plans." However, Baker (1982) found no significant differences between developmental and nondevelopmental students when measured by a writing task. The literature presents no clear conclusive evidence that developmental and nondevelopmental students differ according to certain criteria, however, several authors (i.e. Suydam, 1980) seem to suggest that when a group of variables are considered collectively in a multivariate analysis, differences will appear. However, this analysis did not support this contention. In fact, developmental students actually scored higher on the critical thinking measure. Because of the intricate aspects of critical thinking, it was expected that this would be one of the more discriminating aptitudes.

Secondary Analysis. The findings of this analysis support the following conclusions relative to the effects of reading comprehension, critical thinking, and mathematics achievement on problem solving:

1. There was a significant effect due to the predictors, reading comprehension, critical thinking, and mathematics achievement. After controlling for the effects of demographic characteristics, sex, race, and age, there was a significant predictor effect, as demonstrated in Table 14. The predictors accounted for nearly one-half (49%) of the variance in problem solving. Reading comprehension and mathematics achievement were significant predictors of total problem solving; however, reading comprehension was a more important predictor of total problem solving than mathematics achievement.

2. Reading comprehension was a significant predictor of both problem solving subskill 1 and problem solving subskill 2. Problem solving subskill 1 involves the skill of "understanding the problem" and problem solving subskill 2 involves the skill of "using a particular strategy to obtain the desired solution." This finding differs from one of Oehmke's (1979) findings which she noted that reading comprehension was not a major correlate of problem solving.

3. There was a significant effect of mathematics achievement on problem solving subskill 3. This skill involves the ability to "look back at the solution." Underlying this ability is the ability to assess the conditions of the problem in an attempt to have the solution be one that is considered reasonable. According to Schoen and Oehmke (1980) this subskill requires the problem solver "to determine the effect of varying the conditions in a given problem, or to evaluate a given solution strategy." In addition, this skill involved the ability to ascertain whether there is another way to solve the problem. Similarly, Bellile (1980) found that the higher correlations were between problem solving subskill 3 and the number of high school algebra courses although, apparently, such abilities are predicated on one's conceptual understanding of mathematics.

Further analysis of the demographic characteristics showed the following conclusions:

1. Male subjects were significantly better problem solvers than female subjects. Females scored lower on all subskills of problem solving. That is, female subjects showed a lower degree of proficiency with the skills, "understands the problem," "doing it," and "looking back at the solution." In addition, male subjects were significantly better readers than female subjects as measured by reading comprehension scores.

2. Younger subjects (24 or less) scored significantly higher on the total problem solving measure than older subjects (over 24). Also, younger subjects were significantly better readers than older subjects. One explanation was that younger subjects who recently finished high school were better at reading the kind of text material in the test. This result is inconsistent with the results reported by Moore (1980). Moore (1980) found that older (22 or over) were better readers than younger subjects (less than 22).
3. White subjects were significantly better problem solvers than non-white subjects. In addition, white subjects scored significantly higher on all criterion measures, critical thinking, reading comprehension and mathematics achievement. These results were consistent with the literature.

All of the groups showed differential effects due to problem solving. Subjects who scored higher in problem solving scored higher in reading comprehension. This fact supports the notion that reading comprehension is an important predictor of problem solving.

Discussion

The findings of this study generally supported the literature. However, some important findings were inconsistent with some earlier research. Because no study was found that specifically investigated differences between developmental and nondevelopmental students, it was difficult to compare all of the findings. The study did have some limitations, but the results provide some support for the premise that the difference between developmental and nondevelopmental students is not as significant as many educators believe.

The literature reveals that some authors have in fact found no differences between these two groups. Maybe at a much higher rung on the education ladder, differences will be more discernible. Cartledge, et al (1985) found that developmental and nondevelopmental students did differ significantly from graduate students. It appears that save for certain cognitive variables such as mathematics achievement and perhaps reading comprehension, developmental and nondevelopmental students are more alike than they are different. With the increasing number of students who enter college needing basic skill development, the differentiation between those who need remediation and those who do not becomes increasingly more difficult to make. It is quite possible there is some cross over in that students might be "developmental" only in one area, but quite competent in all other academic areas. This research may provide some explanations as to how best to teach problem solving to a community college population of both developmental as well as nondevelopmental students. It may further supply educators with the impetus to be more creative with those students who are deemed less capable.

Implications for Future Research

This study has several important implications for future research. Community college faculty must seek to develop programs and support services that address the needs of developmental students. These programs and instructional methodologies must be consistent with the students' aptitudes. Commonly held differences between developmental and nondevelopmental students are not supported by this study when multiple variables were considered. Community college faculty should, therefore, seek to avoid limiting intellectual stimulation only to nondevelopmental students. Strong consideration should be given to the capabilities of developmental students. The assumption is that problem solving and other higher level intellectual activities involving critical thinking are appropriate not only for the academically prepared students, but under the right conditions developmental students can broaden their knowledge beyond just the "basics."

While this study was limited to the analysis of a single community college, future research should broaden the population to include additional institutions and additional subjects. It is recommended that additional research be done to determine whether a replication of the present study produces similar results.

Additionally, research should be conducted to determine whether problem solving subskills can be enhanced by participation in certain activities or particular kinds of instruction. Because reading comprehension was a significant predictor of problem solving performance for the present study, it would be of value to determine if specific reading instruction would enhance problem solving in general and individual subskills of problem solving in particular.

It is suggested that future research determine if predictors of problem solving performance are different across groups. A more discriminating look at problem solving would be of value to educators of developmental and nondevelopmental students. Another study could ascertain whether there are significant predictors of problem solving peculiar to developmental students or nondevelopmental students.

Finally, another study should increase the number of variables in an attempt to discriminate between developmental and nondevelopmental students.

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APPENDIX 1

Correspondence with

J. SARGEANT REYNOLDS COMMUNITY COLLEGE

March 2, 1984

Iowa Problem Solving Project
University of Northern Iowa
Cedar Falls, Iowa 50613

Dear

I am a doctoral student at Virginia Polytechnic Institute and State University. I am very interested in verbal problem solving and have chosen "the problem solving difficulties of community college students" as a dissertation topic.

I am interested in using the Iowa Problem Solving Project Test as an assessment of the problem solving performance of community college students. I am familiar with the study completed by Dr. E. K. Bellile, where the IPSP test was used with a sample of college students. I would like to have your permission to use forms 781 and 782 of IPSP test on a sample of community college students. If there are revised versions of this test please forward the same to me.

Thank you very much.

Sincerely,

Roland E. Moore

P.O. Box 12084, Richmond, Virginia 23241

The University of Iowa
Iowa City, Iowa 52242

College of Education

1847

March 28, 1984

Mr. Roland E. Moore
J. Sargeant Reynolds Community College

Dear Mr. Moore:

Enclosed is a copy of the IPSP Problem Solving Test. You have the authors' permission to make as many copies as you need for research or teaching purposes.

We would appreciate receiving a copy of any studies in which you use the test.

Sincerely,

Professor,
Mathematics & Education

cb

Enclosure

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The two page vita has been removed from the scanned document. Page 2 of 2

THE RELATIONSHIP BETWEEN SELECTED VARIABLES AND ARITHMETIC PROBLEM SOLVING AMONG COMMUNITY COLLEGE STUDENTS

by

Roland Eugene Moore

(ABSTRACT)

Students at all academic levels have difficulty solving word problems. Because of individual characteristics, such as inadequate mathematics background, anxiety, and poor study habits, developmental students face a tremendous task in solving word problems.

There is considerable documentation that several variables contribute to problem solving success. For this study, three of these variables, mathematics achievement, critical thinking and reading comprehension, were selected for investigation. The purpose of this study is to establish if there is a significant difference between developmental and nondevelopmental subjects as measured by the aforementioned variables. In addition, the study sought to establish to what extent mathematics achievement, critical thinking and reading comprehension contribute to the variance in problem solving performance among a sample of nondevelopmental and developmental students.

The data will be analyzed by establishing intercorrelations between the independent variables, mathematics achievement, critical thinking, reading comprehension and the dependent variable, problem solving performance. Regression analysis will be used to select the variable which is the best predictor of problem solving performance, and multiple analysis of covariance will be used to establish if a significant difference exists between developmental and nondevelopmental subjects.

Various individual traits influence one's ability to solve problems. The findings of this study may be beneficial in improving the ability of students to solve word problems.