Personality and Problem Solving: An Exploration Using a Computerized, Ill-Defined Problem

Audrey A. Friedman
University of Massachusetts Boston

Follow this and additional works at: http://scholarworks.umb.edu/cct_capstone

Recommended Citation
http://scholarworks.umb.edu/cct_capstone/116

This Open Access Capstone is brought to you for free and open access by the Critical and Creative Thinking Program at ScholarWorks at UMass Boston. It has been accepted for inclusion in Critical and Creative Thinking Capstones Collection by an authorized administrator of ScholarWorks at UMass Boston. For more information, please contact libraryaasc@umb.edu.
PERSONALITY AND PROBLEM SOLVING:
AN EXPLORATION USING A COMPUTERIZED, ILL-DEFINED PROBLEM

A Thesis Presented
by
AUDREY A. FRIEDMAN

Submitted to the Office of Graduate Studies and Research of the University of Massachusetts at Boston in partial fulfillment of the requirements for the degree of

MASTER OF ARTS
May 1991
Critical and Creative Thinking Program
© 1990 Audrey A. Friedman
PERSONALITY AND PROBLEM SOLVING:
AN EXPLORATION USING A COMPUTERIZED, ILL-DEFINED PROBLEM

A Thesis Presented
by
AUDREY A. FRIEDMAN

Approved as to style and content by:

John Murray, Ed.D., Chairman of Committee
Patricia Davidson, Ed.D., Member
Carol Smith, Ph.D., Member

Patricia Davidson, Ed.D.
Director, Critical and Creative Thinking Program
Acknowledgements

The author wishes to thank Professor John Murray for his continued support, advice, enthusiasm, and his creation of the ill-defined problem. Additional thanks are extended to Professor Patricia Davidson for her enhancements to this work and to Professor Carol Smith for helpful critique and aid with the statistical analyses. This study could not have evolved without the wonderful children who participated in it. I thank them for their enthusiasm, spontaneity, and cooperation.
ABSTRACT
PERSONALITY AND PROBLEM SOLVING:
AN EXPLORATION USING A COMPUTERIZED, ILL-DEFINED PROBLEM
MAY 1991
AUDREY A. FRIEDMAN, B.S., UNIVERSITY OF MASSACHUSETTS
AT AMHERST
M.S. UNIVERSITY OF PENNSYLVANIA
M.A. UNIVERSITY OF MASSACHUSETTS
AT BOSTON
Directed by: Professor John Murray

The purpose of this study was to explore patterns of heuristic strategies adolescents used in working on an ill-defined problem and to identify if any possible relationships existed between these problem solving strategies and specific personality traits. Twenty-nine middle-school children were administered a modified version of the Edwards Personality Preference Schedule (EPPS) which identified variables of achievement, autonomy, intraception, deference, aggression, and endurance. The same subjects were asked to work on a computerized, ill-defined problem called the Tribble Task. The Tribble Task asked students to discover rules that governed pattern change among the Tribbles by observing what happened on the computer screen after they placed varying numbers of Tribbles on different parts of
the grid. Students were then encouraged to make, test, and revise predictions about Tribble pattern change rules based on their observations. Each student was asked to verbalize about his or her thinking during a twenty minute period. Students were not expected to solve the problem in the given time. The tape recorded verbalizations were analyzed to determine the problem solving approach(es) each subject used.

The results showed that subjects varied in terms of problem solving strategies they employed, utilizing a directed trial and error, random, trial and error, or creative heuristic in combination or alone in their approach to working on the ill-defined task. Subjects' performance also showed that as subjects gathered more data through observation, their heuristics became more sophisticated. There were statistically significant correlations among the use of heuristics, problem solving processes, and redefinition of the ill-defined task. There were significant differences between males and females in the relation between their performance on the Tribble Task and their raw scores on the EPPS for the personality variable of aggression. Data showed a significant negative correlation between aggression and the problem solving task for males; while females showed an almost significant positive correlation.

Data also showed that overall, subjects ranking lower on the autonomy scale subjects performed better on the
Tribble Task. When analyzed separately for males and females, this observation was statistically significant for males, but did not reach statistical significance for females. There was also a statistically significant negative correlation between deference in males and in the Tribble Task performance. The correlation for females was also negative, but did not reach statistical significance.

New studies might further explore the role of intellectual aggression, autonomy, and deference in solving problems and whether there are systematic differences in personality and problem solving for males and females.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. EVOLUTION OF AN IDEA</td>
<td>1</td>
</tr>
<tr>
<td>An Unusual Problem</td>
<td>1</td>
</tr>
<tr>
<td>Real Problems</td>
<td>2</td>
</tr>
<tr>
<td>Personal Observations</td>
<td>3</td>
</tr>
<tr>
<td>Hunches</td>
<td>5</td>
</tr>
<tr>
<td>A Purpose Evolves</td>
<td>7</td>
</tr>
<tr>
<td>Why Explore?</td>
<td>8</td>
</tr>
<tr>
<td>II. DEFINITIONS</td>
<td>10</td>
</tr>
<tr>
<td>Definition of Problem Solving</td>
<td>10</td>
</tr>
<tr>
<td>Problem Solving and Thinking</td>
<td>12</td>
</tr>
<tr>
<td>III. REVIEW OF LITERATURE</td>
<td>17</td>
</tr>
<tr>
<td>Current Research about Problem Solving</td>
<td>17</td>
</tr>
<tr>
<td>Use of Heuristics</td>
<td>17</td>
</tr>
<tr>
<td>Work on Problem Solving Process and Metareasoning</td>
<td>22</td>
</tr>
<tr>
<td>Ill-defined Problems</td>
<td>25</td>
</tr>
<tr>
<td>Research About Problem Solving and Personality</td>
<td>27</td>
</tr>
<tr>
<td>IV. DESCRIPTION OF EXPLORATION</td>
<td>30</td>
</tr>
<tr>
<td>Population Studied</td>
<td>30</td>
</tr>
<tr>
<td>Problem Solving Task</td>
<td>34</td>
</tr>
<tr>
<td>The Tribble Task as It Appears to Students</td>
<td>36</td>
</tr>
<tr>
<td>The Comrey Personality Scales</td>
<td>40</td>
</tr>
<tr>
<td>Orderliness vs. Lack of Compulsion</td>
<td>41</td>
</tr>
<tr>
<td>Social Conformity vs. Rebelliousness</td>
<td>41</td>
</tr>
<tr>
<td>Activity vs. Lack of Activity</td>
<td>42</td>
</tr>
<tr>
<td>Extraversion vs. Introversion</td>
<td>43</td>
</tr>
<tr>
<td>Masculinity vs. Femininity</td>
<td>43</td>
</tr>
</tbody>
</table>
### Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>V.</td>
<td>THE PERFORMANCE OF STUDENTS ON THE TRIBBLE TASK</td>
<td>53</td>
</tr>
<tr>
<td>VI.</td>
<td>LINKS BETWEEN PROBLEM SOLVING AND PERSONALITY</td>
<td>78</td>
</tr>
<tr>
<td>VII.</td>
<td>CONCLUSIONS AND RECOMMENDATIONS</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>General Conclusions.</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>Suggestions for Further Research.</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Assessing Personality Variables.</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>A Modified Rating Scale.</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>A Variation of the Problem.</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>In Summary</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Epilogue</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>BIBLIOGRAPHY</td>
<td>97</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>MODIFIED COMREY PERSONALITY SCALES</td>
<td>100</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>THE MODIFIED EDWARDS PERSONALITY PREFERENCE SCHEDULE</td>
<td>105</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>TRANSCRIPTS OF RECORDED INTERVIEWS OF STUDENTS COMPLETING THE TRIBBLE TASK</td>
<td>114</td>
</tr>
</tbody>
</table>
**LIST OF TABLES**

<p>| Table 1 | Age, Gender, Cognitive Index, CTBS Math, Language, and Reading Scores for Subjects | 31 |
| Table 2 | Problem Solving Patterns: Number of Students Using Each Heuristic | 59 |
| Table 3 | Rating System for Assessing Performance of Subjects in Problem Solving Task | 62 |
| Table 4 | Student Performance on the Tribble Task Using the Rating Scale | 67 |
| Table 5 | A Comparison of Means for Group A and Group B | 74 |
| Table 6 | Gender, Personality Variable Raw Scores, and Tribble Rating | 79 |
| Table 7 | Correlations Between Personality Variables and the Tribble Problem Solving Task for Males and Females | 80 |
| Table 8 | Patterns of Heuristics, Gender, Tribble Scores, EPPS and Comrey Personality Variable Raw Scores | 86 |</p>
<table>
<thead>
<tr>
<th>List of Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1 Tribble Grid</td>
<td>37</td>
</tr>
</tbody>
</table>
CHAPTER I

EVOLUTION OF AN IDEA

An Unusual Problem

Life is a marvelous adventure for James and his creature-friends as they loll about on the ocean in their enormous and bountiful peach. That is until voracious sharks begin to circle about and to attack the floating home. Frantic, the Grasshopper, Earthworm, Centipede, Silkworm, Glow-worm, Lady-bug, and Spider huddle around James, begging for help. "'Is there nothing we can do?' asked the Lady bug, appealing to James. ‘Surely you can think of a way out of this.'

Suddenly they were all looking at James.

'Think!' begged Miss Spider. 'Think, James, think!'" (Dahl, 1972, pp. 71-73)

In his effort to help his unusual friends, James must devise a strategy - an integration of many discrete and important thinking skills that when linked together will help him successfully face and resolve the dilemma at hand. James is being called upon to be a problem solver.
Real Problems

Although it is highly unlikely that many of our students will be called upon to rescue giant fruit or garden creatures from a shark attack, it is a surety that they will need to solve problems of varying difficulty at various times. If the reader seriously considers all the problems, major and minute, that he/she encounters and must solve in one given day, the quantity can be staggering and especially overwhelming for a youngster who is unfamiliar with most domains as well as the domain of problem solving, itself. What should I wear? Where do I catch the bus? What is the meaning of this passage? How can I buy the baseball card I want? How can I complete all my homework and still go to the concert? How do I refuse drugs or alcohol when my friends encourage me to try them? How do I solve this physics problem? How do I convince my parents to let me go to the dance? What is the meaning of this story? It would seem that most of a person's life is spent solving problems of one sort or another. Thus, the ability to solve problems is a necessary and valuable thinking process (Bail, 1987).
Personal Observations

Throughout my teaching experience, I have observed a very common phenomenon in the classroom: some students are capable problem solvers; while others are not. Certainly, this observation is nothing revolutionary and perhaps, not even interesting, but further examination of it does supply food for thought.

My teaching experience brought me to an inner city high school where I taught chemistry, biology, physics, and English. Because of the "alternative" school setting, at least 30% of the students were enrolled in both my science and English courses—two very different domains that require students to solve very different types of problems. In both domains, the same students stood out as capable problem solvers and shared specific traits. Most were aggressive risk-takers who asked lots of questions and who were not afraid to try different approaches to solving problems. These students tended to be leaders in the classroom, and most of them were males.

Several years later, teaching brought me to a suburban high school English classroom of students who were diagnosed as learning disabled. Again, I observed that among these less able students the better problem solvers demonstrated a persistent stick-to-itness and a penchant for taking risks.
Six years later, I had the pleasure of working in an elementary classroom of fourth and fifth graders whose abilities ranged from above average to gifted/talented. Fifteen of these students later served as Group A for this thesis. Even in this class of very capable students, there were those who were more capable problem solvers than their peers. These students exhibited exemplary problem solving skills in most domains. I worked with these students in English Literature, science, critical and creative thinking, and Future Problem Solving (FPS). Again, certain traits emerged in the better problem solvers; such students were aggressive risk-takers who assumed leadership roles in the classroom and who were persistent in carrying out tasks to closure. Most of these students were males. These students would analyze literary works for theme, conflict, and symbolism with great facility and would suggest solutions to science problems with the same ease. They were also the same students who not only took command of their groups in Future Problem Solving activities, but also brainstormed FPS problems and their solutions with great fluency and versatility. Utilizing a problem solving process seemed consistent in their behavior.

Based on my own personal experience, I hypothesized that a) some students are generally better problem solvers than others; b) the ability to solve problems might be
correlated with certain personality traits; and c) different students may utilize different strategies in solving problems. I thought that students who were intellectually aggressive and who took risks seemed to be better problem solvers. High achievers who demonstrated a "stick-to-it" attitude also appeared to me to be more capable problem solvers. Such personal observations motivated questions that might be investigated through systematic research.

1) What thinking skills and strategies or heuristics do students use in problem solving? Do more capable problem solvers use different heuristics than less capable problem solvers?

2) Are some students better problem solvers than others? That is, are some students consistently better problem solvers across domains?

3) Are there identifiable personality traits that are attributable to better problem solvers? Is this a possible reason for consistency across domains?

**Hunches**

As previously mentioned, I had the opportunity of working with the same students in several domains. On
the cognitive side, these students appeared to share common characteristics. They demonstrated good questioning skills, possessed or were able to develop a specific plan of attacking and solving problems, made excellent guesses, and retrieved and stored information with ease and finesse. The majority of these students were aggressive in class and demonstrated a need to achieve and a certain "stick-to-itiveness" to complete a task. These subjects were also willing to try new ideas and methods and apply new information to an old or stale situation. Another interesting characteristic about these students was their ability to focus intensely on a task. Thus, I hypothesized that the aforementioned problem solving and personality characteristics might be common to good problem solvers.

As I continued to work with these students, it seemed that exploring the possible relationship between problem solving and personality might reveal some interesting information. Perhaps certain personalities lend themselves to better problem solving? It was my guess that students who were aggressive, achievement-oriented and not afraid to take risks and devote time to tasks would solve problems of any type with more ease and finesse than students who did not possess these traits. It also seemed logical that these students probably used different strategies in solving problems than their peers.
Contrary to what I expected, I found that little research has been conducted in education, critical and creative thinking, and cognitive psychology that relates problem solving and personality. Several studies were done in the area of problem solving and personality in the business setting, while another focused on social problem solving. Furthermore, much investigation emphasized problem solving of well-defined problems, but few considered problem solving of ill-defined problems. (A review of the literature is provided in Chapter III.) Thus, the idea of exploring the relationship between ill-defined problem solving and personality seemed worthwhile, interesting, and within the scope of a thesis.

A Purpose Evolves

The purposes of this thesis are two-fold:
1) to explore and learn about the strategies, heuristic methods, patterns, and problem solving processes students use in solving a specific, computerized ill-defined problem;
2) to explore any links that might exist between the strategies, heuristics, problem solving processes or patterns identified in (1) and the subject's particular personality traits.
Why Explore?

Why explore the relationship between problem solving and personality? Problem solving is a thinking process that is an inherent part of everyone's daily life. Even the simplest situation may offer well-defined and ill-defined problems that a person must solve. Success in school and in life depends upon a person's ability to solve problems. If there are identifiable strategies that more capable problem solvers utilize, perhaps these can be honed and taught to less capable problem solvers (Glaser, 1984).

It is common knowledge that problem solving involves several important steps that must be followed to obtain successful results, and curricula have been developed to teach students to become better problem solvers. It may indeed be true, however, that good problem solvers and perhaps better thinkers may possess certain personality traits that are more conducive to better thinking and problem solving. Changing one's personality may be difficult and undesirable, but providing an environment where students might be encouraged to adopt behaviors that are more conducive to better thinking and problem solving might be helpful.

If risk-taking and creativity are beneficial behaviors to adopt, students could be provided with an environment where it is desirable to try a new approach or
something absurd. If being more aggressive might provide a student better results, students could participate in a setting where they are given confidence-building experiences that reinforce positive aggressive behaviors. If there are certain personality traits that predispose a person to better thinking, perhaps nurturing environments can be established in the classroom or at home where students can be encouraged to take risks, be more creative, stick with a task longer, and assume leadership in overseeing the task's accomplishment. Links between problem solving and personality may provide different pedagogical structures for classroom teaching and curriculum development. Such instruction might enhance students' chances for better success in school and in daily life.
CHAPTER II
DEFINITIONS

Definition of Problem Solving

Problem Solving is a thinking process by which information is manipulated to achieve a specific goal. (Costa, 1986) Although the context of problems varies, there are three basic characteristics of any problem be it well-defined or ill-defined (Howard, 1983).
- There is an initial state at which the person begins.
- There is a goal state which the person wishes to achieve.
- There are actions that are necessary to convert the initial state into a goal state.

Well-defined problems are those in which the initial and goal states are clearly defined. Problems of this nature are usually found in the domains of math, physical science, grammar, linguistics, chess, etc. The actions necessary to convert the initial into the goal state may include specific formulae or operations.

Ill-defined problems are those in which the initial state is clear, but the goal state and actions necessary to reach the goal state are unclear and often independent of specific formulae or operations. Often, solving ill-defined problems requires the subject to define the problem into more manageable subunits or "miniproblems"
which may require redefinition. Everyday social and personal problems fall into this category. James' problem is ill-defined; he must identify the real problem or problems as well as the goal state and then suggest a series of actions or steps to move him and his companions from the initial state to the goal state. The ability to solve ill-defined problems thus serves as an invaluable survival process not only for James but also more importantly for students.

Moral decision making or moral problem solving falls into the category of truly ill-defined problem solving. In contemporary society, such problems make daily demands on students. What further complicates the process, is that there are often no "right" answers or solutions to moral dilemmas. The best solution is the best decision given the context, parameters, and all the variables of the problem at the given time (Gilligan, 1982).

Real-life problems and enigmas that scientists and medical researchers face may also fall into the realm of ill-defined problems. Such problems present a myriad of intricate dilemmas requiring researchers to devote years of experimentation and study in order to dissect the global problem into manageable subproblems.

Because the more difficult problems students face are ill-defined, the notion of exploring how students approach solving ill-defined problems seems worthwhile. Although a
moral or social problem might have been the best example of an ill-defined problem for this study, its use may have raised objections from parents. As a result, I needed to select a problem that had a solution, but one that would allow me to observe how students suggest and use operations to redefine the overall problem into more manageable units. The types of heuristics students employ and the kind of problem solving process they follow would therefore seem relevant.

Problem Solving and Thinking

Most, if not all, critical and creative thinking skills, operations, and processes are involved in problem solving. Problem solving is thinking, and good problem solvers are good thinkers. Problem solving usually involves several steps which involve many skills. Often, these steps are followed in a specific sequence, but more often than not, problem solvers retrace steps moving in and out of the process. One step involves the subject gathering data about the problem through observation. Observation involves using the senses to gather information: noticing qualities, textures, colors, forms, positions, etc. Observation also involves questioning which helps the observer not only gather more data but also teases out superfluous, irrelevant, or unreliable information about the problem. A competent
observer makes and reports observations well (Norris, 1984).

Through grouping, classifying, and/or categorizing, students identify common elements of the data and decide whether or not the information is useful and should be put aside for further or later consideration (Costa, 1986). Through comparison and contrast, students examine data in order to note similarities, differences, and changes in the data. All these thinking skills and operations help students better define the initial state of the problem or subproblem and help students proceed to the next step. These skills are also continually involved in a person's thinking as he/she proceeds through defining and clarifying the problem (CAP, 1985). For good problem solvers, these skills and operations are automatic.

In some models of problem solving, students then use the information gathered through observing, questioning, and comparison and contrast to help them make predictions. Prediction is the formulation of possible hypotheses and/or consequences of a particular event or series of events. Through prediction, the subject suggests ideas about what might happen next or what will happen next if a specific operation or set of operations is applied. Prediction involves identifying cause and effect relationships that seem to be in operation and applying these relationships to new or different situations. In
essence, making predictions is like suggesting a hypothesis. Such a prediction may be considered only a mini-hypothesis in the realm of solving ill-defined problems (Ennis, 1985).

Once a prediction or hypothesis is suggested, a sequence of operations must be developed to test out the hypothesis (Matthews, 1980). Testing the hypothesis involves formulating a set of action steps or procedures that will decide if the hypothesis or prediction is accurate. If the hypothesis or prediction is correct and the problem is such that a result can evolve, the subject will successfully move from the initial state to the goal state of the problem or subproblem. In many problems, there is no concrete goal state and the "solution" may not be manifested in a result but in some type of general understanding, insight, or intuition. In determining action steps, the subject may need to be fluent and versatile in suggesting ways of getting to the end state. There may be a number of ways of testing the validity of a hypothesis; therefore, the more flexible thinker may get better results. Furthermore, a subject must be able to elaborate his/her plan to be sure important information has not been discarded or not considered (Beyer, 1990).

A necessary part of testing predictions or hypotheses is assessing whether or not the results support or refute the hypothesis or prediction. Often this
requires repeating the sequence of operations used several times to replicate results. Again, good observation and questioning skills are important in this step.

If the hypothesis or prediction is refuted, the subject must revise his or her thinking and essentially begin again. This may involve reexamining observations, reinterpreting observations, or even making new ones. It is also possible that the hypothesis was accurate but that the plan developed to test the hypothesis lacked a step or incorporated an incorrect step. Revision also requires the subject to participate in the entire problem solving process all over again. Careful revision relies on the use of metacognition—the state of being aware of one's own thinking. A good thinker and problem solver is constantly aware of problem definition, observations, hypothesis, operations used to test the hypothesis, predictions, evaluation, and so on. Metacognition requires that the subject be able to ask the right questions about his or her thinking (Bransford, 1986).

Following revision is retesting the use of new thoughts, ideas, and a revised or new plan. In the final step, a solution, global hypotheses, rules, or a decision is generated. This is the culmination of all the steps of the thinking process. Solutions to well-defined problems can be easily tested for correctness; but, the subject may not realize the success of a solution to an ill-defined
problem until the solution is tried. It seems imperative that a student must utilize a myriad of critical and creative thinking skills in solving any type of problem, especially an ill-defined problem.

The purpose of presenting problem solving in such a mechanical, direction-like style is only to demonstrate the kind of thinking skills that are part of the problem solving process. Real problem solving often weeps in many directions, incorporates making connections, and jumps from one skill to another and from one step to another. Real problem solving is not a fixed or rigid process.
Current Research about Problem Solving

Much of the research in problem solving explores specific types of problem solving, the differences between expert and novice problem solvers, and the types of heuristics that have been identified in solving well-defined problems. Less attention has been given to solving ill-defined problems and the relationship between personality and problem solving strategies or heuristics.

Use of Heuristics

Most of the current research focuses on solving well-defined problems in domains like physics, mathematics, or chess, where the information processing needed to reach the goal state takes place over an extended period of time (Stillings, 1987). Recent exploration in this area concerns the kinds of heuristics used in problem solving, the sophistication and efficacy of these heuristics and the differences between expert and novice problem solvers. Such research evolved from the investigations of Newell, Shaw, and Simon (1958).

In 1958, cognitive psychologists Newell, Shaw, and Simon proposed a theory about problem solving called the General Problem Solver Theory (GPS). The thrust of their
investigation was to write a computer program "that would be capable of solving problems using the same strategies [heuristics] that people used." (Howard, 1983) Heuristics can be guidelines for uncovering propositions encoded in a string of words or processing strategies for uncovering solutions to a problem (Simon, 1983). The assumption is that a person's problem-solving ability occurs within a problem space which consists of states of knowledge about the problem. Each state of knowledge reflects what the problem solver knows about the solution at a particular point in the problem. As knowledge about the problem increases or changes, so does the state of knowledge. In order to move from one state to another, the problem solver must apply certain operations or actions called operators. A problem solver's heuristics determine which operators will be used to change from one state of knowledge to another.

Thus, it was incumbent upon Newell, Shaw, and Simon to uncover the different heuristics used by people to solve problems. Rather than using reticent observation of the subjects, the investigators augmented their study by using verbal protocol. Subjects therefore explained what they were doing while they were doing it, providing, at least, some minor clues as to the general strategies they were employing.
Newell, Simon, and Shaw then identified several heuristic methods that can be employed by both novice and expert problem solvers; each varies in terms of expenditure of cognitive energy and in efficacy in solving problems. The following definitions are reported by Howard (1983).

1. One heuristic method is an exhaustive search which, as the name implies, involves a search of all possibilities—alpha to omega—present in the problem solver’s problem space. A cognitively exhaustive procedure, such a search may be attempted by a novice problem solver, but it is difficult to carry out for a large problem space given the many possibilities involved and the difficulties in keeping a record of the attempts and the results of those attempts.

2. A random search is a heuristic in which the subject selects and attempts solutions at random. There is no specific plan of attack. This method like the other may also be used by a novice. Although less cognitively exhausting, it is error prone since finding a solution by chance is unlikely.

3. Another heuristic method that can be sued by novices is trial and error, a process of solving problems by trying various methods or solutions and eliminating faulty ones. There is usually an underlying direction in the process; the subject wants to see what will happen if
he or she takes a particular action. The subject makes no specific prediction, but the action may be motivated by the need to gather more information. Like the other methods, trial and error relies extensively on gathering data through observation. This is a little better strategy than a random search, but it is still error prone.

(4) Working backwards is still another heuristic method. This can be utilized by both novices and experts in solving mathematical or physics problems (Howard, 1983). The subject works backward from the goal to the subgoal or backward from one subgoal to another. Such a heuristic is extremely sophisticated when utilized by mathematicians and physicists who are unraveling causal connections or breaking down theories. The sophistication depends a great deal on the domain, the type of problem, and the problem solver (Anderson, 1990). Such heuristic methods as previously described place a great demand on cognitive energy (the need to keep track of steps), but in appropriate circumstances, can be highly effective in constraining the search of the problem space.

(5) Newell and Simon argued that means–ends analysis was one of the most effective heuristic methods identified in their research for novices to use. In this method, the problem solver uses operators (means) that will achieve the solution (ends) to the problem. By selecting operators that reduce the difference between the current state of
knowledge and the goal state, the problem solver creates a series of subgoals or partial solutions that give him/her a systematic way of searching through problem space and may eventually lead him/her to a final solution to the problem. However, this strategy is metacognitively demanding since the subject has to keep track of where he/she is in the subgoal decomposition. This method is also slow and time-consuming (Howard, 1983).

How do experts differ from novices in problem solving? One might think that an expert or adept problem solver would perhaps use the same heuristic methods but process the strategies at a faster more efficient rate. This is not the case, however. DeGroot (1966) revealed that expert chess players neither search more moves, search farther ahead, nor search faster; instead they process information in chunks or strands of related information and thus can retrieve it more quickly from long term memory. Chunking allows facility in perceiving relationships between information and making classifications. Chunking is usually a result of intense familiarity with the content of a domain; hence, practice allows a person to avoid problem solving by compiling a specific production for handling a stereotyped situation (Stillings, 1987).

Anderson (1990) discusses the knowledge that underlies problem solving in novices and experts, and
again highlights the importance of heuristics like means-end analysis. Using Kohler's example of the chimpanzee that needed to reach a banana outside of his cage, Anderson cites three essential features of solving a problem that the ape demonstrated: 1) the problem solver is clearly directed toward a goal; 2) the problem solver decomposes the global problem into subgoal; and 3) the problem solver incorporates a set of actions or operators to help transform the problem state into another problem state.

In addition to heuristic methods previously discussed, Anderson includes analogy into the repertoire. Using this method the problem solver tries to use the solution of one problem as a possible solution to another. This heuristic works well when the prior example is similar to the new one as in solving school physics problems that might appear at the end of a science textbook chapter. When the new situation is only superficially similar, however, the problem solver may run into difficulties.

**Work on Problem Solving Process and Metareasoning**

In his work in mathematical problem solving, Polya has suggested that problem solving proceeds in four phases (Polya, 1946). Integral to solving the problem is understanding the problem. The subject must understand and
see clearly what is required. Next the subject must observe how the data are interrelated and connected in order to make a plan for solving the problem. Once the plan is determined, the subject must carry out the plan. Finally, the solution is studied, reviewed, and discussed.

Polya’s four-phase procedure for solving problems seems logical and corresponds for the most part to the implicit problem solving used in means-end analysis and certainly corresponds to the problem solving processes discussed in most critical thinking courses.

Understanding the problem is part of determining the problem space. Making a plan and carrying out the plan involves using operators to help the problem solver move from the initial state to the goal state or at least from one subgoal to another. What seems to be lacking in the General Problem Solving model of Newell and Simon is an explicit discussion of metacognition or the notion of reviewing the thought processes associated with the solution. Such a step would seem to be inherent in any cognitive mechanism involved in chunking and thus a necessary part of progress in proficiency at problem solving. Perhaps this four phase procedure could be termed a type of global heuristic method comprised of other heuristic submethods. In any event, the four-phase procedure provides a map or blueprint that may guide a person in his/her problem solving thinking.
Indeed, new research indicates that metareasoning shows promise as a significant strategy in problem solving. Metareasoning is the ability to reason or think about one's own reasoning (Dillon and Sternberg, 1986).

Greeno (1978) cites strategic planning as a central metareasoning strategy that involves planning or the ability to consider and combine known information to solve a multi-step problem. The ability to combine several equations to create one encompassing equation in a physics problem would involve strategic planning. In the problem solving process, strategic planning could occur in the prediction phase during which a hypothesis or solution is suggested, in the revision phase when one must reconsider all thinking to modify old or suggest new hypotheses, or in the final stage during which a final solution or hypothesis is stated.

Still another metareasoning strategy is testing, that is, investigating the solution for its ability to meet the needs and requirements of the situation and deciding if another option is more appropriate. Testing can fit into the testing stage or revising stage of the problem solving process. Both strategic planning and testing seem to be metacognitive strategies that involve many critical and creative thinking skills.
Ill-defined Problems

Although, most research confines itself to well-defined problems, heuristics and metareasoning strategies may apply to solving ill-defined problems as well. The notion of reflective thinking or metareasoning is probably of key importance, especially in solving ill-defined problems. Reflection includes observation—taking into account the facts of a situation, the evidence gathered through the senses. Based on these data, an inference is made—a suggested proposal or prediction that implies some way of dealing with, clarifying, defining, or even solving the problem until a different condition arises that makes one opt for a different inference. Naturally, what is inferred needs to be tested or acted on. A plan is created and tried. The results are examined and considered with respect to moving ahead in solving a complex problem (Dilloa and Sternberg, 1986).

Dewey (1910) suggests that there are five phases or aspect of reflective thinking that are involved in thinking about perplexing, confusing, or troubling situations: (1) suggestions which "leap out" at us as possible solutions; (2) feeling the difficulty or perplexity of a problem; (3) hypothesizing or using one suggestion after another; (4) reasoning which is a mental elaboration of the idea; and (5) testing the hypothesis. What is reflective about these phases is that they are not
Each improvement in an idea leads to new observations that yield new facts that help the mind judge more accurately the relevancy of facts already at hand" (Dewey, 1910). Metareasoning is a process by which old and new information is constantly recycled with movement toward solution. It would seem then, that ill-defined problems would require a significant amount of recycling as the problem solver moves toward a solution. In fact, future research may reveal that metareasoning strategies, in particular, may be of significant importance in solving ill-defined problems.

This researcher could find no studies in which students were asked to solve an ill-defined problem and verbalize their intermediate solutions. However, the use of verbal protocols have been used extensively in paired problem solving research by Lockhead (1979). In paired problem solving, students work together in pairs on sets of clearly defined problems. Each student has a specific function. One listens attentively, checking for accuracy and demanding constant vocalization while the other partner must read and think aloud verbalizing his/her thinking. Such a protocol combined with tape recording seems an effective means of investigating the kinds of thinking that students may demonstrate.
There are a few studies that seem to investigate how problem solving might relate to personality. In 1976, M.J. Kirton developed a self-descriptive questionnaire which identified participants in a business setting as adapters or innovators or persons who were predisposed either to an adaptive or innovative problem solving style (Goldsmith, 1986). According to the explanation in the questionnaire, innovators prefer radical new solutions to problems, while adapters prefer to improve current solutions to problems. The personality traits of innovators tend to include risk-taking, sensation-seeking and intuition-using behaviors. Adaptive problem solvers are less creative in their thinking and more rigid, opposing change but trying to modify the way things are currently done. This study, however, does not identify one style as more effective, but rather verifies that there is a continuum of problem solving styles that range from adaptive to innovative. In addition, no mention is made of the type of heuristics each style of problem solver might have used.

Another study by Weinman (1987) pointed out that extraverted subjects made more errors in solving problems that involved visual perception (images) as opposed to rigid, introverted subjects. This study seems applicable to my investigation because my study includes an ill-defined problem that is presented visually to subjects.
However, this research indicates that extraverted subjects were not as able to solve visual problems as introverted subjects; these results oppose information I have gathered through my personal observation.

Kumar and Kapila (1982) investigated the relationship between extraversion and masculinity and solving well-defined problems. Results showed that across gender, introverted subjects performed better in most problem solving tasks than extraverted subjects. In males, introversion determined the level of performance while in females, high masculinity boosted performance among extraverted groups and femininity hindered it. This research seems to indicate that introverts are better problem solvers and that subjects who are high in masculinity traits fare better in problem solving.

Chiauzzi and Heimberg (1986) examined differences between assertive and nonassertive subjects in social problem solving. Results affirmed that assertive individuals better perceived their ability to answer questions, evaluate the reasonableness of results, and arrive at workable solutions. Thus, if a person believes that he or she can handle a problem, the probability of successfully solving the problem increases. Assertiveness seems to facilitate conflict resolution and social problem solving.
In summary, research supports some of my hunches, refutes others, and simply fails to test many. While all the research identifies personality traits that might relate to better problem solving, these specific traits were measured using a questionnaire. These few studies do identify traits such as risk-taking, assertiveness, and introversion as having an effect on problem solving. Unfortunately, these studies were performed with adults, thus providing no information about the possible relationship between personality traits and problem solving in younger people. Also these studies do not investigate the relationship between various personality variables such as aggression, achievement, autonomy, and problem solving.
CHAPTER IV
DESCRIPTION OF EXPLORATION

Population Studied

In an investigation of this nature, it is certainly helpful to work with subjects who wish to participate for one reason or another. Thus, I wanted to utilize subjects who were willing to help me, with whom I had a comfortable rapport, and with whose work, ability, and behavior I was familiar.

The first group of students I chose were those described in Chapter I. Group A (Students # 1-16) consisted of sixteen wonderful middle school sixth and seventh grade students. For the past four years, I had worked with these students in elementary and middle school settings in the areas of science, literature, critical and creative thinking, and Future Problem Solving. All students were part of an academically talented program of students who comprise the top 5% of students in the city. These students were selected because of their outstanding ability and achievement as demonstrated by the Comprehensive Test of Basic Skills (CTBS), a standardized achievement test and their CSI, Cognitive Scale Index which is a general intelligence measure (See Table 1). Test scores show that these students possess
### Table 1

**Age, Gender, Cognitive Index, CTBS, Math, Language, and Reading Scores for Subjects**

<table>
<thead>
<tr>
<th>ID#</th>
<th>Age</th>
<th>Sex</th>
<th>CSI</th>
<th>CTBS Total</th>
<th>CTBS Math</th>
<th>CTBS Language</th>
<th>CTBS Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>12-01</td>
<td>M</td>
<td>121</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>2.</td>
<td>12-04</td>
<td>F</td>
<td>126</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>3.</td>
<td>12-01</td>
<td>F</td>
<td>125</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>4.</td>
<td>11-09</td>
<td>F</td>
<td>122</td>
<td>10.9</td>
<td>10.9</td>
<td>9.4</td>
<td>10.9</td>
</tr>
<tr>
<td>5.</td>
<td>11-11</td>
<td>F</td>
<td>138</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>6.</td>
<td>12-02</td>
<td>F</td>
<td>140</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>7.</td>
<td>11-11</td>
<td>F</td>
<td>124</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>8.</td>
<td>11-10</td>
<td>F</td>
<td>122</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>9.</td>
<td>10-11</td>
<td>F</td>
<td>132</td>
<td>9.4</td>
<td>9.4</td>
<td>10.0</td>
<td>9.2</td>
</tr>
<tr>
<td>10.</td>
<td>11-01</td>
<td>M</td>
<td>129</td>
<td>9.1</td>
<td>8.5</td>
<td>8.3</td>
<td>10.0</td>
</tr>
<tr>
<td>11.</td>
<td>11-05</td>
<td>M</td>
<td>131</td>
<td>8.2</td>
<td>8.3</td>
<td>9.3</td>
<td>7.3</td>
</tr>
<tr>
<td>12.</td>
<td>10-11</td>
<td>M</td>
<td>141</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>13.</td>
<td>11-00</td>
<td>M</td>
<td>116</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>14.</td>
<td>12-01</td>
<td>M</td>
<td>141</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>15.</td>
<td>11-03</td>
<td>M</td>
<td>131</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>16.</td>
<td>10-11</td>
<td>M</td>
<td>139</td>
<td>8.8</td>
<td>8.5</td>
<td>9.5</td>
<td>8.7</td>
</tr>
<tr>
<td>17.</td>
<td>13-03</td>
<td>M</td>
<td>131</td>
<td>12.4</td>
<td>12.7</td>
<td>12.9</td>
<td>11.5</td>
</tr>
<tr>
<td>18.</td>
<td>14-05</td>
<td>F</td>
<td>132</td>
<td>12.9</td>
<td>10.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>19.</td>
<td>14-04</td>
<td>M</td>
<td>135</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>20.</td>
<td>13-08</td>
<td>F</td>
<td>141</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>21.</td>
<td>13-06</td>
<td>M</td>
<td>128</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>10.7</td>
</tr>
<tr>
<td>22.</td>
<td>13-09</td>
<td>M</td>
<td>134</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>9.9</td>
</tr>
<tr>
<td>23.</td>
<td>13-09</td>
<td>M</td>
<td>129</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>11.9</td>
</tr>
<tr>
<td>24.</td>
<td>14-05</td>
<td>F</td>
<td>122</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>25.</td>
<td>13-05</td>
<td>M</td>
<td>130</td>
<td>10.1</td>
<td>11.2</td>
<td>8.8</td>
<td>10.6</td>
</tr>
<tr>
<td>26.</td>
<td>13-10</td>
<td>M</td>
<td>138</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
<tr>
<td>27.</td>
<td>13-03</td>
<td>M</td>
<td>123</td>
<td>12.9</td>
<td>NA</td>
<td>NA</td>
<td>12.9</td>
</tr>
<tr>
<td>28.</td>
<td>13-10</td>
<td>F</td>
<td>127</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>11.1</td>
</tr>
<tr>
<td>29.</td>
<td>13-07</td>
<td>M</td>
<td>124</td>
<td>12.9</td>
<td>10.7</td>
<td>12.9</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Superior or above average intelligence as well as high achievement in both math and verbal domains. My experience suggested that some of these students were better at problem solving than others.
As a whole, I can only describe these children as very "neat kids." They were enthusiastic, creative, clever, fun, curious, argumentative, interesting, and caring individuals. In my judgment, the boys were less mature than the girls and tended to be sillier, more sensitive, and more interested in school-related tasks; while the girls displayed an air of semi-sophistication and an interest in more socially related events and issues like parties and sleep-overs. All were interested in helping me and had parents who were interested in helping me. Most of these students resided in my general neighborhood; several had played with my older son. Some were children of parents with whom I had attended school or worked in parents' groups.

Thus, I was not some "alien" or "intruder" violating their space in order to gather secret information. I was their teacher and a friendly face. We shared mutual respect, admiration, and honesty. These children were not afraid to voice their feelings about the personality instrument or their enthusiasm about the problem solving task. Better still, they were not afraid to verbalize their thinking or to ask questions. These students were still "young adolescents" whose spontaneity had not been sombered by peer pressure or personal insecurities. I felt more comfortable with Group A than with Group B.
Group B consisted of thirteen eighth grade students (Student #17-29) from another middle school. These students were also part of an academically talented program but their participation in the program was based on their verbal ability. Most of these students also scored high in other domains of the CTBS and possessed superior or above average intelligence. (See Table 1, p.31) All these students had participated in an extensive Future Problem Solving program. In fact, this is the reason why they became part of the investigation. Their teacher asked me if they could participate. She wanted to know if their experience impacted their ability to solve Tribble type problems. Naturally, she was hoping to see a correlation between their classroom experience and their ability to solve an ill-defined problem.

Prior to this study, I had worked with approximately one third of the subjects in Group B in a classroom setting. Others were patients at my husband’s dental office, so to them I was a familiar face. There were only three students whom I was meeting for the first time. All students were agreeable and friendly, but of course, I did not have the same rapport with these students that I had with Group A. As a whole, this group did not ask a lot of questions. The younger students, particularly males, demonstrated the enthusiasm, energy, and spontaneity I had seen in Group A; while the older children demonstrated a
distance and preoccupation with affairs that were not school related. This distance did not come as a surprise as this group was comprised of older eighth grade students who seemed to have abandoned enthusiasm and spontaneity for sophistication and reserve. It was apparent that I would probably need to ask more questions during the problem solving task in order to elicit a verbal response.

Thus, two groups formed the total population investigated in the study. I selected Group A because of their ability, personalities, and my rapport with them. Group B was selected on the basis of similarity of recorded scores.

**Problem Solving Task**

Well-defined problems are clearly defined tasks often found in part of the math and science domains. Although they are clear cut, involve right answers or single solutions, and are easy to score, they do not represent the type of problem most students encounter in daily life. On the other hand, truly ill-defined problems often enter into the territory of morality, values, medical and scientific research, and higher mathematics. Such problems may have no single right answer or solution or may involve extensive dissection into many subproblems. Also, school systems and parents frown on a teacher inviting students to solve moral dilemmas that may be personal. It seemed
therefore, that the best task for this study should be a problem that was somewhat ill-defined and that had an eventual right answer, but that required students to apply problem solving strategies that would reduce the space between initial and goal states. This task would also require students to utilize important thinking skills in order to proceed through the various steps of the problem solving process. The task would have to be interesting, yet impersonal and perhaps utilize a different medium than pencil and paper. Thus, the Tribble Task emerged as a possible task.

The Tribble Task was developed by Dr. John Murray, the Chairperson of my Thesis Committee, through the modification of a commercially available software program called Tribbles. His intent was to create an ill-defined problem that could be presented on the computer. Tribbles originated from an old episode of the television series Star Trek entitled "The Trouble With Tribbles." Star Trek tribbles are extraterrestrial life forms that reproduce prolifically without rhyme or reason. Dr. Murray’s tribbles differ somewhat; their pattern changes are governed by four rules, and the Tribble Task asks students to discover those rules.
The Tribble Task as It Appears to Students

The following are the description and directions that appear on the computer screen.

"What is a tribble? Well, a tribble is a small furry creature which originally was from the solar system of Alpha Centuri. Due to an accident, tribbles were brought through customs and have managed to find a niche in Earth’s ecology. Researchers are at present trying to understand the life cycle of the tribble...However, little progress has been made, and it is still a mystery. You have been given a grant by the interstellar endowment for extra-terrestrial animals. Hopefully you will be able to discover the rules which govern the tribble life cycle.

OBJECTIVE: find the rules governing tribbles’ lives.

PROCEDURE:

1) Place tribbles in the environmental tank by using the numeric keypad to position where you want a tribble. Use a space bar to place or remove a tribble.

2) When you have finished setting up the environment, press the <enter> key; you will then be shown the initial generation of tribbles. You can then choose to continue watching the tribbles. If you are finished watching, you can decide it is enough work for one day, or set up a new generation.

3) By watching the tribbles generate, you should be able to make hypotheses, and by setting up the tank, you will be able to test them.

Press any key to start." (Murray, 1988).

The students see a grid on the monitor in which they can place as many or as few tribbles in any position they wish. By pressing the <enter> key, students can then observe the next generation of Tribbles. Students may observe as many generations as they wish. Based on what
students observe, they either continue to the subsequent generation or begin again. It is these observations that provide students with information on which to suggest hypotheses and the eventual rules that govern Tribble reproduction and growth. The grid below has 3 Tribbles placed on it. By pressing enter, students can observe the next generation.

Figure 1

Tribble Grid
From previous experimentation with the Tribble Task using college undergraduates, my advisor, Dr. Murray discoveries that many hours were required for a good problem solver to determine the rules for Tribble life cycles. Because my subjects could not devote hours to this task and because I did not want them to become frustrated, I decided that twenty minutes would be sufficient time for me to observe the kinds of strategies or heuristics they would use to approach solving the problem. This time would also be adequate for me to observe whether or not students actually followed a type of problem solving process. As data were collected, it became apparent that twenty minutes was sufficient time for me to identify the various heuristics that students used. During the twenty minute session, students could "play" with the problem. During this time I would observe and record their moves on a grid.

In addition, students would verbalize what they were doing and why they were doing it. Their verbalizations would be tape recorded. Continuous verbalization would be motivated by my questioning. After the introduction, students are presented with a grid, a graphic organizer, that allows them to place Tribbles on the screen. I simply reiterate the nebulous instructions presented on the introductory screens, but add further instruction:
"You are not expected to solve this problem because
the problem has no immediate solution. The purpose
of this exercise is for me to observe how you go
about solving a problem or playing the game of
Tribbles. As you think about the Tribble problem, I
would like you to tell me what you are thinking. In
other words, if you decide to place a Tribble on a
certain part of the grid, explain to me why you are
doing what you are doing. I want you to tell me
what you are thinking.
Although your task is to describe the rules
that govern the Tribbles' life cycles, I am more
interested in how you go about deciding what the
rules are. Thus, I would like you to speak and
think out loud as you try to solve this problem.
I want you to share your thoughts, plans, ideas,
and reasons for your actions."

Verbal protocol is used in this study because I
considered it a useful means of not only gleaning clues
about subjects' problem solving strategies but also
focusing subjects' attention on the task, forcing them to
think metacognitively about what they are doing while they
are doing it.

Occasionally, I would ask questions such as "Why did
you place the Tribble there? What do you think will happen
next? What are your reactions to the results? Was what
happened what you expected to happen? Why?" The purpose
of ancillary questioning was to elicit a verbalization of
the kind of thinking the subject was employing. Students'
transcripts are analyzed according to a rating scale in
Chapter V.
The Comrey Personality Scales

My personal observation seemed to indicate that problem solvers possessed certain personality traits that made them more capable problem solvers and better thinkers. These traits included aggression, extraversion, endurance, achievement, risk-taking, and gender. It seemed important that the personality instrument identify these traits.

After reviewing more than one dozen instruments, Dr. Murray and I first selected the Comrey Personality Scales. (See Appendix A.) The instrument seemed like a good choice for several reasons. The instrument identifies personality traits that I thought might have been related to problem solving; it also contains easy scoring; and it is inoffensive to subjects.

Because the test contains over two hundred items and requires two hours to administer, Dr. Murray and I decided to modify the scale to include the specific traits that might relate to problem solving. I realize that modifying such an instrument may affect its validity, but as this study was exploratory in nature, it was not a serious problem. After studying the Comrey, items relating to the following traits were selected: Orderliness vs. Lack of Compulsion, Social Conformity vs. Rebelliousness, Activity vs. Lack of Activity, Extraversion vs. Introversion, and Masculinity vs. Femininity.
Orderliness vs. Lack of Compulsion

Lack of Compulsion seemed to parallel most closely risk-taking. I assumed that a person who scored low in this variable would be prone to taking risks, trying new things, or perhaps not as likely to follow specific procedures or rules. Such people might be considered innovative rather than adaptive. "Individuals who are high in this factor are very concerned with neatness and orderliness. They are also cautious, meticulous, and enjoy living in a routine way. Individuals who score low in this factor tend to be sloppy, unsystematic in their lifestyle, reckless, and untidy" (Comrey 1970, p.6).

A subject who scores high in this factor may approach a problem in a very systematic way, utilize a specific type of problem solving model, and be cautious about his/her approach. On the other hand, such an individual may be "turned off" or confused about an ill-defined problem and may refuse to complete the task.

Social Conformity vs. Rebelliousness

Rebelliousness may be most similar to autonomy. A rebellious person may tend to be autonomous, preferring to do things his or her way and differently. A rebellious person also tends to be assertive which seems to be a positive factor in problem solving. Social conformists accept society the way it is--respecting the law, seeking the approval of others, and resenting nonconformity in
others. Such individuals may be considered adaptive.
Social conformists may attempt to solve problems in a
regimented, accepted way rather than trying new,
unconventional, or different approaches to the problem.
Such subjects may more rigidly follow a problem solving
process which may lead to more efficiently solving an ill-
defined problem. On the other hand, rebellious subjects
may enjoy trying unusual solutions to the problem and may
accept the ill-defined task as a task that is different
from most. These subjects may be more creative
and also might be more successful in solving problems.
Both possibilities exist. "Individuals who score low in
this trait challenge society and its rules, resent
control, and are nonconforming" (Comrey, 1970, p.6).

Activity vs. Lack of Activity

Activity seems to parallel endurance or "stick-to-
itiveness." Active individuals enjoy physical activity,
"have great energy and stamina, and strive to excel"
(Comrey, 1970, p.6). Inactive individuals tire quickly and
display no motivation and stick-to-itiveness.

An active individual would probably approach an ill-
defined problem as a challenge and show a determination to
solve the problem. Such a person may want to know the
answer even if he/she does not solve the problem. An
inactive individual would either refuse to solve the
problem or quit after a very short time.
Extraversion vs. Introversion

Although my observation revealed that an extraverted individual seems to be a more capable problem solver, some research does not support this observation. These traits were selected to test my observations. "Individuals who are high in this factor are outgoing, easy to meet, and unafraid to speak in front of large groups. An introverted individual is reserved, seclusive, and shy" (Comrey, 1970, p.7) Extraverted individuals will probably find it easy to verbalize their approaches to the problem and to tell why they are taking certain steps. These individuals may also dive right into the problem. Introverted individuals may find it difficult to verbalize their thinking. Introverted subjects may quietly dive into the problem.

Masculinity vs. Femininity

My personal observations revealed that males appeared to be better problem solvers than females; thus, it seemed logical to select this pair of traits. Some research has also indicated that females with higher masculinity traits tended to be better problem solvers on some tasks. "Individuals who score high in masculinity tend to be tough-minded and not bothered by crawling things, blood, vulgarity. Such individuals do not cry easily. Those low in this trait are bothered by insects, blood, and vulgarity. They tend to cry easily and have a high interest in romantic love" (Comrey, 1970, p.7).
The Comrey was administered to all subjects in Group A in the Spring of 1988. Students received the scales favorably. Students were given enough latitude in choosing their responses so they did not feel pressured to force a response. I actually saw children smiling as they completed the items. Some of the items are humorous. "I could live in a pigpen without letting it bother me." Some even elicit a physical response. "Having a slimy creature crawl over my leg would really bother me." Students seemed to enjoy completing the scale and seemed to respond honestly.

Using the Comrey met with rejection from committee members because it was normed on 19-22 year old students attending UCLA. As a result, it was suggested that I use a different instrument to identify personality traits. Dr. Deborah Brome of the Psychology Department at the University of Massachusetts, Harbor Campus suggested that I use the Edwards Personality Preference Schedule because it was normed on 15 year old subjects. It is important to note that of all the instruments Dr. Murray and I considered, none is normed on subjects younger than fifteen. The mean age of the students involved in this investigation is 13 years, 7 months.

The Edwards Personality Preference Schedule

The Edwards Personality Preference Schedule (EPPS)
differs from most other inventories in that it requires the subject to make a choice between two statements rather requiring a yes/no response. While other personality instruments label emotional conditions as well as clinical and psychiatric syndromes, often connoting maladjustment, the EPPS is used for counseling purposes and does not include damaging labels. Stimulus statements are generally inoffensive to students and relate to basic social values. (See Appendix B.)

Due to the length of the EPPS, the schedule was modified to measure only six of the fifteen variables usually included in the instrument: achievement, intraception, deference, autonomy, endurance, and aggression. Each was selected for its possible relevance to problem solving. A description of each variable and how it might relate to problem solving is presented below.

achievement: "to do one's best and to be successful, to accomplish tasks requiring skill and effort, to do a difficult job well, to solve difficult problems and puzzles, to do things better than others" (EPPS Manual, p.11).

It is conjectured that a person who likes to do a difficult job well, such as solving a difficult problem or puzzle, possesses the motivation to tackle an unusual or ill-defined problem and redefine it into a manageable set of tasks. As previously mentioned, research conducted by Goldsmith (1986) using Kirton's Adaptation-Innovation Inventory suggests that there is a typology of successful
problem solvers. One type is an adapter or one who would rather improve the way things are currently done. Such a problem solver is achievement and success-oriented, choosing to modify and improve already accepted and successful methods. This variable might best correspond to Orderliness vs. Lack of Compulsion and Extraversion vs. Introversion on the Cozrey.

intraception: "to analyze one's motives and feelings, to analyze the behavior of others, to predict how others will act" (EPPS Manual, p.11).

Such a personality trait may be reflected in a student's perception of how the tribbles move. If students personify the tribbles, as many did, they become involved in predicting causal relationships between a generation and its subsequent one. Although this trait was not among those originally considered in the investigation, it seemed like a logical choice that would relate to problem solving. It was my hunch that a person who scored high in this trait might be a very reflective person—one who would examine all aspects of a problem and who would make connections among observations and arrive at a conclusion or a prediction.

deference: "to find out what others think, to follow instructions and do what is expected, to conform to custom and avoid the unconventional, to let others make decisions" (EPPS Manual, p.11).

A subject who scores high in this variable may approach an ill-defined problem with reluctance or
confusion or may attack the problem as if it were a simple mathematical problem, thus following a set procedure. Thus, it is my conjecture that there would be a negative correlation between this variable and problem solving. This type of person, however, might actually succeed in a group problem solving situation. This subject may experience difficulty with the Tribble Task. The trait may best correspond to Social Conformity vs. Rebelliousness in the Comrey.

autonomy: "to be able to come and go as desired, to say what one thinks about things, to be independent of others in making decisions, to do things that are unconventional" (EPPS Manual, p.11).

An autonomous person may try to solve a problem using unusual, unconventional, or creative means. Hence they may not be likely to follow a strict problem solving process. I would conjecture that there might be a negative correlation between being high in autonomy and using a structured problem solving process. Alternatively, this subject is not afraid to take a chance and to try something different. Kirton's Inventory would consider this subject an innovator or one who prefers radical, new solutions. (Note: my Tribble Rating Scale is probably not sensitive to this type of person.) These problems solvers are risk takers, sensation seeking, and intuition-sensing. Rebelliousness in the Comrey may best correspond to this trait.
endurance: "to keep at a job until finished, to work hard at a task, to keep at puzzle or problem until it is solved, to stick at a problem even though it may seem as if no progress is made" (EPPS Manual, p.11).

Solving an ill-defined problem in which there are no immediate answers certainly requires endurance and "stick-to-itiveness." Redefining the problem and dissecting it into manageable subproblems requires serious attention and assiduousness. This factor may best correspond to Activity vs. Lack of Activity on the Comrey.

aggression: "to attack contrary points of view, to tell others what one thinks about them, to criticize others publicly" (EPPS Manual, p.11).

The variables of extraversion and assertiveness, as important traits in problem solving, have been supported by research. Kumar and Kapila (1978) and Weisman (1987) illustrated that extraverted subjects did not perform as well on problem solving tasks as introverted subjects. Chiazzi and Heimberg (1986) examined the relationship of assertiveness to social problem solving. Their research indicates that assertiveness facilitates conflict resolution and problem solving. If a person aggressively feels that he/she can handle the task, he/she will fare better at solving the problem.

A significant issue arose due to selection of this variable. Aggression assumes different postures; two significant types are physical and intellectual aggression. When aggression is discussed as a personality
trait in this study, it is an intellectual aggression. Such aggression implies that one actively tackles a difficult situation or problem—a type of intellectual assertiveness.

Since extraversion and assertiveness are not measured in the EPPS, the most appropriately related variable seemed to be aggression. Items in the EPPS that relate to aggression include "I like to attack points of view that are contrary to mine" (EPPS). It could be conjectured that an aggressive person may be assertive and tend to "take control" of the situation. Such aggression may transfer into the domain of problem solving. I admit that the connection is tenuous and interpretive, but it seemed a viable choice.

Alternatively, if aggression is seen as related to extraversion, one might predict that there would be a negative correlation between aggression and problem solving.

**Description of EPPS Instrument**

The EPPS, in its original form, presents students with 225 pairs of items that measure 15 different personality variables. The subject must choose response A or B in each pair. The entire instrument requires about two hours to administer and complete. Because of the length of the instrument and the attention span of the
subjects, the schedule was modified to include only six of the possible fifteen personality variables. These variables were previously discussed.

The modified instrument contains 90 pairs or a possible 180 items that relate to the six personality variables. These pairs reflected combinations of the five variables with each other and also with four other variables. The other four variables included affiliation, change, orderliness, and heterosexuality. In addition, some other pairs were eliminated from the instrument prior to scoring. These pairs contained item combinations that appeared inconsistently across items and included variables not pertinent to the study as part of the combination. These pairs involved the variables: dominance, exhibition, abasement, and nurturance. Thus, on the modified instrument, students could not receive higher than a raw score of 9 for each variable. Students were always asked about the same set of nine item combinations for each personality variable.

Because some combinations of variables appeared two or three times, the score for the items was averaged. For example, if paired items for aggression and autonomy appeared three times, each time the variable was chosen for that set, the choice was given one-third points. Thus, if the student chose the aggression statement in two out of the three pairs, the student was given .67 for that
set. There are a total of nine sets in all; thus the total raw score a student could receive per variable is 9.

Students used a computerized answer sheet on which to record their A or B choices. The responses were then transferred to an EPPS scoring grid. The total number of responses was totaled for each variable. Because the instrument was modified the raw score was used as a basis to calculate all statistics.

Group A students did not like taking the EPPS and voiced complaints throughout the session. What bothered students most was the notion of having to make a forced choice. Students responded, "I don’t like either of these choices!" "Do I have to answer this question?" "I don’t agree with any of these choices!" I felt that the responses in some situations, may have been dishonest because students wanted to cooperate and complete the test.

Group B students did not verbalize any complaints about the EPPS. They completed it quickly. Their reticence could have been a result of their age or grade level, or perhaps they did not feel comfortable enough with me to voice complaints. It also could be a result of not becoming involved or interactive with the items. Such lack of involvement might imply dishonesty or indifference which would certainly impact test results. If time had permitted, I would like to have administered the Comrey to
this group to see if the student-instrument interaction would have been different.

The Actual Exploration

After the subjects, the problem solving task, and the personality instrument had been selected, the following events occurred.

(1) The EPPS was administered to Groups A and B.

(2) Students were observed "playing" with the Tribble Task.

(3) Students' verbalizations about the Tribble Task were tape recorded Tribble Task.

(4) The EPPS results were analyzed, (The results of the Comrey were also analyzed.)

(5) A rating scale was developed to evaluate student performance on the Tribble Task.

(6) Links between problem solving and personality were examined.
CHAPTER V

THE PERFORMANCE OF STUDENTS ON THE TRIBBLE TASK

There were several questions that I needed to consider in developing a means of rating students' performance on the Tribble Task.

(1) What heuristics, if any, did the student exhibit in his or her approach to solving the Tribble Task?

(2) Does one type of heuristic imply more sophisticated thinking than another? If so, should it be weighted more heavily?

(3) Where does a student's performance fit into the overall thinking process of problem solving? Is the student perseverating in one stage of the process, or does he or she progress to other more cognitively demanding steps of the process? Should a higher score be given to a student who moves deeper into the problem solving process?

(4) Because of the ill-defined nature of the Tribble Task, should consideration be given to defining and redefining the problem especially to include hypotheses about position, number, symmetry, and so on?

(5) If metacognition is an important part of thinking and problem solving, how should it be rated? Does it deserve individual consideration or is it inherent in certain stages of the problem solving process or in certain heuristics?
Heuristics

An examination of subjects’ verbal protocols, results of interview observations, and Tribble grids suggest several patterns of problem solving strategies, heuristics, and thinking skills. The most obvious difference in the patterns occurs in the subject’s initial approach to solving the ill-defined problem. This initial approach varies in the heuristic method employed by each subject. The heuristics include random, trial and error, and directed trial and error. An additional heuristic, what I call a creative pattern, was also considered in developing the scale. In most cases, the subject then modifies the approach and even fluctuates among heuristics. A description of each pattern is thus presented.

Heuristic #1 -- Directed Trial and Error

Since most research compiled about problem solving heuristics is based on solving well-defined problems, using a pure means-end heuristic to describe patterns observed in solving the Tribble task seemed somewhat inaccurate. A pure means-end heuristic would involve the subject stating what he/she perceived as a definite global hypothesis about how the Tribble reproduced based on preconceived knowledge about Tribbles/reproduction and then attempting a series of steps (plan) to test the
hypothesis. Generally, a means-end heuristic is utilized in a well-defined problem situation where there is usually only one final solution. Instead, this researcher suggests that the subject is using a problem solving heuristic or strategy that is similar to a pure means-end heuristic. For lack of a better term, the observed strategy will be called directed trial and error in which the subject observes the screen, cues cognitive information relative to the Tribble problem (i.e. what is usually entailed in reproduction), develops a mini-hypothesis about placement and number, predicts what should happen, then tests the local hypothesis. This method is characterized by comments such as "I think I'll start off in the middle (because) I want to see if they'll stay the same." "I'm going to line them up across the middle (because) well, the more I have, the more they (will) reproduce." "I'm going to try different positions (because) position must be important." "The number of creatures have to be important because they have to be."

What differentiates a directed trial and error from a means-end heuristic in this situation is that students are not able to suggest a global hypothesis because they do not have enough time or in some cases enough information.

A directed trial and error approach is fairly sophisticated in light of the nebulosity of an ill-defined problem. Such an approach is highly metacognitive
in that it involves much cognitive retrieval of relevant information, and spontaneous metacognition as the subject proceeds through the experience. It should be noted that due to time constraints, subjects were not afforded the luxury of copying each grid of tribbles on paper; thus, students had to rely heavily on visual memory and accurate retrieval of information stored in working memory and possibly long term memory.

**Heuristic #2 -- Random**

In a random heuristic method, the subject approaches the problem without any preconceived notions or ideas. There is no reason for initial placement and position. This pattern is characterized by comments such as "It’s just sort of random." The random placement of number and position continues throughout the experiences without hypothesis formation or prediction making. In essence, the subject is "playing" and probably gathering information. Usually this pattern is modified to a more sophisticated heuristic as the experience continues.

**Heuristic #3 -- Trial and Error**

In this approach, the subject selects position and placement to see what will happen. This differs from a random heuristic in that a specific position may be selected because the subject wants to see what will happen ("I want to see what will happen if I place a tribble in
each corner of the grid."; in contrast, random selection is made for no reason at all. Such a pattern is characterized by comments like "Let's see what happens when I put three together." "I want to try it in a box to see what happens." A trial and error pattern differs from a directed trial and error in that there is no other apparent cognitive information entering into the decision. An example of directed trial and error is "I'll place three together in the middle because I think there must be at least three tribbles in a row to get a result!" In trial and error, the subject tries different solutions and eliminates faulty ones, but there is no specific plan of attack that the subject thinks will reduce the difference between the initial state and the goal state.

This approach is also an information gathering process, and in most cases, is modified to a different heuristic in the course of problem solving.

**Heuristic #4 -- Creative Pattern**

Several subjects were very creative in their approach to the Tribble Task. Placement and number of tribbles were motivated by unusual reasons that were not relevant to preconceived notions about the tribbles. This approach is characterized by such comments as "I chose it (the position on the grid) because it is a company that makes surfboards." "I chose this because I want to make a
design." Often this pattern would develop into another heuristic or several other heuristics.

Most subjects exhibited patterns that combined heuristic methods. One pattern incorporated an initial random approach which changed into a trial and error heuristic and then developed into a directed trial and error heuristic (#2→#3→#1).

Another pattern began as a trial and error and ended as a directed trial and error (#3→#1). It was not uncommon to observe students fluctuating among several heuristics. As a rule, the heuristic became more sophisticated. This was probably due to a wider knowledge base stemming from enhanced observations of the Tribbles. In other words, as students gathered more information about and became more familiar with the Tribbles, their thinking became more refined and involved more metareasoning. (See Table 2)
Table 2

Problem Solving Patterns: Number of Students Using Each Heuristic

<table>
<thead>
<tr>
<th>Heuristic</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 only</td>
<td>13</td>
</tr>
<tr>
<td>#2 only</td>
<td>13</td>
</tr>
<tr>
<td>Working Up to 1</td>
<td></td>
</tr>
<tr>
<td>#2-1</td>
<td>5</td>
</tr>
<tr>
<td>#2-3</td>
<td>5</td>
</tr>
<tr>
<td>#2-4-1</td>
<td>1</td>
</tr>
<tr>
<td>#4-1</td>
<td>12</td>
</tr>
<tr>
<td>No Direction</td>
<td></td>
</tr>
<tr>
<td>#2-4</td>
<td>1</td>
</tr>
<tr>
<td>#2-3</td>
<td>2</td>
</tr>
</tbody>
</table>

#1-Directed Trial and Error
#2-Random
#3-Trial and Error
#4-Creative
Developing a Rating Scale

In developing a rating scale to evaluate student performance on the Tribble Task, several aspects merited consideration. Since one focus of the exploration was to identify the types of heuristics students employed in their approach to and interaction with the Tribble Task, it was imperative that one part of the scale include point allotment for use of heuristics. Because of the nature of an ill-defined problem, the heuristic of working backwards was eliminated from the possible repertoire of heuristics. The heuristics selected for the rating system included random, trial and error, creative, and directed trial and error. Table 3 (p. 62) demonstrates and explains how points were allotted for this section of the rating system.

After much deliberation about heuristics, research about heuristics, and student performance on the Tribble Task, it seemed that utilizing a direct trial and error heuristic as the initial strategy revealed more sophistication in thinking than using an initial strategy such as random or trial and error and progressing to a directed trial and error heuristic. Thus, it seemed unfair to award a student who immediately used a directed trial and error fewer points than a student who used another strategy that developed into a directed trial and error. I feel that a directed trial and error heuristic reflects better developed problem solving skills and metacognitive
thinking. Immediately, it involves more chunking and may even presuppose a wider knowledge base. Therefore, a student who used a directed trial and error heuristic initially received 5 points, and a student who used the same heuristic but later in his or her thinking received only 3 points for that particular heuristic.

If a student utilized more than one heuristic, each heuristic was allotted the appropriate points only once, regardless of how many times the heuristic was used. Thus, a student who fluctuated between random and trial and error was given 1.5 points; while a student who fluctuated between trial and error and directed trial and error was given 4 points.

The second aspect which seemed significant was to identify the thoroughness of subjects' use of a problem solving process during their interaction with the Tribble Task. A problem solving process was delineated into five steps: (1) making observations; (2) making predictions based on those observations; (3) testing predictions by deciding and utilizing a plan of action; (4) revising predictions based on results of testing; and (5) generating an overall hypothesis as a result of tested predictions. Each step in the process was allotted one point.
Table 3
Rating System For Assessing Performance of Subjects in Problem Solving Task

Criteria for Rating

I. Problem Definition and Redefinition

A. Initial attempt to define an aspect of the problem 1 point
B. Redefinition of problem to note significance of number of tribbles 1 point
C. Redefinition of problem to note significance of position of tribbles 1 point
D. Redefinition of problem to note significance of symmetry of tribbles 1 point
E. Redefinition of problem to note another significant aspect of tribbles 1 point

TOTAL 5 POINTS

II. Use of specific heuristic (Maximum - 5 points)

A. Random Search .5 points
B. Trial and Error 1 point
C. Creative Pattern .5 points
D. Directed Trial and Error—when it is the only heuristic used 5 points
E. Directed Trial and Error—when used with another heuristic 3 points

TOTAL 5 POINTS

III. Use of Problem Solving Process (Maximum - 5 points)

A. Making observations 1 point
B. Making predictions based on observations 1 point
C. Testing predictions 1 point
D. Revising predictions based on results of tests 1 point
E. Generating a global hypothesis 1 point

TOTAL 5 POINTS

RANGE OF POSSIBLE POINTS 0 - 15 POINTS
It is important to note, however, that no one received a point for the last step of the process since no one solved the problem. Although many students would continually suggest mini-hypotheses, in essence they were actually redefining the problem into subproblems and suggesting hypotheses for solving these subproblems. No one solved the problem by stating or even approaching the global hypothesis that included the four rules that governed Tribble reproduction. Perhaps this was a bad decision. However, students were given credit for redefining the problem in a separate section of the rating system (See Section III of Table 3 on page 62).

A significant aspect of solving ill-defined problems is the subject’s ability to define and redefine the larger problem into smaller, more manageable subproblems. Such redefinition involves attention to detail, a willingness to make predictions, and an inclination to utilize flexible and versatile thinking. Thus, it was felt that a student’s ability to focus on a specific aspect of a problem and to redefine the problem should be evaluated. Points were allotted for redefinition to include symmetry, position, number, and other aspects of Tribble reproduction (See Section I of Table 3 on page 62).

In retrospect, I think this was a good decision. In reviewing the results of students’ performance it was observed that even though students may have followed a
definite problem solving process, they did not always redefine the problem to note a particular aspect. Thus, the implication is that redefinition might involve a more focused and integrative thinking.

Given these three aspects of student performance: use of heuristics, application of problem solving process, and focus on problem definition and redefinition, a rating system was developed that incorporated all three aspects. Deference to only one aspect would have detracted from the student’s overall performance on the task and might have overlooked what indeed might be good general problem solving ability.

Explanation of Rating Scale and Point Allotment

I. Problem Definition and Redefinition

A. Initial attempt to define an aspect of the problem.

1 POINT was given to a student who simply placed tribbles on the grid to gather data for making observations.

B. Redefinition of problem to note significance of number of tribbles.

1 POINT was given to a student who observed that number of tribbles was significant.

C. Redefinition of problem to note significance of position.

1 POINT was given to the student who observed that the position of the tribbles was important.
D. Redefinition of problem to note significance of symmetry.

1 POINT was given to the student who observed that there was a pattern or symmetry to the tribbles.

E. Redefinition of problem to note other significant aspect of the tribbles.

1 POINT was given to the student who observed a different but significant aspect of the tribbles i.e. disappearance of the tribbles due to the finiteness of the grid.

II. Use of specific heuristic method.

A. Random search.

Because this was a relatively unsophisticated and cognitively exhaustive heuristic method, only .5 POINTS were given to the student who utilizes this method.

B. Trial and Error.

Because this heuristic was considered slightly more sophisticated than the random search, 1 POINT was given to the student who utilized this method.

C. Creative method.

Research did not acknowledge this heuristic, but there were students who manifested a type of thinking in their problem solving that was different from the thinking of other students. A student who utilized this method was given .5 POINTS.

D. Directed Trial and Error

Although research would probably consider directed trial and error method characteristic of a novice problem solver, it reflected more sophisticated thinking and cognitive efficiency and often involved chunking. If a student utilized this strategy as his/her entire problem solving heuristic, the student was given 5 POINTS. If he/she used it in addition to another strategy, only 3 POINTS were given.
III. Use of Problem Solving Process

A. Making Observations
A student was given 1 POINT for making observations about the tribbles.

B. Making Predictions Based on Observations
A student was given 1 POINT for making predictions or a mini-hypothesis.

C. Testing Predictions
A student was given 1 POINT for testing or carrying out a plan to ascertain whether or not the prediction or mini-hypothesis was accurate.

D. Revising Predictions Based on Results of Testing
A student was given 1 POINT for revising a prediction or mini-hypothesis if observations dictated such a revision.

E. Generating a Hypothesis
A student was given 1 POINT for suggesting a global hypothesis or actual rule that governs the reproduction of the tribbles.

The total number of points a student can receive is 15.

Each of the student's tape-recorded interviews was transcribed and then evaluated according to the Rating Scale. Appendix C provides each transcript as well as an annotation. The annotation describes specifically the number of points allotted for each section of the Rating Scale and explains the details of the thinking that resulted in the rating. A total score is provided at the end of each annotation. The results of rating student performance on the Tribble Task are provided in Table 4.
Table 4

Student Performance on the Tribble Task Using the Rating Scale

<table>
<thead>
<tr>
<th>ID</th>
<th>I</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>T</th>
<th>II</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>T</th>
<th>III</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>T</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 1 1 1</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 1 1 2</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1 1 1 3</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>2.0</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.5</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.5</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1 1 1 1</td>
<td>4.0</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1 1 1 1</td>
<td>4.0</td>
<td>0.5</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1 1 1 2</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1.0</td>
<td>1</td>
<td>1</td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1 1 1 2</td>
<td>0.0</td>
<td>1.5</td>
<td>2.0</td>
<td>1</td>
<td>1</td>
<td>2.0</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>1 1 1 3</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>10.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.5</td>
<td>1</td>
<td>3</td>
<td>4.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>1 1 1 1</td>
<td>4.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>1 1 1 1</td>
<td>4.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>1 1 1 1</td>
<td>5.0</td>
<td>0.0</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I - Problem Definition and Redefinition
A- Initial attempt to define problem
B- Redefinition to note number of Tribbles
C- Redefinition to note position of Tribbles
D- Redefinition to note other aspect of Tribbles

II - Use of Specific Heuristic
A- Random Search
B- Creative Pattern
C- Directed Trial and Error (only)
D- Directed Trial and Error

III- Use of Problem Solving Process
A- Making Observations
B- Making Predictions
C- Testing Predictions
D- Revising Predictions
E- Generating a Hypothesis
Analysis of Performance on the Tribble Task

Table 4 presents the results of rating student performance using the Rating System. In terms of students' performance on Part I - Problem Definition and Redefinition, total scores ranged from 1.0 to 5.0. Since all students interacted with the problem, trying to define or at least make sense of it, they were awarded 1 point. The mean of the scores for this section was 3.86 reflecting that most students attempted to redefine the problem and suggest several mini-hypotheses for the various subproblems they identified. One must also keep in mind that these students are from a high ability group and are part of an environment where they are encouraged to focus on and redefine issues. There were students, however, who accumulated a low score on this part.

Student responses that earned points in Part I include comments like "The pattern keeps changing; they are symmetrical. The screen is missing some." Such a response would have earned a 1.0 because the problem solver was recognizing symmetry as an important feature of the problem. Some students went on to isolate and replicate the symmetry to see if only parts were replicable. Another student enthusiastically revealed his discovery of shape:

That is WILD! I think I know what they're doing! They make like some sort of shape. Grow more inside then expand; grow more
inside then expand...They grow more, then grew some inside. This time they have 20. They had 12.

Recognition of position was also allotted 1.0 point. Often this realization was accompanied by recognition of number which was also allotted 1.0 point. "It makes sense if you count each side of the pattern. The number and placement of the tribbles is very important." "The amount of tribbles must make a difference. They have to be near each other, like in a row because when they were in a box they didn't really do anything." After one student observed no changes when the tribbles were spaced apart, he commented, "Nothing happened; I need tribbles near each other." After placing only two tribbles in a vertical row, another student changed his tack and tried a random placement. After observing no results he said, "I think that the number of tribbles relates to where they are."

Part II - Use of Specific Heuristics revealed scores that ranged from 1.0 to 5.0. These scores reflected use of all four heuristics. Thirteen students employed only a directed trial and error heuristic, twelve students employed a combination of heuristics and worked their way to using a directed trial and error, and four students never employed a directed trial and error heuristic as part of their repertoire. The mean score for this part was 3.81.
In several cases students indicated that there was no reason for their procedure in response to the proctor's question: "Why did you do that?" A few students even responded "Oh, just random." For a random heuristic, students were allotted .5 points. Often a random heuristic evolved into a trial and error approach. In response to the question, "Why did you do that?" one student switched from a random approach replying, "I don't know. I really don't know. I think I'll switch to a horizontal row." Perhaps it was the question that motivated her to try more directed thinking. For the remainder of the activity she fluctuated between a random and trial and error heuristic.

It was exciting to watch students attack the problem using a directed trial and error approach. At the very beginning, one student remarked, "I'm going to line them up right across the center. ("Why?") Well, the more I have, the more they reproduce." He had a specific goal in mind and was establishing operators to help him reach that goal. Another student displayed directed trial and error thinking throughout the activity.

Okay what I am going to do with the tribbles is to make like a box and then I am going to put one in the center and see which way that one in the center tends to move overnight. And then, I can see which way it's preference would be to go...And of course these ones may do something surprising, and I can still learn something like if they were condensing or if they would expand out.
Even if he did not attain the result he was seeking, this student recognized learning as an important goal of the exercise.

Part III - Use of Problem Solving Process demonstrated a range of scores from 1.0 to 4.0 indicating that most students used a problem solving process in their thinking and applied this process to solving an ill-defined problem. The mean for this group of scores was 3.17. Upon examining student performance on this part of the task, it can be observed that students experienced some difficulty in the revision step of the process. Even students who performed well on the entire rating system seemed to have difficulty with this step. This observation might offer useful information in designing curricula to help students assimilate a problem solving process in their thinking.

All students made observations about the task. Some were more imaginative than others, however. "There must be a disease that kills them off at each generation." Others voiced observations like "Oh. I see now. They need to be together...The bigger pattern doesn’t, doesn’t really change." or "Oh my Gosh. That was weird. They just stay the same."

Students who made predictions based on observations made observable connections and voiced their ideas. "I bet it will go back to the vertical if I hit the next."
Another comment reflects a definite notion about what will happen to the tribbles. "If I keep going to the next day, the position will change, but they won't grow in number."

After separating the tribbles into a group of nine and a group of two, one student predicted, "You definitely need more than three. Where I put them makes a difference."

Those students who tested and revised their predictions based on results often moved from one step to another rather quickly. Thus, a statement that reflected testing was rapidly followed by a statement that reflected revision based on the results of the testing. By testing and revising predictions, students often came to some general understanding of the problem. "Well, if one tribble doesn't work, I'll try another." or "Because I am not getting anywhere with spacing, I'll put them together in a vertical row." One student tested, observed, and revised in a matter of seconds.

Well, when I put them in a row next to each other, they grew. Let's see (what happens if I space them out... See you need them in a row, in the middle, and a lot of them. They need room to make their patterns.

Some students demonstrated how heuristics, process, and redefinition came together in their thinking. After placing three tribbles in a vertical row and watching them move to a horizontal position several times, one student commented, "I bet it will go back to the vertical if I hit the next (generation)." Based on this information, she
changed her plan and added another tribble. Together the tribbles formed a box and continued to grow. She observed, "If I keep going, I'm going to get more and more patterns. They are symmetrical." Not only does this example reflect predicting, testing predictions, and revising predictions, it also shows how Parts I, II, and III come together to create movement toward solving the problem. She used a directed trial and error approach to attack the problem, made careful observations about the vertical and horizontal movement of three tribbles, and predicted what would happen next. After more observation, she revised her predictions, tested them, and arrived at the understanding that symmetry was an important characteristic of tribble reproduction. This is a lovely example of how heuristics, problem solving process, and redefinition come together via metacognition to create a better understanding of a problem situation.

In comparing the three parts of the Rating System for total scores, significant correlations occurred using the Spearman Rank Order Correlation Coefficient. For a sample size of 27 and using an alpha of .05, correlations for all three comparisons would be significant with an $r$ of .323. (For significance values, see Table 5.) The $r$ for Use of Specific Heuristic and Problem Definition and Redefinition was .55. The $r$ for Use of Specific Heuristic and Use of Problem Solving Process was .56. The $r$ for Problem
Definition and Redefinition and Use of Problem Solving Process was .73. Such correlations indicate a strong relationship between type of heuristic and problem redefinition and use of a problem solving process. As the heuristic became more sophisticated, the scores for redefinition and use of a problem solving process increased.

Although it was not my intent to compare Group A (#1-16) and Group B (#17-29), close observation of the data suggested differences between the two groups. Group A scored consistently above the total mean in all three parts, while Group B scored consistently below the total mean in all three parts (See Table 6).

Table 5
A Comparison of Means for Group A and Group B

<table>
<thead>
<tr>
<th></th>
<th>Heuristics</th>
<th>Redefinition</th>
<th>Problem Solving Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>4.16</td>
<td>4.00</td>
<td>3.80</td>
</tr>
<tr>
<td>Group B</td>
<td>3.38</td>
<td>3.69</td>
<td>3.38</td>
</tr>
<tr>
<td>Group A and B</td>
<td>3.77</td>
<td>3.85</td>
<td>3.17</td>
</tr>
<tr>
<td>Total Mean</td>
<td>3.77</td>
<td>3.85</td>
<td>3.17</td>
</tr>
</tbody>
</table>

There are several reasons why Group A might have outperformed Group B. First of all, most of these students possessed enthusiastic attitudes and attacked the problem with finesse. They appeared to enjoy what they were doing as if it were some type of game. Most of these students
were also interested in the final answer, implying that they took the task seriously. Group B, on the other hand, tended to be very serious with the exception of a few of the males in the group. Students in Group B were more than one year older than students in Group A and did not exhibit the enthusiasm that the other students did. This could be a function of age and attitude. These students cooperated as part of a daily routine; they were not interested in results and for the most part, did not approach the task as a fun activity. While all Group B students were pleasant and smiling, they did not exhibit the enthusiasm Group A students did. One conclusion might be that attitude is very important in problem solving.

Eighth grade students are generally more reserved and are attempting to be more sophisticated. It should also be noted that the better problem solvers from Group B were the younger, less mature students. I think that the difference may be important to examine in a systematic study. Having taught middle school, there has always seemed a distinct behavioral difference between sixth graders and eighth graders. In most schools, sixth graders are still retained in a nondepartmentalized educational setting, while eighth grade students change teachers for content area subjects. Sixth graders seemed more lively, energetic, task oriented, and spontaneous. They were not
afraid to try new things, were generally eager to please and very friendly.

On the other hand, eighth graders were more serious, more social among peers, more reserved from adults, and not as spontaneous. One might think that because of their age, their problem solving skills would be more honed. Yet the same phenomenon is observed in many adults who are habituated in certain types of thinking and not receptive to new ideas and new avenues of exploration. It would be beneficial if children could always stay spontaneous and enthusiastic throughout the learning years.

Another observation that is rendered by the data is the importance of being able to integrate heuristics, to redefine a global problem into subproblems and to use a problem solving process in trying to solve an ill-defined problem. It might be concluded that facility in integrating all three parts demonstrates metacognition. The ability to gather data through the use of a heuristic, follow a problem solving process, ruminate about the observations, and continually redefine the problem shows how a student might be thinking about his/her own thinking. While many students might have performed well on individual parts, it was only those students who could "put it all together" who did well on the Tribble Task.
I had originally hypothesized that males would be better problem solvers than females. Generally, males outperformed females on the problem solving task. Out of 29 subjects, the mean Tribble Score for males was 11.74 and 9.67 for females. The mean for the entire sample was 10.88. The actual distribution of scores showed a negatively skewed curve for males with the mode at 14.0 as well as a less negatively skewed curve for females with a mode of 11.0. However, the difference was not statistically significant (using a Mann-Whitney U-test).
CHAPTER VI
LINKS BETWEEN PROBLEM SOLVING AND PERSONALITY

General Observations

In comparing specific personality traits and solving the Tribble Task, only a few statistically significant correlations occurred. These correlations were performed using the Spearmann Rank Order Correlation Coefficient. Raw scores of personality variables and the Tribble Task are found in Table 7 and the correlations are presented in Table 8. There were three variables where correlations occurred: autonomy, aggression, and deference. In the areas where correlations occurred, significant differences were noted between males and females.
<table>
<thead>
<tr>
<th>ID</th>
<th>G</th>
<th>Ac</th>
<th>De</th>
<th>Au</th>
<th>In</th>
<th>En</th>
<th>Ag</th>
<th>Tribbles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>7.50</td>
<td>1.83</td>
<td>2.50</td>
<td>3.33</td>
<td>5.17</td>
<td>2.50</td>
<td>14.0</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>4.50</td>
<td>2.00</td>
<td>5.50</td>
<td>7.00</td>
<td>4.17</td>
<td>3.33</td>
<td>13.0</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>4.00</td>
<td>2.50</td>
<td>3.67</td>
<td>6.83</td>
<td>6.67</td>
<td>2.00</td>
<td>9.0</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>5.33</td>
<td>2.00</td>
<td>6.50</td>
<td>4.00</td>
<td>1.50</td>
<td>1.50</td>
<td>8.0</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>1.50</td>
<td>2.33</td>
<td>3.83</td>
<td>5.00</td>
<td>4.00</td>
<td>3.50</td>
<td>9.0</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>4.67</td>
<td>1.67</td>
<td>4.17</td>
<td>2.17</td>
<td>6.50</td>
<td>3.83</td>
<td>14.0</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>not available</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>5.67</td>
<td>4.00</td>
<td>3.67</td>
<td>5.83</td>
<td>4.50</td>
<td>5.67</td>
<td>14.0</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>2.00</td>
<td>4.50</td>
<td>3.67</td>
<td>7.67</td>
<td>7.00</td>
<td>3.00</td>
<td>11.0</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>8.67</td>
<td>1.83</td>
<td>7.00</td>
<td>2.17</td>
<td>5.33</td>
<td>5.17</td>
<td>12.5</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>5.50</td>
<td>3.50</td>
<td>2.50</td>
<td>3.17</td>
<td>6.17</td>
<td>7.33</td>
<td>13.0</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>8.50</td>
<td>2.83</td>
<td>2.50</td>
<td>3.33</td>
<td>5.17</td>
<td>2.50</td>
<td>14.0</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>4.50</td>
<td>4.17</td>
<td>3.67</td>
<td>7.00</td>
<td>5.17</td>
<td>3.83</td>
<td>12.5</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>not available</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.0</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>7.17</td>
<td>3.67</td>
<td>6.00</td>
<td>5.00</td>
<td>1.33</td>
<td>5.33</td>
<td>12.0</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>4.33</td>
<td>5.17</td>
<td>3.50</td>
<td>1.83</td>
<td>3.83</td>
<td>4.00</td>
<td>12.5</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>2.33</td>
<td>4.00</td>
<td>5.50</td>
<td>3.17</td>
<td>2.67</td>
<td>4.50</td>
<td>4.0</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>5.50</td>
<td>4.17</td>
<td>3.50</td>
<td>5.00</td>
<td>6.67</td>
<td>2.83</td>
<td>6.0</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>5.50</td>
<td>.33</td>
<td>8.00</td>
<td>3.67</td>
<td>2.67</td>
<td>7.83</td>
<td>10.5</td>
</tr>
<tr>
<td>20</td>
<td>F</td>
<td>3.83</td>
<td>1.67</td>
<td>6.67</td>
<td>4.50</td>
<td>2.83</td>
<td>4.33</td>
<td>12.5</td>
</tr>
<tr>
<td>21</td>
<td>M</td>
<td>3.33</td>
<td>3.00</td>
<td>5.50</td>
<td>6.50</td>
<td>2.83</td>
<td>3.33</td>
<td>14.0</td>
</tr>
<tr>
<td>22</td>
<td>M</td>
<td>4.83</td>
<td>2.67</td>
<td>6.67</td>
<td>6.00</td>
<td>1.33</td>
<td>4.50</td>
<td>2.5</td>
</tr>
<tr>
<td>23</td>
<td>M</td>
<td>6.50</td>
<td>4.33</td>
<td>5.83</td>
<td>2.33</td>
<td>3.33</td>
<td>4.83</td>
<td>2.5</td>
</tr>
<tr>
<td>24</td>
<td>F</td>
<td>5.00</td>
<td>2.33</td>
<td>4.00</td>
<td>3.00</td>
<td>1.33</td>
<td>5.17</td>
<td>10.5</td>
</tr>
<tr>
<td>25</td>
<td>M</td>
<td>5.23</td>
<td>2.00</td>
<td>6.33</td>
<td>4.00</td>
<td>1.00</td>
<td>4.83</td>
<td>14.0</td>
</tr>
<tr>
<td>26</td>
<td>M</td>
<td>2.17</td>
<td>2.83</td>
<td>5.83</td>
<td>4.50</td>
<td>5.33</td>
<td>2.67</td>
<td>14.0</td>
</tr>
<tr>
<td>27</td>
<td>M</td>
<td>8.00</td>
<td>3.33</td>
<td>3.83</td>
<td>3.50</td>
<td>1.83</td>
<td>3.17</td>
<td>12.5</td>
</tr>
<tr>
<td>28</td>
<td>F</td>
<td>7.67</td>
<td>2.67</td>
<td>7.00</td>
<td>5.00</td>
<td>.83</td>
<td>3.83</td>
<td>7.0</td>
</tr>
<tr>
<td>29</td>
<td>M</td>
<td>7.33</td>
<td>3.50</td>
<td>7.00</td>
<td>5.67</td>
<td>2.67</td>
<td>7.83</td>
<td>11.0</td>
</tr>
</tbody>
</table>

G - Gender  
Ac - Achievement  
De - Deference  
Au - Autonomy  
In - Intraception  
En - Endurance  
Ag - Aggression
Table 7

Correlations Between Personality Variables and The Tribble Problem Solving Task for Males and Females

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males</th>
<th>Females</th>
<th>Total Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=16</td>
<td>n=11</td>
<td>n=27</td>
</tr>
<tr>
<td>achievement</td>
<td>-.04</td>
<td>-.14</td>
<td>.03</td>
</tr>
<tr>
<td>deference</td>
<td>-.42*</td>
<td>-.21</td>
<td>-.20</td>
</tr>
<tr>
<td>autonomy</td>
<td>-.45*</td>
<td>-.17</td>
<td>-.31*</td>
</tr>
<tr>
<td>intraception</td>
<td>.18</td>
<td>-.29</td>
<td>-.10</td>
</tr>
<tr>
<td>endurance</td>
<td>.32</td>
<td>.19</td>
<td>.23</td>
</tr>
<tr>
<td>aggression</td>
<td>-.61**</td>
<td>.47*</td>
<td>-.10</td>
</tr>
</tbody>
</table>

* significant at .05
** significant at .01

Although two possible relationships between autonomy and problem solving were discussed earlier in the study, no hypotheses were generated. Data for males do reflect that autonomous subjects did not perform well on the ill-defined task. This might be because such a person might not care to follow a problem solving process. Such a person might in fact find the entire task unengaging and perhaps too controlling. For males there was a negative correlation of -.45 and a negative correlation of -.17 for females between the results of the Tribble Task and autonomy. For a sample of 16 an r of -.45 is significant at the .05 level. It appears that less autonomous males scored higher on the problem solving task than autonomous males. Although the correlation was also negative for
females (-.17), it was not statistically significant. Overall, the correlation for both groups was significant (-.31) at the .05 level. Therefore, it is possible that the same basic pattern occurs in males and females and would be revealed for females with a larger sample of subjects. Alternatively, the effect may only hold for males.

Aggression

There was also a significant relationship between the variable of aggression and performance on the problem solving task for both males and females. The results, however, do not wholly support my initial hypothesis. I had originally hypothesized that there would be a positive correlation between aggression and problem solving for both males and females. For males, a negative correlation of -.61 existed between aggression and performance on the Tribble Task and a correlation of .47 for females. This correlation for a sample of 16 and an alpha of .05 is significant with an r of .4. The less aggressive males performed better on the problem solving task than the more aggressive males. In contrast, females demonstrated an almost significant positive correlation of .47 for the relationship between aggression and problem solving. With a sample of 12 and an alpha of .05, this correlation would be significant with an r of .5. Although not statistically
significant, the relationship seemed noteworthy because it showed difference in patterns between males and females. More aggressive females tended to perform better on the Tribble Task than less aggressive females. Several interpretations of these results are possible. Perhaps these students possess non-sex typed, open patterns of behavior; thus, they would not fit in to the stereotypic behaviors usually reflected by gender. Another possibility is that the students in this sample are moving toward an optimal level of aggression; females are becoming more assertive and males less. It is also possible that these items may not actually be measuring aggression for males.

Having had the opportunity to observe more than half of the males in the sample for an average period of two years, it is also my feeling that the instrument choice for this variable may not have been appropriate. Most the males in this sample were quite intellectually aggressive in the classroom situation, and in some cases, physically aggressive. These students would immediately assume leadership positions, voice how they would like things to be done, freely disagree with others, and challenge peers to a debate. Transcripts of males who scored high on the Tribble Task show them immediately delving into the task and verbalizing a direction. Initial comments included "The number of creatures has to be important...They have
to be." "There must a disease that kills them off at each generation." "My theory is untrue." "I'm going to try different positions. Position must be important. It must be or I wouldn't have this big screen to work with." "I think I'll start off with four in the middle." "Oh my gosh!...Maybe they will not multiply in a closed in space." At least four of the highest scoring males wanted to know the answer and were disappointed when they discovered that I did not know the answer. This seemed strange to them. No females asked what the answer was.

To gather more insight into the differences, I compared the individual aggression item responses of five top male scores (14.0) and the two top female scores (14.0) on the Tribble Task. The results were fascinating. A few of the items on which the males responded nonaggressively were items on which the females responded aggressively. Ex. To items such as "I like to attack points of view that are contrary to mine," all but one male responded in favor of the second choice "I like my friends to confide in me and tell me their troubles." The top female scorers responded in favor of the first choice. To the item "I feel like telling people off when I disagree with them," males responded in favor of the second choice "I like to participate in new fads and fashions." Females responded oppositely. To the item "I feel like criticizing someone publicly if he or she
deserves it," all males except one chose the second choice, "I like my friends to make a fuss over me when I am hurt." Both females chose the first item in the pair. Both males (except one) and females responded similarly to the item "I get so angry that I feel like throwing things" by choosing the second response in the pair, "I like to tell others how to do their jobs."

These differences need to be examined further. It almost appears that perhaps the feminist movement has encouraged females to be assertive and aggressive and males to be less assertive and aggressive. Perhaps a comfortable medium will be eventually reached by both genders.

**Reference**

There was a statistically significant negative correlation $-0.42$ between deference and problem solving for males and $-0.21$ for females. For males this correlation is significant at $0.05$ for a sample of 16 and an alpha of $0.05$; the correlation for females is not significant. The result for males had been consistent with my original hypotheses. However, I would also have expected a similar relationship for females. Perhaps such a relationship would have been found with a larger sample size. The negative correlation of $-0.21$ between deference and the problem solving task for females does raise some
interesting questions. Deference involves the notion of caring, respect, and concern for others. According to Gilligan (1982), it is usually a trait reflective of females. In this investigation, females scored relatively low on this variable. Perhaps this too reflects a trend for females. Upon considering the traits of aggression and deference, it seems that the least sex-typed student performed better on the problem solving task.

**Other Variables**

There were no statistically significant correlations for the variables of intraception, endurance, and achievement. See Table 8. For the variable of achievement there was not even a hint of a relationship. In contrast, there were low to moderate positive correlations between endurance and problem solving for both males and females. Perhaps with a larger sample size, a significant relation between this variable and problem solving would be revealed.
Table 8
Patterns of Heuristics, Gender, Tribble Scores, EPPS and
Comrey Personality Variable Raw Scores

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>14.0</td>
<td>7.50</td>
<td>1.83</td>
<td>2.50</td>
<td>3.33</td>
<td>5.17</td>
<td>2.50</td>
<td>3.63</td>
<td>4.00</td>
<td>4.47</td>
<td>3.79</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>14.0</td>
<td>8.50</td>
<td>2.83</td>
<td>3.87</td>
<td>3.17</td>
<td>3.83</td>
<td>7.17</td>
<td>3.42</td>
<td>4.00</td>
<td>4.00</td>
<td>3.42</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>14.0</td>
<td>2.17</td>
<td>2.83</td>
<td>5.83</td>
<td>4.50</td>
<td>5.33</td>
<td>2.67</td>
<td>2.11</td>
<td>3.00</td>
<td>3.47</td>
<td>3.42</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>14.0</td>
<td>4.67</td>
<td>1.67</td>
<td>4.17</td>
<td>2.17</td>
<td>6.50</td>
<td>3.83</td>
<td>3.53</td>
<td>4.00</td>
<td>3.00</td>
<td>2.26</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>14.0</td>
<td>5.67</td>
<td>4.00</td>
<td>3.67</td>
<td>5.83</td>
<td>4.50</td>
<td>5.67</td>
<td>3.12</td>
<td>3.00</td>
<td>3.63</td>
<td>3.16</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>13.0</td>
<td>5.50</td>
<td>3.50</td>
<td>2.50</td>
<td>3.17</td>
<td>6.17</td>
<td>7.33</td>
<td>3.26</td>
<td>3.00</td>
<td>3.58</td>
<td>3.78</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>13.0</td>
<td>4.00</td>
<td>2.50</td>
<td>3.67</td>
<td>6.83</td>
<td>6.67</td>
<td>2.00</td>
<td>3.05</td>
<td>4.00</td>
<td>3.79</td>
<td>3.95</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>12.5</td>
<td>8.67</td>
<td>1.83</td>
<td>7.00</td>
<td>2.17</td>
<td>5.33</td>
<td>5.17</td>
<td>3.00</td>
<td>4.00</td>
<td>3.17</td>
<td>3.11</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>12.5</td>
<td>4.50</td>
<td>4.17</td>
<td>3.67</td>
<td>7.00</td>
<td>5.17</td>
<td>3.83</td>
<td>3.00</td>
<td>4.00</td>
<td>5.88</td>
<td>3.12</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>12.5</td>
<td>4.33</td>
<td>5.17</td>
<td>3.50</td>
<td>1.83</td>
<td>3.83</td>
<td>4.00</td>
<td>3.68</td>
<td>4.00</td>
<td>3.37</td>
<td>2.74</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>12.5</td>
<td>4.83</td>
<td>2.67</td>
<td>6.67</td>
<td>6.00</td>
<td>1.33</td>
<td>4.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>12.5</td>
<td>8.00</td>
<td>3.33</td>
<td>3.83</td>
<td>3.50</td>
<td>1.83</td>
<td>3.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>12.5</td>
<td>3.83</td>
<td>1.67</td>
<td>6.67</td>
<td>4.50</td>
<td>2.83</td>
<td>4.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>12.0</td>
<td>7.17</td>
<td>3.67</td>
<td>6.00</td>
<td>5.00</td>
<td>1.33</td>
<td>5.33</td>
<td>3.58</td>
<td>3.00</td>
<td>3.21</td>
<td>3.37</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>11.5</td>
<td>5.00</td>
<td>2.33</td>
<td>4.00</td>
<td>3.00</td>
<td>1.33</td>
<td>5.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>11.0</td>
<td>7.33</td>
<td>3.50</td>
<td>7.00</td>
<td>5.67</td>
<td>1.17</td>
<td>4.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>F</td>
<td>11.0</td>
<td>1.50</td>
<td>2.33</td>
<td>3.83</td>
<td>5.00</td>
<td>4.00</td>
<td>3.50</td>
<td>3.42</td>
<td>3.00</td>
<td>3.53</td>
<td>3.53</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>9.0</td>
<td>2.00</td>
<td>4.50</td>
<td>3.67</td>
<td>7.67</td>
<td>7.00</td>
<td>3.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>10.5</td>
<td>5.50</td>
<td>3.33</td>
<td>8.00</td>
<td>3.67</td>
<td>2.67</td>
<td>7.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>F</td>
<td>4.0</td>
<td>9.0</td>
<td>5.33</td>
<td>2.00</td>
<td>6.50</td>
<td>4.00</td>
<td>1.50</td>
<td>2.53</td>
<td>3.00</td>
<td>3.53</td>
<td>3.53</td>
</tr>
<tr>
<td>21</td>
<td>F</td>
<td>7.0</td>
<td>7.67</td>
<td>2.67</td>
<td>7.00</td>
<td>5.00</td>
<td>.83</td>
<td>3.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>F</td>
<td>6.5</td>
<td>unavailable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>F</td>
<td>6.0</td>
<td>5.00</td>
<td>4.17</td>
<td>3.50</td>
<td>5.00</td>
<td>6.67</td>
<td>2.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>F</td>
<td>4.0</td>
<td>2.33</td>
<td>4.00</td>
<td>5.50</td>
<td>3.17</td>
<td>2.67</td>
<td>4.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>F</td>
<td>2.5</td>
<td>6.50</td>
<td>4.33</td>
<td>5.83</td>
<td>2.33</td>
<td>3.33</td>
<td>4.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>F</td>
<td>4.50</td>
<td>2.50</td>
<td>5.00</td>
<td>7.00</td>
<td>1.71</td>
<td>3.33</td>
<td>3.79</td>
<td>4.00</td>
<td>3.79</td>
<td>3.95</td>
<td>3.42</td>
</tr>
</tbody>
</table>

*Heuristic patterns in the P column are not hyphenated.

<table>
<thead>
<tr>
<th>Ac-Achievement</th>
<th>In-Intraception</th>
<th>O-Orderliness</th>
<th>E-Extraversion</th>
<th>De-Deference</th>
<th>En-Endurance</th>
<th>C-Conformity</th>
<th>M-Masculinity</th>
<th>Au-Autonomy</th>
<th>Ag-Aggression</th>
<th>A-Activity</th>
<th>Trib-Tribble Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Scores</td>
<td>Male</td>
<td>Female</td>
<td>Mean Scores</td>
<td>Male</td>
<td>Female</td>
<td>Orderliness</td>
<td>Conformity</td>
<td>Activity</td>
<td>Extraversion</td>
<td>Masculinity</td>
<td></td>
</tr>
<tr>
<td>EPPS</td>
<td></td>
<td></td>
<td>Comrey</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement</td>
<td>5.71</td>
<td>4.51</td>
<td>3.22</td>
<td>3.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defence</td>
<td>3.06</td>
<td>2.71</td>
<td>3.44</td>
<td>3.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomy</td>
<td>6.14</td>
<td>4.74</td>
<td>3.55</td>
<td>3.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraception</td>
<td>4.07</td>
<td>5.09</td>
<td>3.46</td>
<td>3.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endurance</td>
<td>3.79</td>
<td>4.23</td>
<td>3.46</td>
<td>3.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggression</td>
<td>4.63</td>
<td>3.54</td>
<td>3.22</td>
<td>2.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER VII
CONCLUSIONS AND RECOMMENDATIONS

General Conclusions

The Tribble Test, results of verbal protocol, personality variable raw scores, and my observation of interviews suggest interesting information about the methods used in solving ill-defined problems and the types of personality traits that might relate to problem solving. In addition, some of the data support the suggestion that there are differences between male and female problem solvers.

First of all, students do utilize various problem solving strategies to work on ill-defined problems that are similar to those used to solve well-defined problems. These heuristics are diverse and range from random to directed trial and error. Most subjects who scored high overall in the Tribbles Task employed a Directed Trial and Error heuristic. Although not the most sophisticated of heuristics, it involves planning and taking steps to reduce the distance between initial and goal states of a problem and metareasoning skills. Eventually, these students want to solve the problem in the most expedient, successful way available to them. As Anderson (1990) suggests, problem solvers work to reduce the space between the initial states and the goal states.
In their verbal protocols most of these subjects demonstrated metareasoning skills by continually evaluating and reevaluating their steps and results, as well as those other critical and creative thinking skills involved in good problem solving. These students were very adept in utilizing the thinking skills of observation, comparison/contrast, prediction, identifying cause and effect, suggesting hypotheses, testing hypotheses, evaluating hypotheses, and revising hypotheses.

Most students utilized critical and creative thinking skills in a type of problem solving process: observing and gathering data, comparing and contrasting data, suggesting mini-hypotheses, making predictions and testing hypotheses, evaluating hypotheses, accepting established hypotheses or suggesting new ones. Some students appeared to be more capable than others at attacking the problem and arriving at some local hypotheses about the tribbles.

Analysis of the three parts of the Tribble Rating Scale shows that types of heuristics used, adherence to a problem solving process, and suggesting mini-hypotheses are significantly related. The most significant correlation occurs between following some type of problem solving process and the number of redefinitions of the problem in a short time. In working on ill-defined problems, students used one or several heuristics that help them gather information and set mini-goals for
themselves. These heuristics guide their thinking. Heuristics are not enough, however. Once information has been gathered it must be organized into predictions which can be tested and revised. This problem solving process is flexible and dynamic. Although there seems to be a very "basic" order to the skills, the problem solver constantly moves one or several steps forwards and backwards until a prediction is made. If predictions bear out under testing, a hypothesis is often suggested or at least some type of specific understanding of the problem is acquired.

Statistical analyses of the EPPS did reveal data that support significant differences between males and females for the variable of aggression. Aggression was significantly negatively correlated to success at solving the Tribble Task for males and positively correlated for females. This may reflect a trend for females to become more aggressive (like stereotyped males) and for males to become less aggressive (like stereotyped females). Questions about whether or not the instrument is measuring intellectual aggression remain unanswered, however. There was the suggestion that the type of aggression the EPPS is measuring may differ, however, for males and females.

The less autonomous males scored high on the Tribble Task. Although not significant, females who scored high on the Tribble Task were also less autonomous. These data seem to confirm this researcher's suggestion that less
autonomous students would be more likely to follow a process more rigidly and therefore score higher on a problem solving task.

For males there was a significant negative correlation between deference and the problem solving task. This was somewhat expected in that stereotyped males do not usually make decisions with respect to principles of caring but function more out of a sense of utility. Although not statistically significant, the correlation for females for the relationship between deference and problem solving was also negative. Again, this may reflect a trend in females to assume a less deferent perspective in behavior.

The data in this exploratory study thus indicate that there might be significant relations between personality and problem solving. However, more attention to how to specify and possibly to differentiate sex patterns is needed.

Suggestions for Further Research

My findings combined with the limitations of this exploration suggest that further research should address several concerns. These concerns include better assessment or identification of personality variables, an improved or modified rating scale, and variation of the type of problems used in the study.
Assessing Personality Variables

First of all, an improved modified EPPS or Comrey or other personality inventory which focuses on similar or other variables such as adaptability, innovativeness, and so on, should be employed. Because the Comrey was not utilized with the entire sample, statistical information was not gathered. Although the Comrey is not normed on adolescents, it still presents as a useful instrument for measuring personality variables that may influence problem solving. Students, especially in Group A, criticized the forced choice aspect of EPPS as well as the content of the items. Their reactions to the test may have effected their responses.

A new inventory could be developed that utilizes the best of all instruments and that is more suitable to young adolescents. In item construction, careful attention would need to be paid to selecting items that truly reflect intellectual aggression instead of physical aggression.

Another observation revealed by the data suggests that problem solving be investigated for different age groups. On all parts of the problem solving task, students in Group A scored higher than students in Group B. Statistical analyses might have yielded significant results about differences between groups and differences in personality variables. Transcripts of students in Group A as well as transcripts of the younger students in Group
receptivity to the task. Most of these students regarded the task as a challenge that was fun. Such information might suggest that students around the age of twelve are still receptive to new kinds of educational activities and might benefit from a creative or unique curriculum in problem solving. At this age, students might still be a captive audience.

A Modified Rating Scale

In rating the performance of students, several modifications might be in order. One consideration is that students be allowed to continue the Tribble task until they wish to stop. The entire session could be tape recorded and each grid would be printed out via computer. This would provide richer data about heuristics and metareasoning skills. Students could then study their printouts.

In a recent unpublished study, Dr. Murray tape recorded students who verbalized what they were doing while trying to solve the Tribble Task. These students were selected because of their ability to articulate clearly what they were thinking. These students were then allowed to take their printouts home for study. After studying the printout, one student returned the next day and proceeded to solve the task within a short time. It seems that the student truly benefitted from an "incubation" period or time to think about what he had
done, make sense of the data that had been gathered, and perhaps recognize patterns that emerged from the data. We don’t know from the present study whether or not students who scored high on the Tribble Task would be more likely to solve the problem.

Although not incorporated in this study, Anderson (1990) suggests analogy as a type of heuristic used by students to solve problems. It might be worthwhile to add analogy to the rating scale. Perhaps through questioning, students could be encouraged to develop an analogy that might help them solve the Tribble Task. Only one student in this investigation incorporated analogy in his problem solving protocol. He attributed human characteristics and events to the tribbles: birth, room to move, growth, death, skipping generations, and offspring. He was very concerned about his inability to help the dying tribbles. This particular student was from Cambodia. While the issue of tribble reproduction suggests this analogy, it seems that the analogy may also be related to culture.

Another consideration is whether or not the rating of each student is reliable. The Tribble Task could be rated by an additional two raters using the Rating Scale, thus providing inter-rater reliability and improved validity of scores.
Variation of the Problem

Another recommendation might be to present the Tribble Task in different terms or in a different mode or to present a very different ill-defined problem. One criticism of this study is that the problem may have been uninteresting or dull to some students. As previously mentioned, only two students in the study (one male and one female) chose only to participate for a few minutes. All others enjoyed the problem and seemed to have fun.

There are also improvements that might enhance the validity of the findings with respect to each subject's problem solving ability. Subjects could be administered several types of problems to offer a more representative reflection of each subject's problem solving ability and to observe differences and similarities in a subject's ability to solve ill- and well-defined problems. These problems could include a moral dilemma that represents a truly ill-defined problem. Another problem could present a modified Tribble Task problem that is not totally ill-defined yet not clearly defined. The third problem could include a verbal or mathematical problem that has a definite correct answer that can be reached in a short period of time.

Recent literature discusses the Nintendo video game "Tetris" and depicts it as the most psychologically challenging video game developed. Created by a Soviet
software engineer, the game capitalizes on the player’s strategic, problem solving, and metareasoning skills. Its creator further contends that a player’s success draws directly from his or her personality. Perhaps using this type of video game as the ill-defined problem solving task would be valuable in discovering relationships between personality and problem solving (Ferrell, 1990).

**In Summary**

Data gathered from this exploration suggest that there is a significant relationship among heuristics, problem solving process, and suggestion of hypotheses. Furthermore, there might be relationships between personality variables and ill-defined problem solving although the patterns may be more complex than I originally assumed with interaction among age, gender, and even the problem solving situation. A more carefully designed and fine-tuned study may further explore these relationships and interactions and reveal useful information about personality and problem solving.

**Epilogue**

James does not let his friends down. He sharpens his senses and surveys the situation, taking into account the talents and skills of his creature-friends. With convincing tact and genuine sensitivity, he persuades his
friends to work as a team. Sweetly, he persuades the Earthworm to entice the seagulls toward the top of the peach. As the seagulls dive for the juicy morsel, James lassos each bird with silk thread spun by Miss Spider and the Silkworm, while the others pull the Earthworm to safety. This team effort is repeated five hundred and two times until five hundred and two seagulls gently soar into the clouds, lifting and freeing the golden peach and its inhabitants from their captors. Quietly tenacious and eager to please, James has proven to be a good thinker and a successful problem solver. For the time being, he has made the world a safer and better place for himself and his new friends.


APPENDIX A

MODIFIED COMREY PERSONALITY SCALES

1. You will read a series of statements. Respond to each statement by darkening in the letter on your answer sheet that best reflects how you feel.

   A = Never or Definitely Not
   B = Rarely or Probably Not
   C = Occasionally or Possibly
   D = Frequently or Probably
   E = Always or Definitely

Sample: The average person is honest.

1. I could live in a pig pen without letting it bother me.
2. This society provides too much protection for criminals.
3. If I think about exercising, I lie down until the idea goes away.
4. I am a very talkative person.
5. Big bugs and other crawling creatures upset me.
6. I am a cautious person.
7. If the laws of society are unjust, they should be disobeyed.
8. I love to work long hours.
9. I find it difficult to talk with a person I have just met.
10. I could assist in a surgical operation without fainting if I had to.
11. Living according to a schedule is something I like to avoid.
12. The laws governing the people of this country are sound and need only minor changes, if any.
13. I seem to lack the drive necessary to get things done.
14. At a party I like to meet as many people as I can.
15. A sad movie makes me feel like crying.
16. I will go to great lengths to correct mistakes in my work which other people wouldn't even notice.
17. I ignore what my neighbors might think of me.
18. I can work a long time without feeling tired.
19. It would be hard for me to do anything in front of an audience.
20. I can tolerate vulgarity.
21. My room is a mess.
22. Young people should be more willing than they are to do what their elders tell them to do.
23. Being a big success in life requires more effort that I am willing to make.
24. It is easy for me to talk with people.
25. I like motives which tell the story of two people in love.
26. If I come into a house where everything is in disorder, I get a very negative reaction.
27. People who break the law while protesting bad social conditions should get off without punishment.
28. I enjoy doing things that involve quite a bit of exercise.
29. In a group of people I keep quiet.
30. I could pick up a non-poisonous snake with bare hands without being afraid.
31. I enjoy taking chances.
32. If a law is bad you should obey it and try to get it changed rather than to disobey it.
33. Hard work is an activity which I like to avoid if possible.
34. I find it easy to start a conversation with a stranger.
35. Seeing a lot of blood would make me feel faint.
36. I like to maintain a regular schedule of activities.
37. I am critical of the way our present society is organized.
38. I seem to have lots of vim and vigor.
39. I try to avoid contacts with new people.
40. It would be hard to make me cry.
41. If I get the most important part of a job done right, I forget about the little details.
42. It is important for me to be accepted in my community.
43. I need to allow a lot of time to stop and rest.
44. It would be easy for me to make a speech.
45. Some jokes are so crude and disgusting that they almost make me ill.
46. I keep everything in its proper place so I know just where to find it.
47. High school boys should be allowed to wear their hair long and shaggy if they want to.
48. I am willing to work very hard to get ahead of the next fellow.
49. After being introduced to someone, I have difficulty thinking of something to say.
50. A book about love and romance would bore me.
51. I feel more relaxed and comfortable around people who aren't always worried about things being neat and tidy.
52. Law enforcement agencies should have greater powers than they do now to put law breakers behind bars and keep them there.
53. I hate vigorous physical activities that get me all sweaty.
54. I love to talk.
55. Having a slimy creature crawl over my leg would really bother me.
56. I like to play it safe.
57. If I can get away with it, I will break any law that I think is bad.
58. I like to work hard.
59. At a party, I find it hard to mix with people I do not know.
60. I could and would drink blood if I were thirsty and had nothing else to drink.
61. Living in an orderly way bores me.
62. I believe the society we live in is pretty good the way it is.
63. I seem to be less energetic than most other people.
64. I enjoy meeting new people.
65. I am easily moved to tears.
66. I am a perfectionist in my work.
67. I am inclined to disregard what the public may think of me.
68. I have a great deal of endurance.
69. I get stage fright easily.
70. I have more important things to do than spending time thinking about love and romance.
71. I am disorderly.
72. People should be careful to dress properly when they are away from home.
73. I lack ambition.
74. When I am with someone else it is easy for me to find something to talk about.
75. I like to think about falling in love.
76. When people don't keep things spic and span, it bothers me.
77. The police in society abuse their powers.
78. I like to work up a good sweat.
79. I do less than my share of the talking in a conversation.
80. I enjoy having spiders close by so I can watch them.
81. I like to live dangerously.
82. I obey the law even when I am convinced it is in need of change.
83. I believe it is better not to work too hard.
84. I feel comfortable with people I have never seen before.
85. The sight of blood tends to make me ill.
86. I like my life to be orderly and well-planned in advance.
87. I would make a lot of changes in the laws of this country if I could.
88. Other people think I am an energetic person.
89. I keep to the people I already know instead of seeking new friends.
90. I am too well controlled to ever break down and cry.
91. If the mistakes in my work are only minor ones, I forget about them.
92. I want the people in my neighborhood to have a good opinion of me.
93. I tire quickly.
94. It would be easy for me to act a part in a play.
95. There are certain words which are so vulgar I would never use them.
This schedule contains a number of pairs of statements about things that you may or may not like; about ways in which you may or may not feel. Mark the letter of the statement on the answer sheet that best reflects your feelings. You may like both A and B, but you must make a choice between A or B.

1. A. I like to help my friends when they are in trouble.  
   B. I like to do my very best in whatever I undertake.

2. A. Any written work that I do I like to have precise, neat and well organized.  
   B. I would like to be a recognized authority in some job, profession, or field of specialization.

3. A. I like to be able to come and go as I want to.  
   B. I like to be able to say that I have done a difficult job well.

4. A. I like to solve puzzles and problems that other people have difficulty with.  
   B. I like to follow instructions and to do what is expected of me.

5. A. I like to experience novelty and change in my daily routine.  
   B. I like to tell my superiors that they have done a good job on something, when I think they have.

6. A. I like to avoid situations where I am expected to do things in a conventional way.  
   B. I like to read about the lives of great men and women.

7. A. I would like to be a recognized authority in some job, profession, or field of specialization.  
   B. I like to have my work organized and planned before beginning it.

8. A. I like to find out what great men and women have thought about various problems in which I am interested.  
   B. If I have to take a trip, I like to have things planned in advance.
9. A. I like to be independent of others in deciding what I want to do.
   B. I like to keep my things neat and orderly on my desk or workplace.

10. A. I like to be able to do things better than other people can.
    B. I like to tell amusing stories and jokes at parties.

11. A. I like to conform to custom and to avoid doing things that people might consider unconventional.
     B. I like to talk about my achievements.

12. A. I like to criticize people who are in a position of authority.
     B. I like to use words which other people often do not know the meaning of.

13. A. I like to accomplish tasks that others recognize as requiring skill and effort.
     B. I like to be able to come and go as I want to.

14. A. I like to praise someone I admire.
     B. I like to feel free to do what I want to do.

15. A. I get so angry that I feel like throwing and breaking things.
     B. I like to avoid responsibilities and obligations.

16. A. I like to be successful in things undertaken.
     B. I like to form new friendships.

17. A. I like to follow instructions and to do what is expected of me.
     B. I like to have strong attachments with my friends.

18. A. I like to be able to come and go as I want to.
     B. I like to share things with my friends.

19. A. I like to solve puzzles and problems that other people have difficulty with.
     B. I like to judge people by why they do something—not by what they actually do.

20. A. I like to accept the leadership of people I admire.
     B. I like to understand how my friends feel about various problems they have to face.

21. A. I like to feel free to do what I want to do.
     B. I like to observe how another individual feels in a given situation.
22. A. I like to accomplish tasks that others recognize as requiring skill and effort.
   B. I like my friends to encourage me when I meet with failure.

23. A. When planning something, I like to get suggestions from other people whose opinions I respect.
   B. I like my friends to treat me kindly.

24. A. I like to avoid situations where I am expected to do things in a conventional way.
   B. I like my friends to sympathize with me and to cheer me up when I am depressed.

25. A. I would like to write a great novel or play.
   B. When serving on a committee, I like to be appointed or elected chairperson.

26. A. When I am in a group, I like to accept the leadership of someone else in deciding what the group is going to do.
   B. I like to supervise and to direct the actions of other people whenever I can.

27. A. I like to avoid responsibilities and obligations.
   B. I like to be called upon to settle arguments and disputes between others.

28. A. I would like to be a recognized authority in some job, profession, or field of specialization.
   B. I feel guilty whenever I have done something I know is wrong.

29. A. I like to read about the lives of great men and women.
   B. I feel that I should confess the things that I have done that I regard as wrong.

30. A. I like to criticize people who are in a position of authority.
   B. I feel timid in the presence of other people I regard as my superiors.

31. A. I like to do my very best in whatever I undertake.
   B. I like to help other people who are less fortunate than I am.

32. A. I like to find out what great men and women have thought about various problems in which I am interested.
   B. I like to be generous with my friends.
33. A. I like to say what I think about things.
    B. I like to forgive my friends who may sometimes hurt me.

34. A. I like to be able to do things better than other people can.
    B. I like to eat in new and strange restaurants.

35. A. I like to conform and to avoid doing things that people I respect might consider unconventional.
    B. I like to participate in new fads and fashions.

36. A. I like to be independent of others in deciding what I want to do.
    B. I like to do new and different things.

37. A. I like to be able to say that I have done a difficult job well.
    B. I like to work hard at any job I undertake.

38. A. I like to tell my superiors that they have done a good job on something, when I think they have.
    B. I like to complete a single job or task at a time before taking on others.

39. A. I like to do some things that other people regard as unconventional.
    B. I like to put in long hours of work without being distracted.

40. A. I would like to accomplish something of great significance.
    B. I like to kiss attractive persons of the opposite sex.

41. A. I like to praise someone I admire.
    B. I like to be regarded as physically attractive by those of the opposite sex.

42. A. I like to do things in my own way and without regard to what others may think.
    B. I like to read books and plays in which sex plays a major part.

43. A. I would like to write a great novel or play.
    B. I like to attack points of view that are contrary to mine.
44. A. When I am in a group, I like to accept the leadership of someone else in deciding what the group is going to do.
   B. I feel like criticizing someone publicly if he or she deserves it.

45. A. I like to avoid responsibilities and obligations.
   B. I like to be able to say that I have done a difficult job well.

46. A. I like to put myself in someone else's place and to imagine how I would feel in the same situation.
   B. I like to tell my superiors that they have done a good job on something, when I think they have.

47. A. I like to understand how my friends feel about various problems they have to face.
   B. If I have to take a trip, I like to have things planned in advance.

48. A. I like to think about the personalities of my friends.
   B. I sometimes like to do things to see just what effect it has on others.

49. A. I like to study and to analyze the behavior of others.
   B. I like to do things that other people regard as unconventional.

50. A. I like to analyze my own motives and feelings.
   B. I like to make as many friends as I can.

51. A. I like to accept the leadership of people I admire.
   B. I like to understand how my friends feel about various problems they have to face.

52. A. I like to judge people by why they do something—not by what they actually do.
   B. I like my friends to show a great deal of affection toward me.

53. A. I like to think about the personalities of my friends and to try to figure out what makes them as they are.
   B. I like to be able to persuade and influence others to do what I want to do.

54. A. I like to analyze the feelings and motives of others.
   B. I feel depressed by my own inability to handle various situations.
55. A. I like to analyze my own motives and feelings.
    B. I like to sympathize with my friends when they are hurt or sick.

56. A. I like to think about the personalities of my friends and to try to figure out what makes them as they are.
    B. I like to try new and different jobs—rather than to continue doing the same old things.

57. A. I like to analyze the feelings and motives of others.
    B. I like to avoid being interrupted while at my work.

58. A. I like to predict how my friends will act in various situations.
    B. I like to go out with attractive persons of the opposite sex.

59. A. I like to predict how my friends will act in various situations.
    B. I like to attack points of view that are contrary to mine.

60. A. I like to work hard at any job I undertake.
    B. I would like to accomplish tasks that others recognize as requiring skill and effort.

61. A. I like to read newspaper accounts of murders and other forms of violence.
    B. I would like to write a great novel or play.

62. A. I like to stay up late working in order to get a job done.
    B. I like to praise someone I admire.

63. A. I feel like getting revenge when someone has insulted me.
    B. When I am in a group, I like to accept the leadership of someone else in deciding what the group is going to do.

64. A. I like to finish any job or task that I begin.
    B. I like to keep things neat and orderly on my desk or workplace.

65. A. I like to tell other people what I think of them.
    B. I like to have my meals organized and a definite time set aside.
66. A. I like to stick at a job or problem even when it may seem as if I am not getting anywhere with it.
   B. I like people to notice and to comment upon my appearance when I am out in public.

67. A. I feel like blaming others when things go wrong for me.
   B. I like to ask questions which I know no one will be able to answer.

68. A. I like to complete a single job or task at a time before taking on others.
   B. I like to feel free to do what I want to do.

69. A. I get so angry that I feel like throwing and breaking things.
   B. I like to avoid responsibilities and obligations.

70. A. When I have some assignment to do, I like to start in and keep working on it until it is completed.
   B. I like to participate in groups in which the members have warm and friendly feelings toward one another.

71. A. I like to attack points of view that are contrary to mine.
   B. I like to write letters to my friends.

72. A. I like to stay up late working in order to get a job routine.
   B. I like to understand how my friends feel about various problems they have to face.

73. A. I feel like making fun of people who do things that I regard as stupid.
   B. I like to predict how my friends will act in various situations.

74. A. I like to keep working at a puzzle or problem until it is solved.
   B. I like my friends to treat me kindly.

75. A. I feel like criticizing someone publicly if he or she deserves it.
   B. I like my friends to make a fuss over me when I am hurt or sick.

76. A. I like to finish any job or task that I begin.
   B. I like to be able to persuade and influence others to do what I want.
77. A. I get so angry that I feel like throwing or breaking things.
   B. I like to tell other how to do their jobs.

78. A. I like to stick at a job or problem even when it may seem as if I am not getting anywhere with it.
   B. I feel that the pain and misery that I have suffered has done me more good than harm.

79. A. I feel like blaming others when things go wrong for me.
   B. I feel like I am inferior to others in most respects.

80. A. When I have some assignment to do, I like to start in and keep working on it until it is completed.
   B. I like to help other people who are less fortunate than I am.

81. A. I like to attack points of view that are contrary to mine.
   B. I like my friends to confide in me and tell me their troubles.

82. A. I like to work hard at any job I undertake.
   B. I like to experience novelty and change in my daily life.

83. A. I feel like telling other people off when I disagree with them.
   B. I like to participate in new fads and fashions.

84. A. If I have to take a trip, I like to have things planned in advance.
   B. I like to keep working at a puzzle or problem until it is solved.

85. A. I like to tell other people what I think of them.
   B. I like to avoid being interrupted while at my work.

86. A. I like to keep working at a puzzle or problem until it is solved.
   B. I like to be in love with someone of the opposite sex.

87. A. I like making fun of people who do things that I regard as stupid.
   B. I like to be regarded as attractive by members of the opposite sex.

88. A. I like to avoid being interrupted while at my work.
   B. I feel like telling other people off when I disagree with them.
89. A. I like to avoid responsibilities and obligations.
   B. I feel like making fun of people who do things that I regard as stupid.

90. A. I like to experience novelty and change in my daily routine.
   B. I like to avoid responsibilities and obligations.
APPENDIX C

TRANSCRIPTS OF RECORDED INTERVIEWS OF STUDENTS COMPLETING THE TRIBBLE TASK

The following are transcripts of students' verbalizations during the Tribble Task. These have been transcribed from tape recordings of the twenty minute sessions. At the right of each transcript is an annotation of how the rater applied points to arrive at a score for the Tribble task. Students are listed in order of student number.

(description/silent observation)
(researcher's comments)

Student #1

Danny was very aggressive. He dove right in as if it were a challenge he had to master. Search and destroy mission.
The number of creatures have to be important. (Why?) They have to be. [No reason was given; he just knew he was right. He placed tribbles in every box on the grid. Immediately he saw results.] The shape relates to this somehow. There must be a disease that kills them off at each generation. [After day three, he saw that the number did not decrease, but that the onset pattern changed.] My theory is untrue. (Why?) The number would have gone down, but it didn't. [He continued. The pattern kept changing.] They are symmetrical. This screen is missing some. The pattern continues off the screen. How do you know? It makes sense if you count each side of the pattern. The number and placement of tribbles are very important. The shape is very important; symmetry is important! What is the

Danny was one of those students who stood out as an excellent problem solver who took risks, was aggressive, and autonomous.

Section I - Danny began defining and, redefining, (1.0) deciding that number (1.0), position and shape (2.0) are important. Then he noted that symmetry (1.0) was important.

Section II - From the Danny presupposed factors to be true. He had a goal state and then found ways to achieve that goal. His behavior manifested a directed trial and error (5.0).

Section III - Danny exhibited meta-cognition. He was constantly thinking about what he was doing and
answer? [Danny was very, very sure of himself. He definitely wanted to know the answer. He was not afraid to make predictions and And, he was not afraid to admit that he was wrong and to try something else. He seemed to be a risk-taker.]

Student #2
[Tiffany placed five tribbles different points on the Tribbles’ screen. (Why?) I don’t know. Three days later there were no results. She tried five tribbles in a different set of positions. Three generations. Nothing happened. She tried the same idea again, and again, nothing happened. I really don’t feel like doing this. Do I have to? (Of course not, thank you for trying.)
[Tiffany was the only student in Group A who did not suggest any ideas.

Student #3
Can I place them anywhere I want? (Sure.) [Next day. Nothing happened.] I’m going to try this, but I don’t think anything will happen. I was right. [She tried three in a vertical row. The next day showed three in a horizontal position.] I bet it will go back to the vertical if I hit the next [It did.] I’m going to add followed the steps of problem solving.
He observed (1.0), predicted (1.0), tested and revised predictions (2.0).

Tribble Score 14.0
Heuristic #1

Of Group A, Tiffany was least interested in playing with the Tribbles. She found the problem confusing and boring. Tiffany is the kind of student who, if she cannot be the best at what she does, will not participate.

Section I - She got only (1.0) for making sense of the problem.
Section II - She used a random approach (.5).
Section III - Making minimal observations about the Tribbles she earned (1.0).

Tribble Score 2.5
Heuristic #2

Section I - Susie made sense of the problem (1.0), taking note of position (1.0) and number of Tribbles (1.0). She also said that symmetry was important (1.0).
Section II It was difficult to decide what Susie’s initial strategy was; another
another tribble and try a different place and tried four in a horizontal row. They formed a box. She continued. I'm going to try a lot of them across. (Why?) When I added one, something happened. Susie tried nine across and got definite results. She was grinning. They are growing and there are patterns. If I keep going, I'm going to get more patterns. They are symmetrical.

[Susie did not waste moves. She seemed to do more thinking than playing. She also predicted more than many of the others. She was able to predict accurately what the next screen would be like.]

Student #4

Ahm. (This is how you would place them on the grid. See?) Okay. (That's what they look like on Day 2.) Do I increase the number? (You may do whatever you wish.) I want to stay with the pattern. Yes. Okay. I want to start something else. (Type that right in.) Okay. I only put five in. Yeah. (Now why did you place them in this position?) I was just trying to get different positions. I am trying to figure out how these tribbles multiply. Am I trying to decide what the rules are? (Yes) Will the rules show what the patterns will be? (Yes). The patterns are important. Okay let's see the next day. I didn't get any results on the next day! I wish I could put all the little patterns together. Can I put them all together?

rater would have been helpful. I felt that there were definite reasons for her moves, it seemed that she was using a directed trial and error (5.0).

Section III - It was clear that Susie was using a method of problem solving. She made observations and predictions (2.0), tested predictions (1.0) and revised predictions (1.0). Of all students, Susie was the most aggressive in making predictions.

Tribe Score 13.0

Heuristic #1

Section I - From Erin's questioning behavior, it was apparent she was defining and redefining (1.0). She also noted that position was important (1.0).

Section II - What initially begins as trial and error (1.0) ends as directed trial and error (3.0); she tries patterns in an attempt to get results.

Section III - Erin asks questions to help her better define the problem (1.0). She predicts the importance of patterns (1.0) and tests her predictions (1.0) but does not get in-
(Sure) How?. (I’ll help you... There we are.) I want to go to the next day. Looks like they killed each other? What happened? (Silence) Let’s try three together. How about if I keep going down? [Next day.] I want to use the second pattern and see if I can go back to the original in a later day. Let’s see what happens. The patterns have something to do with this. They are important. I don’t want to do this anymore. (Fine, thank you.)

Student $5$

I’m going to try different positions. Position must be important. (Why do you think so?) It must be or I wouldn’t have this big screen to work with. They must need the room. [Donna was quiet, but proceeded to try twenty screens using only one tribble.] Well, one tribble doesn’t work, I think I’ll add another one. Hm. Nothing. (Why did you place them there?) I don’t know. I’m just trying things. [Donna continued to work quietly. When she placed the tribbles next to each other, she saw a pattern develop.] Ahh, the pattern has nothing to do with the symmetry. [She studied it for awhile, pressing next day keys. Then she asked to stop.]

Section I - Immediately Donna defined the task (1.0) to sub-units, noting that it was important to place Tribbles in positions (1.0). When results showed nothing, she assumed that the number was important (1.0). She later decided symmetry was also important (1.0).

Section II - Donna’s initial approach is Trial and Error (1.0) but then develops to a directed trial and error (3.0) She knew where she wanted to go and ways to get there.

Section III - Donna observed (1.0) but did not verbalize her predictions. The placement of Tribbles seemed to be part of an information gathering process. She makes and tests predictions, but does...
Student #6

I'm just going to place these four in a box. (Okay) Ahh, nothing happened. Hm, nothing again. Let's try this. Wow they keep reversing. I bet if I go to the next day they will keep reversing. Yup. I'm going to try more tribbles, maybe five in a row. Okay. They grew into a box. Now it's a pattern. They are growing. (Why do you think this happened?) The amount of tribbles must make a difference. They have to be near each other, like in a row because when they were in a box they didn't really do anything.

[From here on Amanda was very quiet. What she did was quite interesting. She abandoned everything she had done until now and tried something totally different. She copied old patterns that she had observed onto the grid and pressed next day keys. When I asked why she was doing that, she said she was trying to see if the new patterns related to the old patterns. Then she went back to the beginning. She said she was trying things.]

Section I - Amanda worked on the task as I hoped she would, attacking the problem if she knew what was expected and would happen (1.0). She noted that number and symmetry (2.0) were important. She worked and decided position was important (1.0). Finally, she noted proximity of Tribbles was important (1.0).

Section II - Amanda used directed trial and error (5.0). She had a specific plan in mind as she moved from one point to the next.

Section III - Amanda's problem solving used observation, prediction (2.0), testing (1.0), and revising predictions testing (1.0). Amanda is an organizer and a leader in the classroom. She is one of the most articulate and thoughtful problem solvers in the class.

Tribble Score 11.0
Heuristic #2-1

not spend time revising predictions.

Tribble Score 14.0
Heuristic #1
Student #7
I’ll try two of them. [On Day 2, the tribbles look like this, 3, etc.] Ahm, I want to try something else. Ahm. (Why did you stop?) Cause I don’t see them anymore. This must not be working. Ahm., (What are you thinking now?) I don’t know, I’m, thinking this is really weird. Okay. Ahm. Now where there’s none on the screen, does that mean they are gone? Hmm. Oh. Hm Okay. Ahm. Okay. Now they’re gone; they’re not there anymore? (Why are you spacing them?) Well because I don’t know. It’s just sort of random. All right. Because I’m not getting anywhere with spacing. I’ll put them together in a vertical row. [She continues for a few grids.] I don’t want to do it this way. I want to try it in a box. See what happens. Okay... (Why did you do that?) I don’t know. I really don’t know? There are patterns. I think I’ll switch to a horizontal row. Ahm, they’re doing the same thing. Neat.

[Stephanie tried 16 screens of random placement without any rhyme or reason. She tried various amounts and various positions. When she tried a vertical line of ten, she saw results. She continued the screens and saw patterns. She was smiling. When she switched to a horizontal line, she saw similar results. It was marvelous watching her. It seemed that she really did know what she was doing, but did not want to share it.]

Section I - It does not seem that she was defining or redefining the problem. She eventually manifests clearer thinking (1.0). She observes position as important (1.0). She realizes that patterns or symmetry are also significant (1.0).

Section II - There was to be no true rhyme or reason to her actions. She said that her approach was random and she was allotted (.5). This approach became trial and error (1.0) showing that she was taking some direction.

Section III - Although she makes observations and predictions (2.0), she does not test out these predictions.

Tribble Score 6.5

Heuristic #2-3
Student #8
[Lynn was very quiet, but seemed to have a real strategy in mind. She tried increasing the tribble number from 1 to three using various positions. If the combination did not work after two days, she tried a new combination. She took somewhat of a trial and error approach with a specific direction in mind, however. After 26 screens, she increased the number to four and placed them in the middle but still not next to each other. After several more tries, she tried them in a row. Oh. I see now. They need to be together and I need a lot of them. (She continued the screens.) They grown in number and pattern. The bigger patterns doesn't really change, just the patterns inside. [We had to stop. She asked to try more later as she was just getting warmed up. She is a neighbor and I told her that she could work on it at a later time. Lynn seemed to have a particular plan in mind, but did not care to share it with me. She seemed to be testing her hypotheses and trying new ones when the old ones did not work.]

Section I - Lynn tried to redefine the problem into more smaller tasks (1.0). Soon she determined position and number (2.0) were important. She noted growth as symmetrical (1.0) and the pattern within the pattern was important (1.0).

Section II - What seemed like trial and error was directed trial and error (5.0) Each move was a result of specific thinking and planning.

Section III - Lynn observed and predicted (2.0), tested and revised predictions (2.0) when results did not check out.

Tribble Score 14.0
Heuristic #1

Student #9
[Katie began with a strategy right away. Tried 1, 2, then 3 tribbles.] If I don’t get anything after Day 3, that means there is nothing, and I’ll try something else. (Katie never increased to more than three tribbles for more than 20 screens. She seemed to perseverate.) If I keep going to next day, the position changes but they never grow. [She decided

Section I - Katie redefined the task (1.0), decided that number (1.0) was important. Katie did not look at other variables.

Section II - Katie used directed trial and error (5.0). She determined a specific set of steps}
to increase the number to 9. She saw results. You need more than three tribbles to get them to grow. She separated 9 into 2 tribbles 7 tribbles. She saw that the 7 tribbles gave her results.

You definitely need more than three. Where I put them makes a difference.

[Katie decided to stop. She was probably bored. She seemed to move around a lot, very busy-looking.]

Student #10
Matthew placed two tribbles in a random position on the screen. [Next day - nothing.] Either they are not there or they were have moved off the screen. One didn’t work either. Let’s see what all happens if I put three together [Like an L. Nothing.] Let’s see what happens if I place four in box. [The same pattern occurs.] If I hit it again, the same thing will happen. [He’s right.] Let’s finally try a different pattern. Triangle. Oh. These have a specific pattern. Shape must be important. [Matthew tried various positions and numbers; a diagonal; solid triangle using the diagonal as the longest side.] Wow! Shape really is important. The more I use the making better it is. If I use the number and the same place, I always get the same patterns. [Matthew could have stayed all day. He seemed to possess a quiet tenacity and enjoyed playing with the tribbles.]

followed those steps over and over.

Section III - After observing (1.0), she predicted and tested those predictions (2.0). Katie spent a lot of time revising her thinking (1.0). There seemed to be a lot of metacognition.

Tribble Score 11.0
Heuristic #1

Section I - After defining the task (1.0), he decided that number (1.0), pattern and position (2.0) were significant and the relationship among the variables (1.0).

Section II - Matthew began the task in a random fashion (.5) It progressed to trial and error (1.0) and directed trial and error (3.0). He needed a wider knowledge base before getting to more better thinking.

Section III - Matthew progressed through observation (1.0), predictions (1.0), and testing predictions (1.0). He seemed to be thinking about making connections.

Tribble Score 12.5
Heuristic #2-3-1
Student #1
Immediately, he placed two in a vertical row. After seeing no results for two generations, he stopped. I’m going to try something else. Maybe they need only one tribble. [After nothing happened, he increased the number. I need more tribbles. [He saw patterns, then placed three spaced apart. Nothing happened.] Nothing happened; I need tribbles near each other. [He placed two rows of three tribbles on the screen. Jeff was silent. He tried four more screens. Again, he changed his tack and tried a random placement without results. He changed again.] (Why are you changing?) I think that the number of tribbles relates to where they are. [He tried to vary position keeping the same number. Finally, he placed 9 tribbles in a row and saw results.] Holy Gosh. The tribbles grow in multiples of a certain number. I don’t know what the number is but I know they do. We had to stop. Jeff enjoyed playing with the tribbles. He seemed to possess a definite strategy—testing position and number. There was little randomness to his thinking. He had a plan.

Student #12
I’m going to line them up right across the center. (Why?) Well, the more I have, the more they reproduce. They need room to move. Okay. [Next day.] Well, that worked. (What do you mean?) They went from 10 to 27. [Next day.] Now there’s a definite pattern, but I lost some. I’m going to go on. Whoa! They’re filling in. I have more now.

Section I - Jeff redefined the problem noting number and position (2.0) He determined that reproduction might occur in multiples of one number. (1.0).
Section II - Jeff used a specific set of operations and hypotheses and ways to check hypotheses. He definitely used directed trial and error (5.0).
Section III - Jeff predicted (1.0) and tested (1.0) based on observations (1.0). He observed new data, and revised predictions (1.0).

Tribble Score 13.0
Heuristic #1

Section I - No one attacked the problem like Jim. He had pre-conceived notions (1.0) and set out to solve the problem. He noted that position (1.0) and number (1.0) were important. He decided that patterns (1.0) and possibly multiples were sig-
The pattern's getting bigger. I've lost some. They must be dying or I am losing them off the screen. They're gone. I'm going to try something else and then come back to this. I'm only going to try a few to see how many makes a difference.

Jim was quiet, but followed the screens through until none appeared. (What do you think?) I think the more you have, better it is. I'm gonna try the opposite of the first one I did. [? in a vertical row. Same thing except in a different direction.] The row must have something to do with it. (Why?) Well, when I put them in a row next to each other, they grew. Let's see if I space them out. (Goes right to it. Next day. Nothing, nothing, nothing.) See, you need them in a row. You've got to have them in a row, in the middle, and a lot of them. they need room to make their patterns. They have symmetry; what happens on one side, happens on the other. Do I have the right answers? (I don't know, but you certainly have done a lot of good thinking.) Will you tell me the answers after all the other kids are done? (As soon as I know them, I will share them with you.) You mean you don't know them? (No, I don't know them. That way, I can't give them away by accident.) Oh.

Jim was very aggressive; he attacked this like a video or computer game. Placing the tribbles immediately in a row and in the middle hinted that he had preconceived notions about what would happen. He seemed to be right.
Student §13
I'll try one. [No results for three days.] I'll try it in a different place. [No results for three days.] I think maybe more than one will make a difference. [No results.]
What happened? If something happens then I know I will get something. If I bunch them up in the corner. Okay, at least we got something. [He continued for 6 days.] Maybe they reproduce in ratios. I started with 6, then got 6, then got 9, then twelve, 12 again. [Mo tried one of the patterns he saw while the days changed (9 in a diamond) as before. He got the same results.] I bet the same thing happens if I keep going. [He saw that the tribbles were beginning to diminish.] They're going to die out. [Mo began something totally different. He tried three tribbles in a row and saw that the pattern reversed.]
If I keep hitting the next day, the pattern is going to keep reversing. [He tried the pattern in the middle, and saw a box.] The position makes a difference in the pattern. [Time was up, so we stopped. Mo used more "if then" statements than the other children. He seemed to develop mini-hypotheses as he went along.]

Student §14
I think I'll start off from the middle. [4 together in a box. Each one next to each other.] Maybe they'll stay the same. They look like they are staying the same. They aren't doing any-

Section I -
Mo tried to redefine the task into subproblems (1.0). He decided that position and number make a difference (2.0). He discerned that patterning might also be important (1.0). Mo considered the idea that the tribbles grew in ratios (1.0). section II - Mo’s thoughts changed during the task. He was using a random heuristic (.5) but incorporated some direction in thinking manifested by trial and error (1.0). He utilized a directed trial and error; he tried operations in order to get him from one point to another (3.0).
Section III - Mo spent time observing and gathering data (1.0). He worked backwards when it came to making predictions. This helped him predict (1.0) and test them (1.0). Mo stuck to one idea and did not get into revising.

Tribble Score 12.5
Heuristic #2-3-1

Section I
Kenny was apparently redefining as he dove into the exercise (1.0). He immediately decided that number and position were important (2.0).
thing. Maybe I need to concentrate more. Oh My Gosh! That was weird. They just stay the same. Maybe I'll try one or two more. Can I try a new one after this? (Sure) Ahm, I'll try something else. (WHY?) I tried them in the center. Maybe they will not multiply in a closed in space. Four in a row. Maybe they don't like this either. Can I add more? (Do whatever you wish) All right. Hold on. That's weird. Two are gone and two moved out. I'm going to try the next things. They'll either grow out, stay the same. I'll lose them. This is weird. Maybe it takes them a while to grow. I want to find a new pattern. Ahm. (Why did you pick that pattern?) Maybe they need to be next to each other. Maybe I need more than four. Yeah they grew. All right. [Five of them went to nine. Then they got into a 3,3,3, box pattern.] That's weird; they keep expanding. There's a pattern. And more of them grow inside. The overall shape stays the same. That's wild!!! I think I know what they're doing. They make like some sort of shape. They make more inside then expand; grow more inside then expand. They grow more, then they grew some inside. This time they have 20. They had twelve. I think they grow in multiples of 4.

They have to grow in an open slot. They have to be more than four of them. They have to be in an open spot. I already said that. They have to grow in multiples of four. They grow in, grow out, grow in, grow out.

What? Where did they go? Did they die? Do they have a short life cycle? (Anything is possible.) There were twenty of them. Now He noted symmetry (1.0) is significant and that Tribbles need a specific amount of space for reproduction (1.0). This notion had not been suggested by anyone thus far.

Section II - It was clear that Kenny had operations in mind in solving the task. He tried many subgoals and used mini-hypotheses. His behavior indicated a directed trial and error approach (5.0).

Section III - Kenny followed a specific process. He made observations and predictions (2.0), tested them (1.0) and revised his predictions when results did not confirm hypotheses (1.0). Kenny is fun to watch in class because he exudes enthusiasm, is an excellent problem solver and likes to try new things.
there are only twelve left. Maybe the older ones died. Maybe that's why they grow so fast because most of them die. What??? They are dying off; the poor little things. I get it. A lot of them. It depends on how much you have for what you are gonna have. Say you had maybe twenty. Like I only started with four and went to twenty. Maybe I should start with twenty and go to 100. Maybe it would take 100 days to die. Maybe these four are the only ones that will stay.

[Kenny actually got into hypothesizing and personalizing the hypotheses. He would conjecture something, then test out his ideas.]

Student §15

[Brandon tried 1 tribble for three generations. Nothing happened. He varied the positions. 24 screens. (Why?) I didn’t get anywhere with first try, I’m going to try something else. [He skipped from one tribble to three tribbles placing them in random positions. Two tries, he suddenly changed his strategy placing two rows of eight near the bottom of the screen. (Why the sudden change?) Maybe the number has something to do with it, and maybe if they are placed together, something will happen. [Next day. A pattern. Tried next day, etc. He stops and places exact pattern at the top side of the screen. He is smiling.] (What are you thinking? Some are moving and some aren’t. I bet if I place the same pattern on the left side, the same thing will happen. (Try it.) [It did. The pattern did not change; the pattern continued just as it had before.] Where I put them makes a difference. Patterns are important. They move in patterns. [We stopped. Time was up.] Can we do this again

Section I - Although it took some time, Brandon decided that number number was important. (1.0). Playing, he was able to redefine the task (1.0). Position was noted as being significant (1.0). He eventually noted that patterns were also important (1.0).

Section II - What began as trial and error changed to directed trial and error (4.0) Brandon noted there were specific subgoals he needed to accomplish and that certain operations might get him there.

Section III - Brandon made observations and predictions (2.0) tested those predictions (1.0) and revised his thinking
sometime? I think I am finally getting somewhere. (Perhaps another time. Thank you Brandon.)

Student #16
[Place one tribble in the middle of the screen. Two days. They died. I wonder why they died out? [He continued to try different positions using only one tribble.] If there is only one tribble, they die out. I’m going to try more than one. [Roy tried three in a random position. Nothing happened.] Maybe the tribbles skip a generation. I really don’t think so though. Maybe where I place them will make them grow. [He placed 6 in row at the top left of the screen. They multiplied. They moved.] They moved. I bet they move again. They did. They must need space to grow. They grow in number. [Roy counted the numbers each time; he seemed to be looking for a mathematical progression. He continued. The tribbles decreased.] The tribbles are dying. [The next screen showed an increase.] The original ones are dying and children are born. They are having offspring. [Roy truly personalized the tribble experience. He attributed human characteristics and events to the tribbles: birth, room to grow, dying, skipping generations, offspring. He seemed concerned that they were dying but that he could do nothing about it.]

Tribble Score 12.0
Heuristic #2-1

Section I - Roy attacked the problem (1.0) decided position was important. (1.0). After observation, it was clear that number was also important (1.0). Roy also decided that the tribbles needed space to grow (1.0). Section II - Roy progressed through three heuristics: random (.5), trial and error (1.0), and directed trial and error (3.0). His thinking changed as he observed more data.- Section III - Roy spent time observing and making predictions (2.0). He tested and revised predictions (2.0). Roy was interesting because he truly personalized the task. This could be cultural. Roy is from Cambodia where living is a daily struggle.

Tribble Score 12.5
Heuristic #2-3-1
Student #17

[He begins by randomly placing one in the grid, Day 2.] They still aren't there; I must have put them dead spot. [He tries a different spot. Again, no response. He continues to place tribbles, one only, randomly on the grid. Each attempt shows no response.] (Why are you placing them in those positions?) It's just random. (Randomly?) Yeah. [He continues to place a single tribble on the grid. Nothing happens.] (Why only one?) No reason. [He tries two separated, and nothing happens.] Can I put as many patterns as I wish? (Absolutely, you're in control.) Does the grid expand or does it only go up to 1? (Why?) I'd like to use letters that I wish like R for my name. [He placed four does tribbles in different areas. Nothing happens.] (Why are you choosing those particular spots on the grid?) I chose it because it is a company that makes surfboards. A-1 because it is steak sauce. (Ahm.) [He continues to place tribbles in a pattern but not together.] (Why?) Maybe if I put them in a district of tribbles, something will happen.

Heather begins by placing four at each corner. The tribbles vanish. (Why did you choose that pattern?) I don't know [there is no response.] I want to try something else. I'm going try a whole row of them. [Days 2, 3, 4, 5, 6, 7 show definite changes.] (What do you think is happening?) Sometimes they multiply. One time there were sixteen. Sometimes they

Section I - It takes Ryaz a while before redefining the problem to make any sense of it (1.0). He decides that the Tribbles should probably be placed in groups "districts" or patterns (1.0). Section II - Ryaz uses a random approach to solving the problem (.5). This develops into a creative heuristic (.5) placing them in positions because of the name surfboard. Section III - Ryaz spends time gathering data, but he does nothing with the data. Eventually, he makes some observations (1.0)-no predictions are made however.

Tribble Score 4.0
Heuristic #2-4
decrease. Then there are more. Every time is different. [She continues with the following days.] It’s keeping the same shape - a pattern. There’s not enough room. (Do you have any ideas why things are happening the way they are?) No. They’ve been keeping kind of the same shape. It’s like there are two U’s. That’s like a U and then there is half U. Maybe there is not enough room. (You may stop any time you want.) I just want to see what they look like. (Sure.)

Student #19
[He places one tribble on the grid. Day 2 shows an empty grid.] Can I put more than one? (Sure.) [He tries a different pattern that includes four tribbles in a closed diamond.] I want to make them even. [Then he places four tribbles—one in each corner.] (Why?) No reason. I don’t really know. [He tries a single tribble. Day 2 shows nothing. He tries three in an L. Nothing. He tries four in a box. The screens stay exactly the same for three days.] (What do you think is going to happen?) The next one will stay the same. (It does. He tries only one.) (What do you think will happen?) Nothing. [He places four in a box with an extra tribble and sees a pattern form. He continues to see patterns at each subsequent generation.] (Do you have any ideas why this is happening?) If you increase the number, it makes a difference. [He continues the generations and sees the patterns change. He stops.]

to use trial and error as well (1.0.)
Section III - Heather spends much time making observations (1.0) and predictions about shapes and patterns (1.0).

Tribble Score 6.0
Heuristic #2-4-1

Section I - After defining the task (1.0), he plays with the pattern. He does not verbalize it, but thinks patterns are important. His actions show it (1.0). He says that number is also important (1.0).
Section II - What begins as random changes to trial and error (1.5) and then to directed trial and error (3.0). At the end, he moves in a specific direction for specific reasons.
Section III - Much time is spent playing, observing, predicting, and testing (3.0).

Tribble Score 10.5
Heuristic #2-3-1
Student #20

[She begins by placing two on the grid. The next day shows an empty screen.] They're dead. (Could be.) [She tries four in a random place. No particular reason. Shows nothing. She tries a diagonal row. Day 2 shows a shorter diagonal. Two of them died. I want to see if two more die.] Day 3 - shorter. Day 4 shows an empty screen.] Two seem to die every day. [She tries a diagonal in the opposite direction.] (Why did you do this?) I want to see if they will do the same thing in reverse. [She observes two die each day for four days.] They decrease by two each day even though I started with an odd number instead of an even number this time. [Now she tries nine tribbles in a row.] (Why did you do that?) I want to see what will happen. [Day 2 shows a definite pattern. The patterns continue for four days; the tribbles keep separating.] They are separating. If there were more grid, they would probably spread out even more. [New patterns form.] Oh! (What are you thinking?) I don’t know. They look like little cells coming together. [She stops.] (Why are you stopping?) I want to try in a vertical line. [Day 2 shows a definite pattern as does day 3.] I don’t really understand what they are doing. (Do you have ideas?) Placement has something to do with it. The more I use makes a difference. The higher number makes a difference.

Student #21

I put them there so I could get them away from the others. [Down below at day 2 the tribble moved. They seem to be moving away from each other. [He requested Section I - Christy defines the task (1.0) and works on specific notions. Soon she decides that number (1.0), position and pattern are important (2.0). She notes a kind of separation occurring (1.0).

Section II - Christy moves from random to trial and error (1.5) and then to a directed trial and error (3.0). She was doing some good thinking.

Section III - During the task, Christy observes (1.0), predicts (1.0) and tests predictions (1.0). No time is spent revising.

Tribble Score 12.5

Heuristic #2-3-1

Section I - John attacked this problem the way students in Group A approached it (1.0). He decided that number (1.0),
clarification with directions.

There’s no one there, so I can move them to a different section? (Sure.) I want to see what they do when they are separated. They seem to move away from each other. He moved again. They seemed to like groups. (Why do you think that?) They may be more secure. [There was a problem with the computer; we needed to begin. Wherever I put them, they move in groups, so I might as well put them in groups to start. I want to put them into the center so you can track them easier if they move. [Day 2.] Oh! Neat. They look the same. They stayed together. Whoa. They haven’t moved at all. They must really like each other. They just switch position. [Day 3.] They haven’t moved at all. Day 4. So if just move one it goes back to the group. I noticed that if you placed them in the corner they moved back to where they were originally. So if I wanted to control them, I just keep them in groups. I am going to separate them to see if there is any effect on them. (He seems to be enjoying the exercise.) I’ll place three in the middle. [Day 2.] Oh! They changed position. Wow! They’re vertical instead of horizontal. Okay, so they disappear when they are high up or too low. They like the center. They like the same groups. I don’t know. So they definitely moved. (Why do you think they moved?) I know they don’t like staying in groups of two. They stayed in the middle when they were three. (Why might they be moving?) They are going anywhere they want. Maybe they are dying. [He tries four—one in each corner.] They’re dead. They’re not there. They disappeared.

position (1.0), and pattern (1.0) were important. He also saw that separation was important. (1.0)

Section II - John attacked the problem using directed trial and error (5.0). He had a plan for each move. He was constantly thinking about his thinking.

Section III-John made observations and predictions (2.0), and tested predictions (1.0). When his prediction did not work, he revised and began again (1.0). John was considered one of the most immature students in the class; I found this refreshing. It did not detract from his ability to solve problems.

Tribble Score: 14.0
Heuristic #1
Okay. So if they are separated by themselves, they die. Maybe I should try them in two groups of two. Day 2. They're dead again. It might be when they are separated. I don't know. (You can stop any time you wish.) This is strange. I don't know.

Student 22
[He tries one tribble. Nothing happens for 4 subsequent generations. He tries two together. No response on Day 2.] Did they just leave? He laughs. You need a lot of them. (Try it.) He tries a diagonal. (Why did you do that?) No reason. (He observes a change in the pattern.) (Do you have any idea why that happened? They are getting spaced out. They are going to decrease. [He checks it out, and he is right. He tries them spaced out.] (Why?) I want to see what would happen if they are spaced out. [He tries three together. The pattern changes direction.] You need at least three in a row to see any changes. [On day 3, the pattern changes.] That's weird. They should go to only 1, but it didn't. [He tries five in a row and sees an increase.] They should switch back to the first pattern but they don't. [He continues for four generations, losing tribbles.] If the grid were bigger, there would be more; they're off the screen. [He continues the generations for 21 screens during which I ask what he thinks will happen.] They change a little each time. They might go back to what they were the first time. [He seems to enjoy the exercise. He smiles during the entire sitting. He worked the longest of any child.]

Section I - Bret tried worked through it immediately (1.0), noting number and position (2.0) as important. He quickly observes the patterns and separation (2.0).

Section II - Although the first strategy is random (.5), it develops into directed trial and error (3.0). He plans moves for testing ideas.

Section III - Bret makes observations (1.0), predicts (1.0), and tests predictions (1.0). He too thinks about thinking and revising thinking (1.0).

Bret is one of a set of identical twins in this study. His responses are different from his brother's 23.

Tribble Score 12.5
Heuristic $2-1$
Section I - Brant tried to define the task (1.0) but was not interested.

Section II - Brant’s approach was strictly random (.5). Perhaps if he had discovered something unusual he might have wished to continue.

Section III - He seemed to be making observations but said nothing (1.0).

Student #24
[Brenda immediately placed four tribbles in a box.] (Why did you place them that way?) I want to make a design. (After two generations, she placed five tribbles in a vertical row.) (Why a vertical row? I’m getting used to the screen. I’m playing.
[On the second generation, she saw results and was quite pleased. She continued for six generations and stopped.
She then placed tribbles on the screen in an elaborate pattern.] (Why are you doing that?) I like the way this pattern looks. [She continued for five generations and asked a question.] Are they keeping the same number I put in but changing shape? [She then tried the next generation and answered her question.] No. [She continued for 13 more generations until all the tribbles were gone. She seemed to be enjoying herself and asked to try another pattern. Again, she tried a very elaborate pattern. At the fourth generation, she commented that the number had in-

Tribble Score 10.5
Heuristic #4-1
creased. She tried several more screens. They seem to take away then put back in. Then they reach a point where they finally decrease. They multiply in a specific shape. Like symmetry.

[Brenda did an interesting thing. She was able to predict where the tribbles would be on the screen for the next 2 generations. She stopped and tried only one tribble.] (Why?) I want to see if they will increase when there is only one of them. [There were no responses for the second and third generations.] Brenda stopped because time was up.

Student #25

[Tristan possessed the most enthusiasm of all children in the sample. He immediately placed five tribbles in a horizontal row.] (Why did you pick that?) Okay what I am going to do with the tribbles and make like a box and then I am going to put one in the center and see which way that one in the center tends to move overnight. And then, I can see which way its preference would be to go. (Tristan does not place the pattern as he wishes and begins again this time doing what he wants. I offer to show him the grid so he can better visualize what he wants to do.) That guy in the center is key. He’s the key guy. (What do you think is going to happen?) Well these guys are going to move too. But before they move he’s going to have to make a decision about which way he’s going to have to go and whichever way this one tends to move. And of course these ones may do something surprising, and I can still learn the something about like if they were condensing or if they would expand out. (All right.) (Tristan hits the

Section I - Tristan was another one of those students who dove right into the problem and was determined to have fun (1.0). He said that number, position and symmetry were important (3.0). He noted interrelationship among the variables as important (1.0). Section II - Tristan also approached the task using directed trial and error (5.0). He thought about his actions and his thinking. Section III - He followed steps of the problem solving process: observation, revision (4.0) He was one of the youngest in the class. He was like a student in Group A.
wrong button and erases the pattern. He begins again.] They multiplied obviously. This line multiplies here and this line multiplies here. They tend to be spreading out. They multiply outwards not inwards. (What happened to your little buddy in the middle?) The little buddy in the middle must have just spread outwards to. Can I get another day? (Yes) Ohoo. The populations diminished consider­ably. We started out with a lot, quite a few, like 28 when we started out. Everything seems to be pretty symmetrical. I diminished the population by almost half. There were 28 instead of 50. can we try one more day? Is that what happened? All these guys just kept spreading out. So we started out with this condensed circle and just put them all in one space. Yeah, but this is a major population explosion. They diminished by half and spread out. Now there is only one fourth the population there. Want to see what happens the next day? (Sure.) There are still four. Obviously, maybe now they just kept spreading out and spreading out off the grid. (Does that mean then that maybe we still have more, but they spread right off the grid?) Yes. Let’s see if there is another change. Yup. Either they’re not changing or they spread right off the grid. I think they are changing now. I am going to try another pattern, like in the corners. (What do you think is going to happen here?) If they don’t multiply they will probably go off the grid. Well can they multiply by themselves? (You’ll have to try that out.) [He tries only one, and nothing happens.] They definitely need two tribbles to multiply. [How do you know?] Well let’s, try. It’s looks as if they died too
or they multiplied off the screen. They're still not there. Maybe they multiply in a larger mass. [He tries five in a diamond pattern.] They multiplied. They went from five to eight. So let's see what happens the next day. They multiplied again. (Are you sure?) No, they just changed direction. This time they multiplied. It seems to be a pattern to this. I started out with a cross shape, then they turned into a box and the box turned on sideways. Now there is another box in the middle. So if the next day comes, there might be another box on the side then another box in the middle. Another box. Let's see if there's another in the middle. See another box in the middle. Yes, see there is. So we know. We know two things that they can't multiply without a larger group or they'll die, so maybe if you spread them out more they won't be able to interact to reproduce. They need to be in a denser group. There's a pattern: a diamond, a box, a diamond, a box, and the diamond probably goes off the grid too. So I bet if you made those diamonds all over the grid, you would get the same pattern. A diamond, a box, a diamond, a box, and the diamond probably goes off the grid too. So I bet if you made those diamonds all over the grid, you would get the same pattern. [He tries that and gets the same results. Time ends. Tristan would have stayed there all day, and asked if he could do this some other time. Tristan is a wonderful, neat child. This has been a lot of fun.]

Student §26
[Matthew originally placed one in each of the four corners of the grid.] (Why?) I wanted to see if they would go to the middle. They all die off on the second day. Ahm. Oh. The same thing happens on the next day. I'm going to try a new pattern. [The pattern is somewhat]

Section I - Matthew lost no time getting to work (1.0). He notes the importance of number and position (2.0). He sees that symmetry and relationships are significant (2.0).
random. The next generation reveals only two. He stops and tries a pattern of 9 in a horizontal row.

(Why did you try this pattern?) I want to see if they'll scatter. Matthew continues the generations for 22 days. It is on the 7th day he notices a pattern. (He continues the generations.) When there is a straight line, they multiply by three horizontally or vertical. Oh. Oh. All right. There was 24, now there's less. They decrease by if I'm right they are going to decrease. Oops I was wrong. Is there a pattern? (What do you think?) I think there is. (Okay. What do you think is happening?) I have no idea. I think they just split up. Brilliant deduction. I bet they go in two straight lines parallel. [Laughter] Two lines parallel and one going straight through. Well two lines parallel! Oh they did connect. (He continues for 8 days.) There's an odd number. These guys don't multiply very much. It went down by two. (It decreased by two.) Yep. 10—that is even number. It went down by three. My guess is that the next will be 6. (He counts.) It went down by two, down by three, up by four, and maybe now it will be up by five. Still at 14. No, it didn't change, but the design changed. 19 or 9, 12 down by two. It will be 9 next time. 10 - it went down by 2 again. 16, no that's wrong. It went up by 5. (He continues to count numbers.) I just want to see something. Okay. Oh great! Now we're going up. (Interesting.) That's it. (Do you have any ideas?) They were trying to attach with each other. As they attach, they somehow reproduce. Then they separate again.

Section II - His approach also shows directed trial and error (5.0). He sees clearly where he is going and what should happen. He is thinking about his thinking as he proceeds.

Section III - He makes observations (1.0) and predictions (1.0). He tests them out and revises when necessary (2.0).
(Is there any reason why you are picking those positions?) No. It is just at random. [Next day.] I want to try something different. [Danny tried something very different by varying positions using three tribbles. After trying this strategy several times, he changed to four tribbles.] (Why did you increase to four?) Well, I noticed that every time I used three, nothing would come. So I decided that maybe it would be different when I used four. [He discovered a result, but not quite what he expected. His pattern produced two tribbles on the next day. He began to laugh.] So if nothing comes up on the second or third day, then nothing is going to come up on the next day. (If you want to test this, try it.) You have to have at least two come out on the second day in order to have some come up on the next day. (Why are you placing them in those positions?) I want to try positions that I have never tried before. [Danny focuses on a very specific pattern and varies it by one tribble each time. It is as if he wants to see which position or positions is important. So one comes up now and if what I said before is right, another one will come up. [When his prediction did not come true, he tried something else.] Okay so I need to put in more tribbles the first time. [This time he places the tribbles in pairs.] Oh man. That’s weird. Eight tribbles worked, but ten tribbles didn’t work. Maybe nine would work. Or it could have been the position. [Now he focuses on a specific position—one that he has used with eight tribbles, but this time adds one more.] Okay so you

Section I - Danny also defined the task and saw that number (1.0) and position (2.0) were important. He notes symmetry and that specific positions are important (2.0).

Section II - Although Danny began with a random plan (.5) it became directed trial up. and error (3.0). Danny becomes very focused using a plan of action very carefully.

Section III - Danny is a good thinker and problem solver, moving from observation to revision. (4.0) He also seemed to think about his own thinking.

Tribble Score 12.5
Heuristic #2-1

Student #27

(Is there any reason why you are picking those positions?) No. It is just at random. [Next day.] I want to try something different. [Danny tried something very different by varying positions using three tribbles. After trying this strategy several times, he changed to four tribbles.] (Why did you increase to four?) Well, I noticed that every time I used three, nothing would come. So I decided that maybe it would be different when I used four. [He discovered a result, but not quite what he expected. His pattern produced two tribbles on the next day. He began to laugh.] So if nothing comes up on the second or third day, then nothing is going to come up on the next day. (If you want to test this, try it.) You have to have at least two come out on the second day in order to have some come up on the next day. (Why are you placing them in those positions?) I want to try positions that I have never tried before. [Danny focuses on a very specific pattern and varies it by one tribble each time. It is as if he wants to see which position or positions is important. So one comes up now and if what I said before is right, another one will come up. [When his prediction did not come true, he tried something else.] Okay so I need to put in more tribbles the first time. [This time he places the tribbles in pairs.] Oh man. That’s weird. Eight tribbles worked, but ten tribbles didn’t work. Maybe nine would work. Or it could have been the position. [Now he focuses on a specific position—one that he has used with eight tribbles, but this time adds one more.] Okay so you
have to have ten tribbles with one in A6 and in A6 in order to get a result. These positions are crucial. Okay. So it will be A6 and A8, B3 and B6 and D7, H5 and H7, J7 and J5, and B3 and B5. Okay. Now we get three. It should be something on the next day. [Nothing.] Darn it. I need an even number of tribbles on the first day. [Danny decided that specific positions were more crucial than others. He focused on individual positions within each pair. He predicts a pattern on the next day, but none arises; yet he gets a pattern on the third day.] You don't get any on the second day. [He smiles and stops.]

Student #28
[Heather immediately tries a five tribble arrow pattern headed to the right.] (Why?) No reason. [She gets result.] That's neat. [A pattern continues on the next day.] Boy, this is neat. There are four now. [Next day.] Now there are six. Ooh! [She continues for five more days.] (What do you think is happening?) The pattern keeps changing from a square to a diamond. They separate then come back together again. There seem to be three times as many tribbles as there were before. It's going back to a square again. [She continues for a few more days.] It looks kind of like a face, eyes like that. Ooh. They disappeared. One is like part of a cross. [She continues.] It's starting to repeat again. [She predicts what the amount will be next and she's right.] I think it is going to stay the same now. [She tries it.] She is right.

Section I - She tries to make the task workable (1.0) noting patterns are important and there is a pattern to the patterns (2.0).

Section II - Her approach is random (.5) and somewhat creative (.5). It appears that she is following some direction but she really is playing.

Section III - Heather makes observations. and predictions and tests them out (3.0).

Tribble Score 7.0
Heuristic #2-4
Student #29

[Patrick places two tribbles, one at each end of row 1.] (Why are you doing that?) I want to separate all. [Next day shows nothing. He continues for three days. He tries another pattern--four close together.] (Why did you try that pattern?) Ahm, to see what would do when they are close together. [The same patterns occur for two generations.] I think the it will happen again.

[He is right. Next he spaces them out a little more to see if that has any effect. The tribbles disappear.] They just disappeared. [Patrick tries three in a row, and one separated from the group.] (Why did you try that?) I want to see what will happen if they are separated. [The horizontal row changes to a vertical row, and the pattern reverses.] (What do you think will happen next?) The pattern will go back to what it was. [He is right. Now he places three in a row at the top and three in a row at the bottom.] (What do you think will happen now?) The pattern will change like the others. [They disappear.] (What do you think happened?) There is no more room on the screen so you can’t see them. If there were more room, the pattern would be the same [as it was before]. [Patrick stops.] They separate then re-attach, reproduce again.

section I
Patrick begins with a specific plan (1.0). He does not verbalize much; his actions show that position and symmetry (2.0) are important. Section II - Patrick uses specific moves. His behavior has a purpose. He is using directed trial and error (5.0). Section III - Patrick also follows a process and proceeds from making observations to predicting and testing (3.0).

Tribble Score 11.0
Heuristic #1