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Paper Title: **EXPERT SYSTEM AND PROBLEM SOLVING PATTERNS IN FREELY FALLING BODIES**

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Motion on a plane and two-body problems were found to be the most difficult problems in freely falling bodies for the subject of this study. The misconceptions obtained were mostly on directions of velocity and displacement and the implicit given in the problem.

The significant result of t-test for main gain score and the reduced number of misconceptions committed after treatment using Physics Problem Solver (PPS) indicate the effectivity of PPS as a tool for problem solving instruction.

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EXPERT SYSTEM AND PROBLEM SOLVING PATTERNS IN FREELY FALLING BODIES *

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ABSTRACT

Physics Problem Solver (PPS), a computer program based on a hypothesized

successful problem solving approach was developed to investigate problem solving patterns in freely falling bodies. There were three basic patterns identified during the analysis of the problem solving moves of the objects. These were linear, circular and looping. Out of 1,200 solutions done by 60 subjects, 24 different patterns were obtained. There were classified into four general patterns: linear, linear with circular, linear with looping and combinations of the linear, circular and looping.

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INTRODUCTION

Finding out what information and strategies a student uses and how these are used while solving a problem are difficult tasks confronting problem solving researchers. These tasks become more difficult as problem becomes complicated. Most studies on problem solving used video tapes, think aloud strategy and questionnaires in gathering information.

Expert system programs utilize human-like reasoning. These systems are presently used in solving problems in business and industry. Such systems could be used to investigate problem solving behavior of students and could be an effective tool in problem solving.

First phase of this study was aimed at constructing a model for a successful problem solving approach and developing a computer program based on this model. Part two was aimed at investigating problem solving patterns, misconceptions using the developed computer program (Physics Problem Solver) and determining the applicability of Physics Problem Solver (PPS) as a teaching tool for solving problems in freely falling bodies.

SUCCESSFUL PROBLEM SOLVING

Polya (1945) describes four stages of problem solvin- understanding, planning, executing and evaluating. These processes or stages are chained forward toward a goal. Expert problem solvers favor forward chaining while novice favor backward chaining. Although when problems are difficult backward chaining and trial and error strategies are also used by experts (Sweller, 1988 ; Hawks and Tsai, (1987). Each stage is chunked into specific subprocesses each with specific strategy and subgoals. Furthermore in the working memory (Short Term Memory or STM) are empty slots that need to be filled up in sequence, and the required fillers are the outputs in these subprocesses. The right side of the brain controls the start, checking validity, storing, retrieving and stopping.

Figure I is the hypothesized model of successful problem solving approach. It was hypothesized that an experts problem solver will favor the forward linear pattern. Consequently the poor problem solvers favor the backward and looping pattern.

Cognitive load and time to hold this load at STM are limited and short lived. Sweller (1988) ; Staver (a980) ; Lawson (1987). It was hypothesized that at the working memory only information and processes at a particular stage are present. The output of each stage is stored at the buffer storage, an extension of working memory. And these are chained and evaluated at the last stage.

PHYSICS PROBLEM SOLVER

The Artificial Intelligence (AI) Systems have been modeled after the human brain. Its expert system and neural network are parallel to the left and right sides of the brain. Expert system (left brain) excels when hard and fast rules and when precise computation are needed, while the neural network (right brain) excels at decision making and analysis.

The Physics Problem Solver used in this study was modeled after VP Expert System. It consists of inference engine, knowledge base and language. The inference engine navigates the knowledge base. The knowledge base consists of production rules expressed in If- Then Statements.

The Physics Problem Solver (Expert System) works hand-in-hand with the human brain (left brain) while solving a problem. It is hypothesized that after long interaction of left human brain with an expert system, the former becomes expert also. Expert System may be used as teaching tool in problem solving.

The design of Physics Problem Solver was based on the hypothesized model of Successful Problem Solving Approach (Fig.5). Teaching aspects were incorporated. Also it is capable of displaying all the stages and even the buffer storage. This was written in Pascal.

THE SAMPLE

The sample in this research consisted of all the students enrolled in Physics 121 (Introductory College Physics Course) offered at Trinity College of Quezon City, summer school year 1991-1992. The students were third year Medical technology and Computer Science major students who finished at least three units of Computer Science.

The students were randomly assigned to each group (experimental and control). All the students with odd diskette number were assigned to the experimental group while those with even number diskettes to the control group. There were 30 students in each group. There were 12 males and 18 females in the experimental group while 9 males and 21 females in the control group.

THE TREATMENT:USING PHYSICS PROBLEM SOLVER

After finishing the lesson on freely falling body, the students were given orientation on the use of PPS. The orientation lasted for four hours (one laboratory period). The next day the pretest using the PPS was given to these students. The pretest consisted of two sets, and this was conducted for two days, one set a day during their laboratory period. But the problems were given one at a time. The solution and moves were recorded on their diskettes. After the pretest, the students were randomly assigned to each group (experimental and control). All the students with odd diskette numbers were assigned to the experimental group while the even number diskettes were assigned to the control group. The experimental group was instructed to attend the problem solving sessions for six days (24 hours) during their laboratory period while the control group continued attending their laboratory class but they also had problem solving sessions minus the PPS. Both groups solved the same problems during the sessions. After finishing the problem solving sessions on freely falling body both groups took the posttest. The pretest and posttest problem sets were the same. The two tests were conducted in the same manner.

RESULTS

a) Problem Solving Patterns

There were 3 basic patterns identified during the analysis of the problem solving moves. These were linear, circular (repetition more than twice) and looping (move involving at least two stages). The actual moves were combinations of at least

two basic patterns. The two problem sets with five problems each and taken twice (Pre and Post) by 60 samples produced 1,200 different solutions that were interpreted and analyzed. There were 24 different patterns that were obtained (Table I). And these were classified into four general patterns. General pattern I includes 7 different patterns using linear. General pattern II includes 7 different patterns using linear and circular. General pattern III includes 3 different patterns using linear and looping. General pattern IV includes 7 different patterns using all the basic patterns.

The answers in each problem were corrected and classified into 3 types namely: successful, moderate and unsuccessful. The percentage of solutions falling under each type for all the different patterns were tabulated and plotted. Graphs I and II (percentage of solution vs. problem solving patterns) for Set 1 and Set 2 show the following: clusters of points for each type of solution, highest unsuccessful and successful points, specific patterns used by each type of solution, common patterns used by all types of solutions and unique patterns used only by a particular type of solution.

The clusters of points indicate the general patterns for the three types of solutions. For the successful problem solving the general patterns are General Patterns I and III (linear and linear with looping) for both simple and application problems. And for unsuccessful there were two general patterns for both simple and application problems. These were General Pattern I (linear with wrong values) and General Pattern IV (combination of all three basic patterns). It seems that there were two subgroups under unsuccessful, one with very limited knowledge and the other was just guessing. The moderate group used only one general pattern and only in simple problems. This was General Pattern II (linear and circular). This group used trial and error strategy.

The specific pattern is the pattern that was consistently used in at least four problems by each type of solution. For successful problem solving the specific pattern for both simple and application problems was Pattern 1a (linear and forward). For moderate they were patterns 2a, 2b, 2g (linear and circular) for simple problems and Pattern 4d (linear with looping and circular) for application problems. For unsuccessful the specific patterns were Patterns 4a and 4f (combination of linear, circular and looping) for simple problems and Patterns 1d and 1f (linear with wrong values) for application problems.

The common pattern is the pattern that was used by all samples whether they were successful, moderate or unsuccessful. There was none in simple and there were 3 patterns in application problems: Patterns 2g, 4g, 3b (linear with circular, linear with looping and combination of linear, circular and looping).

Unique pattern is pattern that was used only by a particular group. Pattern 1a (linear and forward) was used only by successful. Pattern 4f (combination of linear, looping and circular) was used only by unsuccessful.

Table II : Summary of Problem Solving Patterns of Successful Unsuccessful and Moderate Solutions

Set 1

	General Pattern	Specific Pattern	Common Pattern	Unique Pattern
Successful	I,III	1a		1a
Moderate	II	2a, 2b, 2g	none	none
Unsuccessful	I',IV	4a, 4f		4f

Set 2

	General Pattern	Specific Pattern	Common Pattern	Unique Pattern
Successful	I,III	1a		1a
Moderate	none	4d	2g, 4g & 3b	none
Unsuccesful	I',IV	1f, 1d		none
	^ I' wrong values			

b) Most Difficult and Easiest Problems

The highest successful points (Graphs I and II) indicate the easiest problems and the highest unsuccessful points indicate the most difficult problems. The easiest problems for the samples in both simple and application problems were about body dropped from rest. While the most difficult problems were about bodies thrown horizontally and at an angle and the two-body problem.

c) Treatment Effects

The experimental and control groups were not significantly different before treatment. This was shown by the t-test results of pretest scores of the two groups for both problem sets. After treatment the mean gain scores and mean gain speeds of the two groups were compared using t-test. There was a significant difference in the mean gain scores for both problem sets but none in mean gain speeds.

CONCLUSION

The successful problem solving patterns for simple and application problems were the same, linear and forward. Whereas the unsuccessful problem solving patterns for simple and application problems were different. For simple problems it was a combination of linear, forward and backward, looping and circular. And for application problems it was linear, forward and backward but wrong input of Find and Given variables. This seems to confirm McMillen (1986) that unless students complete stage one successfully , they would not be able to solve the problem. The few problem solving moves of unsuccessful problem solvers for application problems indicates their lack of exposure to application problems. This seems to confirm Lawson (1985) students are taught the concepts but they are seldom confronted with the type of problems to link cues with the right strategies.

The significant results of t-test for mean gain score for both problem sets indicate the effectivity of PPS as a teaching tool for problem solving in freely falling bodies. The extended memory feature of the program allowed more space for additional information that may have led to acquisition of right schema for problem solving. This seems to confirm Kuhn (1978), Sweller (1988) and Derry, Hawkes, and Tsai (1987).

RECOMMENDATION

It is recommended that teachers, curriculum developers and trainors emphasize sign conventions and explain motion along a curve more comprehensively. The results show the lack of exposure to application problem. These problems could provide the experience for students to think logically and critically. Using intelligent tutor as a tool and application problems may develop problem solving skills among students.

BIBLIOGRAPHY

Bodner, G.M. and McMillen, TLB (1986). "COGNITIVE RESTRUCTURING AS AN EARLY STAGE IN PROBLEM SOLVING". National Association for Research in Science Teaching. John Wiley & Sons, Inc.

Derry, S.J. (1987). "A THEORY FOR REMEDIATING PROBLEM- SOLVING SKILLS OF OLDER CHILDREN AND ADULTS". Educational Psychologist, 22(1), 55-87. Lawrence Erlbaum associated, Inc.

Hale, J.P. (1983). "PROBLEM SOLVING ANALYSIS : A PIAGETIAN STUDY". National Association For Research in Science Teaching. John Niley & Sons, Inc.

Harootunian, B. and Tate, M.W. (1960). "THE RELATIONSHIP OF CERTAIN SELECTED VARIABLES TO PROBLEM SOLVING ABILITY". Journal of Educational Psych., Vol. 51, No.6, 326-333.

Johnson, P.E. (1965). "WORD RELATEDNESS AND PROBLEM SOLVING IN HIGH-SCHOOL PHYSICS". Journal of Educational Psycho., Vol.56, No. 4, 217-224.

Kantowski, M.G. (1977). "PROCESSES INVOLVED IN MATHEMATICAL PROBLEM SOLVING". Journal for Research in Mathematics Education, Vol. 8, No. 3.

Knight, J.S. (1980). "THE ROLE OF STRUCTURE AND DEVELOPMENT IN SPATIAL PROBLEM SOLVING". J. Struct. Learn. Vol. 6, 215-235. Great Britain : Gordon and Breach Science Publishers, Inc.

Krajick, J.S. (1988). "A RESEARCH STRATEGY FOR THE DYNAMIC STUDY OF STUDENTS' CONCEPTS AND PROBLEM SOLVING STRATEGIES USING SCIENCE SOFTWARE". National Association for research in Science Teaching. John Wiley & Sons, Inc.

Kuhn, D. J. (1973). "a STUDY OF THE EFFECTS OF INCREASED LEVEL OF INFORMATION ON SUBSEQUENT PROBLEM SOLVING BEHAVIOR". School Science and Mathematics, 13 (Whole No. 642), 111-117.

Kulm, G. and Days H. (1979). "INFORMATION TRANSFER IN SOLVING PROBLEMS". Journal for Research in Mathematics Education, 10 (2), 94-100.

Larson, G. (1991). "LEARNING AND INSTRUCTION IN PRE- COLLEGE PHYSICAL SCIENCE". Physics Today : Vol. 44, No. 9, 56-62. American Institute of Physics.

Lawson, Anton E. (1985). "A NEUROLOGICAL MODEL OF SENSORY MOTOR PROBLEM SOLVING WITH POSSIBLE IMPLICATION FOR HIGHER ORDER COGNITION AND INSTRUCTION". national Association for Research in Science Teaching. John Wiley & Sons, Inc.

Lester, NK.K. JR. (1980). "PROCEDURE FOR STUDYING THE COGNITIVE PROCESSES USED DURING PROBLEM SOLVING". Journal of Experimental Education, 48 (4), 323-327.

McGuire, C. (1976). "SIMULATION TECHNIQUE IN THE TEACHING AND TESTING AND TESTING OF PROBLEM SOLVING SKILLS". Journal of Research in Science Teaching, Vol. 13, No. 2, 89-100. John Wiley & Sons, Inc.

Schoenfeld, A.H. (1982). "MEASURES OF PROBLEM SOLVING PERFORMANCE AND OF PROBLEM SOLVING INSTRUCTION". Journal for Research in Mathematics Education, Vol. 13, No. 1, 31-49.

Sherald, M. (1991). "SOLVING THE UNSOLVABLE". The Information Technology Journal for executives, Vol. 3, No. 11, 32-34. Philippine Computer Society.

Smith, M.U. (1988). "SUCCESSFUL AND UNSUCCESSFUL PROBLEM SOLVING IN CLASSICAL GENERIC PEDIGREES". Journal of Research in Science Teaching, Vol. 25, No. 6, 411-433.

Soreno, I.J. (1991). "RECOGNIZING HANDWRITTEN SIGNATURES USING NEURAL EXPERT SYSTEM". The Information Technology Journal for Executives, Vol. 3, No. 11, 24-30. Philippine Computer Society Publication.

Staver, JR. (1986). "THE EFFECTS OF PROBLEM FORMAT, NUMBER OF INDEPENDENT VARIABLES, AND THEIR INTERACTION ON STUDENT PERFORMANCE ON A CONTROL OF A VARIABLES REASONING PROBLEM". Journal of Research in Science Teaching, Vol. 23, No. 6, 533-542.

Swanson, H.L. and O' Connor, J.E. and Looney, J.B. (1990). "AN INFORMATION PROCESSING ANALYSIS OF EXPERT AND NOVICE TEACHERS' PROBLEM SOLVING". American Educational Research Journal, Vol. 27, No. 3, 533-556.

Sweller, J. (1980). "HYPOTHESIS SALIENCE, TASK DIFFICULTY, AND SUBSEQUENTIAL EFFECTS ON PROBLEM SOLVING". American Journal of Psychology Vol. 93, No. 1, 135-145.

Taylor, J.L. AND Evans, G. (1985). "THE ARCHITECTURE OF HUMAN INFORMATION PROCESSING : EMPIRICAL EVIDENCE". Netherlands: Science

Publisher B.V. Amsterdam.

Books:

VP Expert Building Tool

Smith & Cooper. "FUNDAMENTALS OF PHYSICS".

Sears & Zemansky (1976). "UNIVERSITY PHYSICS". Addison Wesley Publishing.

Weber, White, Manning & Weygard (1977). "COLLEGE PHYSICS". McGraw Hill Book Company.

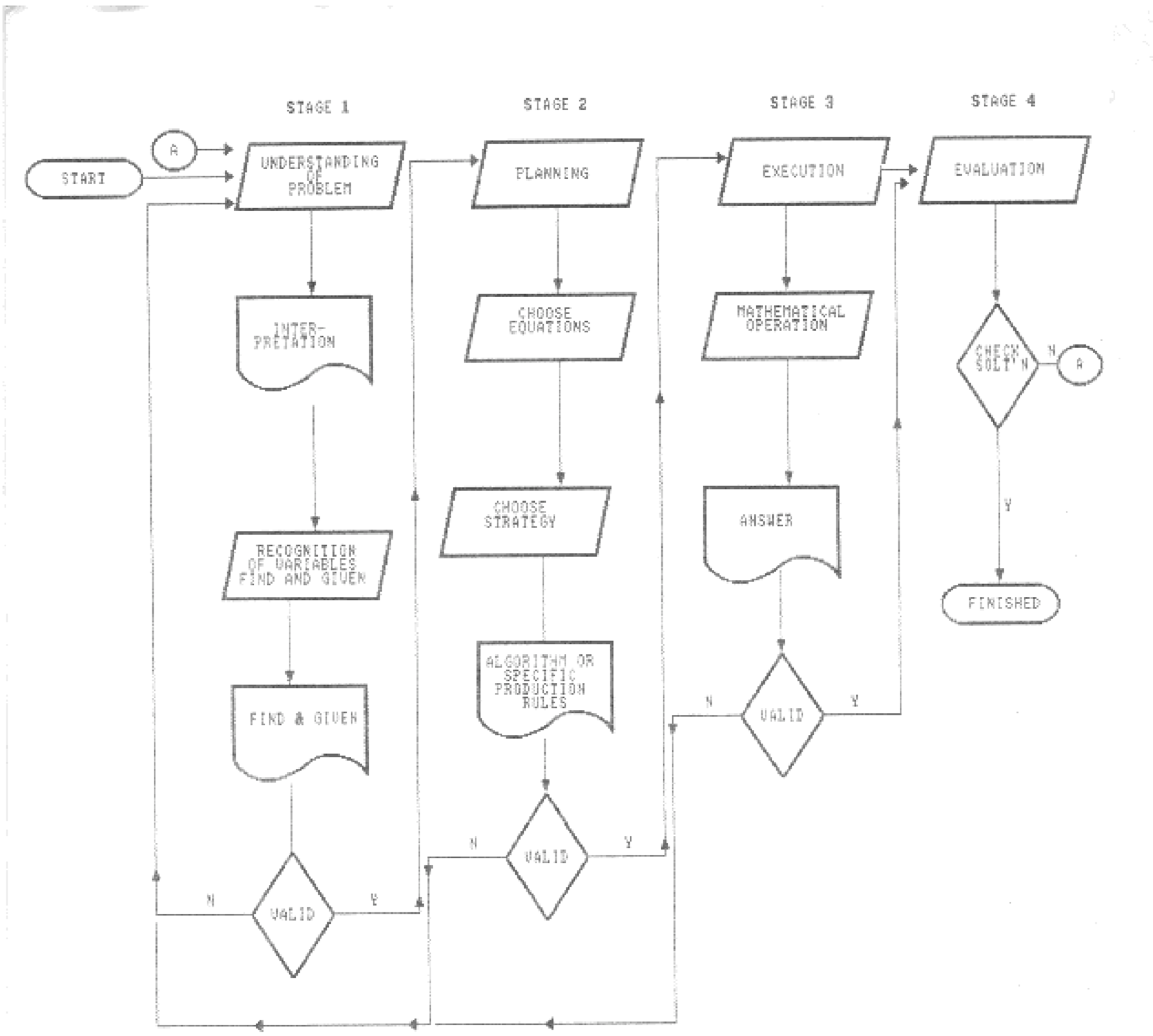


Fig. 1

Successful Problem Solving

Fig. 1 Successful Problem Solving

Table I PROBLEM SOLVING PATTERN

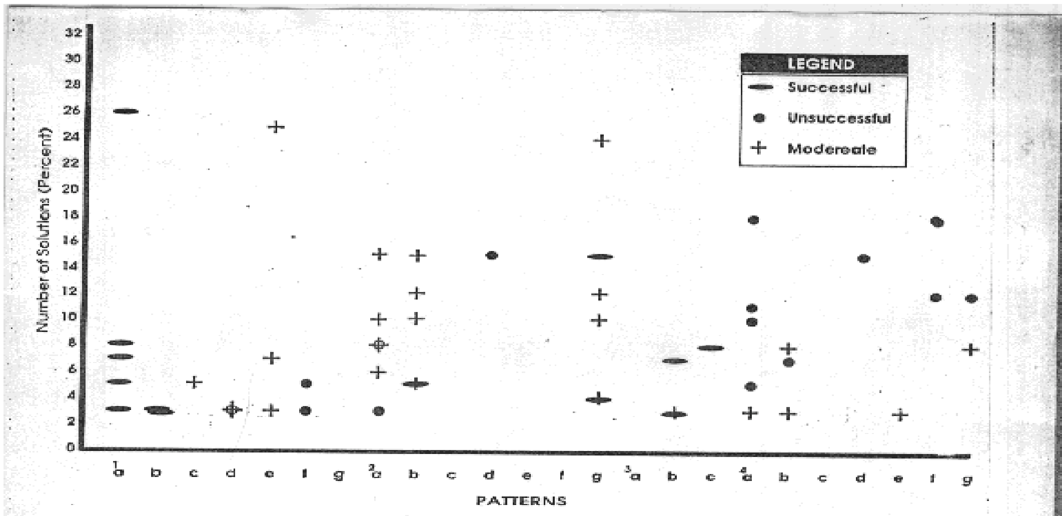
General Pattern I linear	General Patter II circular (trial & error) & linear	General Pattern III linear & looping	General Pattern I linear, circular & looping
1.a I -> F -> G -> E	2.a I -> F -> G -> E* <-	3.a I -> F -> G -> E <-	4.a I' -> F -> G - <-
1.b I -> F -> G -> E <-	2.b I -> F -> G -> E <-	3.b I -> F -> G -> E <-	4.b I -> F -> G -> <-
1.c I -> F -> G -> E	2.c I -> F -> G -> E	3.c I -> F -> G -> E	4.c I -> F -> G ->
1.d I -> F -> G -> E <- <- <-	2.d I -> F -> G -> E		4.d I' -> F -> G <- <
1.e I -> F -> G' -> E' <-	2.e I -> F -> G -> E		4.e I -> F -> G - <-
1.f I -> F' -> G -> E'	2.f I -> F -> G -> E*		4.f I' -> F -> G <-
1.g I' -> F -> G -> E'	2.g I -> F -> G -> E <-		4.g I -> F -> G - <- <- <-

legend: I - Interpretation F - Fined G - Given E - Equation

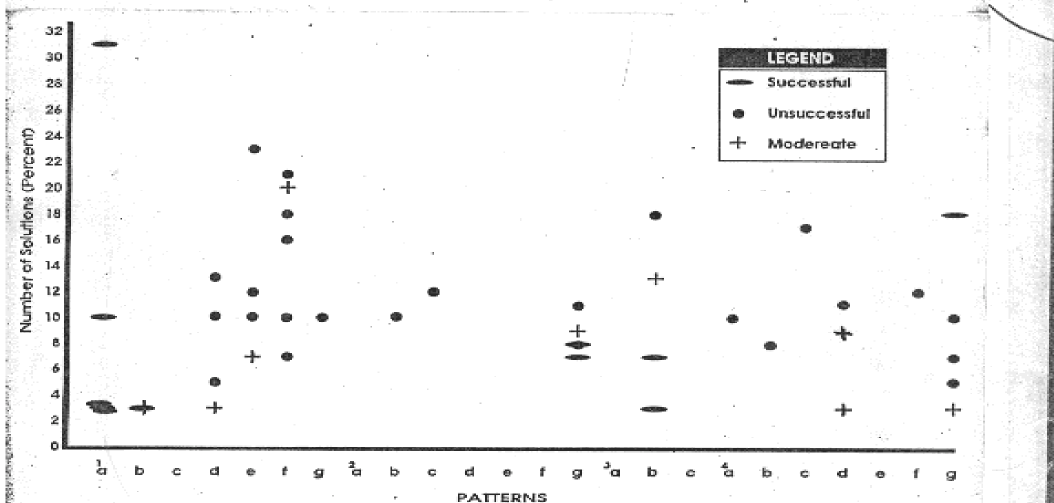
(I*) (F*) (G*) (E*) - tried all options

I' F' G' E' - wrong input of values

(I) (F) (G) (E) - tried more than twice



Graph I Combined Successful, Moderate and Unsuccessful Problem Solving (Set 1)



Graph II Combined Successful, Moderate and Unsuccessful Problem Solving (Set 2)

Graph I Combined Successful, Moderate and Unsuccessful Problem Solving (Set 1)

Graph II Combined Successful, Moderate and Unsuccessful Problem Solving (Set 2)