MEANINGFUL PROBLEM SOLVING WITH SCHEMA BASED INSTRUCTION

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Problems are crucial in physics learning because they are essential for enhancing the depth of conceptual understanding in the learner. The best means to understand a concept in Physics is by presenting that concept as the part of a problematic situation. This study examined the effects of a Schema Based Instruction on Problem Solving Ability in Physics among grade 11 students. A quasi-experimental pre-test, post-test non-equivalent group design was used. Two intact classes with a total of 114 students (60 in experimental group and 54 in control group) doing science course from two Government Higher Secondary Schools of rural background following NCERT syllabus were randomly assigned to either experimental or control group. The experimental group was taught problem solving through Schema Based Instruction, while the control group was taught through Direct Translation Strategy of teaching problem solving. Results indicated that Schema Based Instruction significantly increases the problem Solving Ability in Physics of grade 11 students better than the Direct Translational strategy of teaching problem solving.

INTRODUCTION

Physics students have this notion “I understand the concepts, but I just can’t solve the problems.” Young, Freedman, Ford and Sears (2004) say that in physics, “truly understanding a concept means being able to apply it to a variety of problems.” For effective and meaningful learning, the students must encounter various contextual problems. So it is meaningless to teach or learn physics concepts merely as a textual meaning or definition without giving due weightage to the problem solving process.

Researchers and educators regard problem solving as a necessary 21st century skill. In most disciplines the knowledge that is not used for problem solving tasks is too quickly forgotten within short time (Jonassen, 2010). Therefore the real goal of education in every educational context should be to engage and support meaningful problem solving. Unfortunately the traditional methods like Direct Translation Strategy for problem solving do not support meaningful problem solving. Some students and inexperienced teachers indeed think that the best way to solve problems in physics is to get equipped with a battery of equations and formulae that suits every problem situation. This notion regards problem solving as an answer getting process, not meaning making (Wilson, Fernandez and Hadaway, 2001). Problem solving is not a simple cognitive process like memorizing equations and mathematical operations. It includes a complex set of cognitive, behavioral and attitudinal components (Bautista, 2013).

Physics problems require careful analysis and interpretation of the problem scenario. The cognitive activities i.e. understanding a problem and organizing all relevant information meaningfully play a vital role in problem solving process. Jonassen (2010) argued that problem solving as a process has two critical attributes: first the mental representation of the problem (known as problem schema) and second the manipulation and testing of the mental representation in order to generate a solution. Successful problem solving requires domain of specific knowledge that includes both conceptual and procedural knowledge. Organization of conceptual knowledge and procedural knowledge of a type of problems in a meaningful pattern provides mental representation (schema) of that problem type. This mental representation of problems is the basis of successful problem solving (Chi, Feltovich & Glaser, 1981; Fuch & Fuch, 2005; Jonassen, 2004). Thus for meaningful problem solving to occur, students have to construct problem schema of the problem and to apply the correct problem solution plans based on those schema (Jonassen, 2010).

Review of earlier works on Schema Based Instruction discloses that "Schema Based Instructional Strategy" is an effective instructional strategy for promoting problem solving skill. Using a pretest–intervention-posttest–retension design, Jitendra, Star, Dupuis and Rodriguez (2013), studied the effect of Schema Based Instruction on Mathematical problem solving performance of seventh grade students. The study results demonstrate that Schema Based Instruction was more effective than students' regular mathematics problem solving instruction. Fang (2012) considered Schema Based Instruction as one of the most supported strategy for teaching word problem solving. Jitendra and Star (2011) claim schema-based instruction (SBI) as "an alternative to traditional instruction for improving the mathematical problem solving performance of students with learning disabilities (LD)". Schema strategy is a practical approach for training students with learning disabilities in solving word problems (Jitendra, DiPipi, and Perron-Jones, 2002)

PROBLEM SCHEMA

The concept problem schema means knowledge structure used to identify type of problem being solved (Rumelhart & Ortony, 1977). It is the mental representation of the pattern of information that is represented in the problem (Riley & Greeno, 1988). Researchers (Jonassen, 2010; Marshall, 1995;) have studied the role of problem schema on meaningful problem solving and found that a robust problem schema includes situational characteristics and structural information about the problem. According to them, most successful problem solvers are those who can integrate the situational and structural characteristics of the problems. Problem schema could act as a facilitator for improving problem solving skills in learners. If novices learn to organize all relevant information about different problem types in a meaningful and sequential pattern, information will be effectively and easily retrieved while solving problems. So the development of an Instructional strategy that enables novices to develop the same problem schema as conceived by the expert problem solver will enrich meaningful problem solving.

In the present paper the researcher designed Schema Based Instructional Strategy for teaching problem solving in Physics and examined the effect of the strategy, to increase Problem Solving Ability in Physics among grade 11 students. The investigator also designed schema diagram of various problem types included in the selected topics (example is given in Appendix 1). The design of Schema Based instructional strategy is an attempt to integrate the situational and semantic information of the problem. The design of the instructional strategy was based on the schema theory. According to Schema theory of problem solving, the problem solving ability depends on construction and development of schema of problems.

SCHEMA BASED INSTRUCTION

Meaningful Problem solving in physics requires not only calculation accuracy but also the comprehension of textual information, the capacity to visualize the data, the capacity to recognize the semantic structure of the problem, the capacity to sequence their solution activities correctly and capacity and willingness to evaluate the procedure that they used to solve the problem (Lucangeli, Tressoldi and Cendron, 1998). This implies that other than providing for calculations, the design of problem solving learning environment for Physics problems should include means to view the problem holistically to extract meaning from text, to construct situational model of the problem, to casually relate the data sets with structural configuration of the problem, to map the structure with readymade algorithms and to reflect upon the result of applying the algorithm on the basic premise of the problem.

In an attempt to make problem solving more meaningful, the investigator designed a Schema Based Instructional strategy. Schema based instruction is a method of teaching problem solving that emphasizes on both the semantic and mathematical structure of the problem. It utilizes recognition of key words (does a simple key-word strategy) but goes further than simple recognition to stress understanding of the situation represented in the problem (Marshall, 1995)

The composition of this instructional strategy has five basic components: the problem type, the structure map, problem schema, worked examples and practice problems. In this study the investigator classified problems in the selected topics: 'Work, Energy and power' in to following eight problem types: work, kinetic energy, potential energy, work-energy theorem, conservation of mechanical energy, conservation of linear momentum, mechanical power, and kinetic energy & linear momentum conservation. The classification was done based on the structural relationships embedded in the problems. The structure map is a network of the interrelationships between the different physical quantities in the problems (Gentner, 1983). Before attempting problems the learners should get acquainted with the structure map of each problem type (Example of structure map of problem type 'Work' is given in Figure 1)

Constructing and developing schema of each problem type is one of the crucial processes in problem solving. In this study, the investigator designed schema diagram of various problem types included in the selected topics. This schema diagram consists of the following attributes of robust problem Schema suggested by Jonassen (2010): Situation Model (consists of key features of problem scenario and its interpretation); Structural Model (represents inter-relationship between problem elements); and Arithmetic Model (represents required mathematical formula). A problem Schema represents a type of problems that can be tackled using it. Example of general framework of a Problem Schema of 'Work' type problems is given in Figure 2.

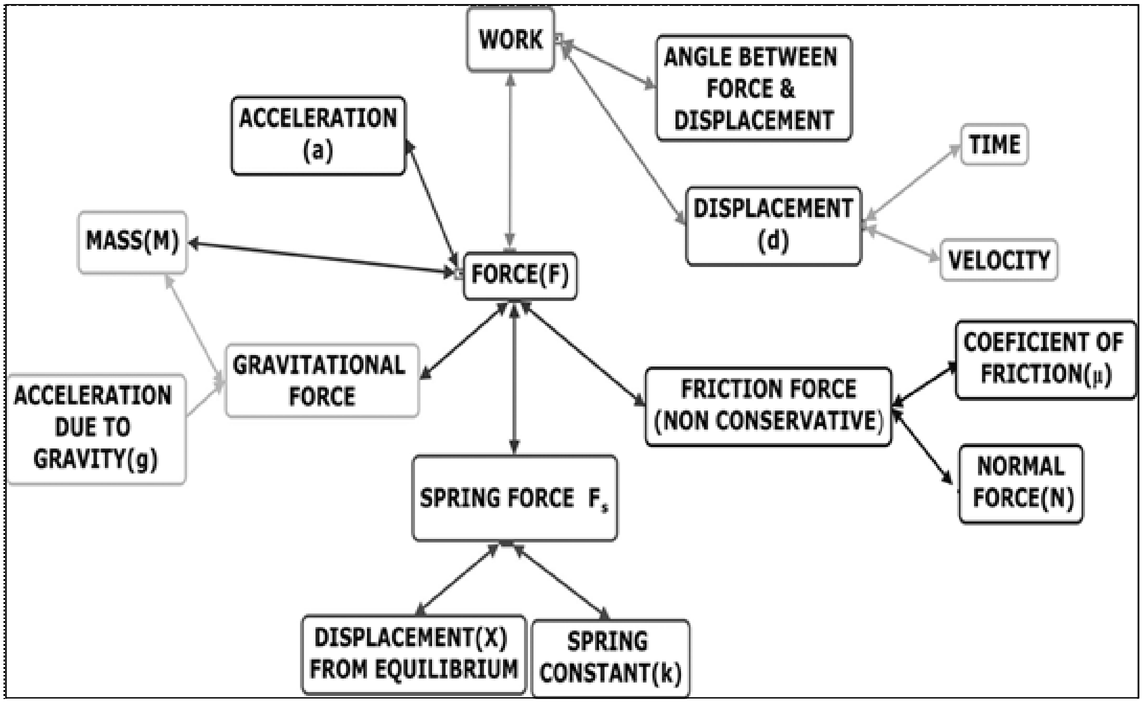

Figure 1: Structure map of problem type 'Work'

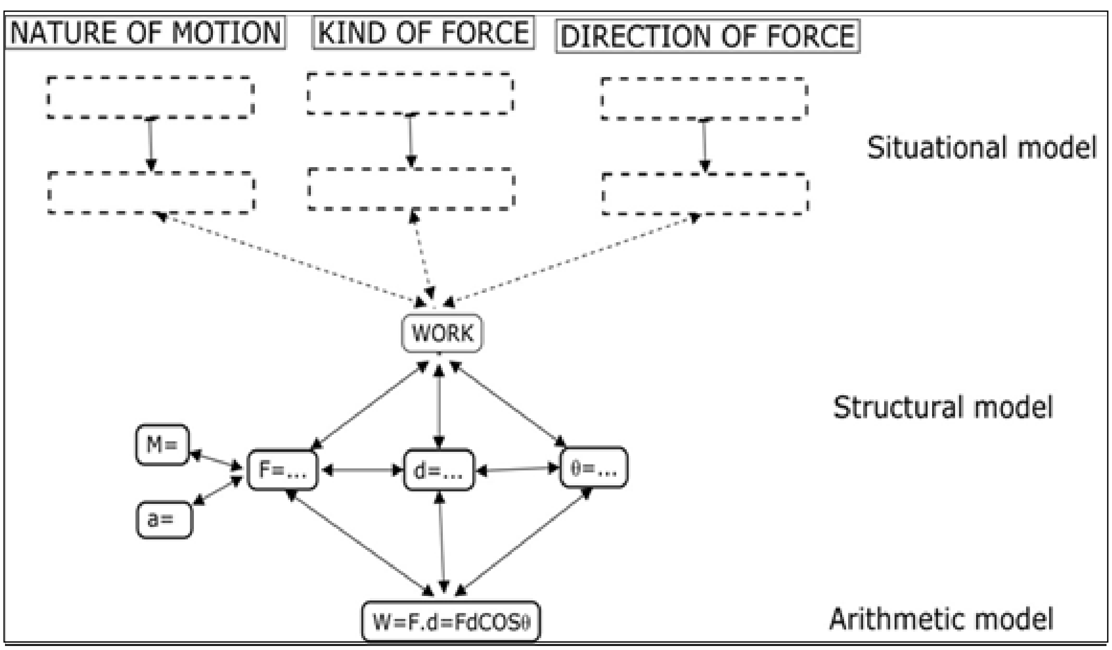

Figure 2: Problem schema of Problem type 'Work'

Physics problems require close reading of the statement to analyse the situations presented in it. This helps to get a feel of the problem and helps to identify the type of problem. Once we identify the problem type, the associated problem with the inclusive concepts and relations come in to our mind. This problem schema can be in the form of a readymade template for a problem type. Whereas this template serves as a basic structure to solve all problems of the type, it has to be outfitted with situational aspects as well as data sets to truly represent the problem at hand.

The 3rd component of the Schema Based Instruction is worked example. This involves hand holding the learner for walk through over the customized sequence of the schema based problem solving procedure. And the last component of Schema Based Instruction is the Practice problem. Practice problem helps learner to apply the newly learned skill in to practice. It gives them confidence to transfer the problem solving skill to new unfamiliar problems in the content domain.

The design of the Schema Based Instruction consists of the following phases:

1. Preparation for problem solving: The intention of this phase is to prepare the learner to solve problems of each problem type with the support of problem schema. In this phase Students are asked to list out familiar and unfamiliar concepts embedded in the problem scenario. They are also asked to draw situation diagram of the problem.
2. Familiarizing with problem types: The development of the situational and semantic information of a problem type and mapping all problem relevant information on to the problem schema of problem type are part of this phase. This includes understanding the concept embedded in the problem, identifying situational elements needed to solve the problem, identifying correct structural relationships in the problem, identifying the appropriate Problem schema.
3. Familiarizing with situationally dissimilar and structurally similar problems: Situationally dissimilar problems aid in recognizing the conceptual elements and to integrate it with the problem schema of the problem type. This phase includes comparing situational features with the help of situation diagrams.
4. Familiarizing with situationally similar and structurally dissimilar problems: in this phase teacher presents situationally similar and structurally dissimilar problems. Students are requested to select problems that can be solved with schema-1 (of type-1 problem). Students are also asked to formulate arguments for their selection of problems.
5. Practicing problem solving using problem schema: in this phase students are asked to practice problem solving by identifying key features of problem situation, drawing thumb nail sketch of problem scenario, identifying relevant data, identifying major concepts embedded in the problem, and identifying correct mathematical equations and operations.

DIRECT TRANSLATION STRATEGY OF PROBLEM SOLVING

According to Jonassen (2010), Direct Translation Strategy is a "form of problem solving that typically involves reading a well-structured story problem, attempting to identify the correct equation, inserting values from the problem statement into formula and solving for the unknown value." (p.308). In this strategy students learn to "directly translate the key propositions in the problem statement into a set of computations" (Jonassen, 2010, p.28).

OBJECTIVE OF THE STUDY

To find out the effect of instructional strategy (Schema Based Instruction/ Direct Translation Strategy of problem solving) with Non-Verbal Intelligence and Logical Mathematical Intelligence as covariates on Problem Solving Ability in Physics among grade 11 students.

METHOD

Quasi-experimental pre-test- post-test non-equivalent group design was used in the study. The symbolic representation of the design of the Experimental phase of the study is given below

$$G_1 \; O_1 \; X \; O_2$$
$$G_2 \; O_3 \; C \; O_4$$

Where, O_1, O_3 – Pre-tests; O_2, O_4 –Post-tests; G_1- Experimental group; G_2 -Control Group; X-application of experimental treatment; C- application of control treatment

Participants

Two intact class divisions of 114 students (60 in experimental group and 54 in control group) of grade eleven students doing science courses from two Government Higher Secondary Schools (Government Higher Secondary School Cheemeni and Government Higher Secondary School Vellur from Kasargod and Kannur districts in Kerala respectively) of rural background following Kerala state syllabus, were selected as the participants.

Research Instruments

The following standardized tests were used for the present study:

1. Standard Progressive Matrices (1996 Edition, prepared by Raven, Court and Raven published by Oxford Psychologists Press, Lambowne House, Oxford, UK): This nonverbal test is intended to measure the subjects' ability to discern and utilize a logical relationship presented by nonverbal materials.

2. Logical Mathematical Intelligence Test (prepared by the investigators): To measure the Logical Mathematical Intelligence of the subjects, a test was developed based on Logical Mathematical components of the theory of multiple intelligence proposed by Gardner (1983). Reliability of the test was established by the test retest method, on 31 grade 11 students doing science courses. The test-retest reliability coefficient was 0.74. The validity of the test was estimated empirically by comparing the scores of the test with Raven's standard progressive Matrices on a group of 48 grade 11 science students. The coefficient of correlation so obtained was 0.59.

3. Problem Solving Ability Test (prepared by the investigators): This test contained 14 Physics problems from the topics 'Work, Energy and Power'. Reliability of the test was established by the test-retest

method on 54 grade 11 students doing science courses. The test-retest reliability coefficient was found to be 0.77. Content validity was ensured by obtaining the judgment of four experienced higher secondary school physics teachers and three physics teachers in collegiate education from Kasargod and Kannur districts of government and aided sectors. Concurrent validity was estimated empirically by correlating the test scores of 54 grade 11 science students with their scores of Problem Solving Ability test developed by Praveen (2017). The coefficient of correlation so obtained was 0.64. Intervention study was performed to confirm construct validity (Brown, 1996) of Problem Solving Ability test.

All tests were administered as paper-pencil tests with appropriate time restriction.

Statistical Technique

Since the experiment was conducted using intact study groups of students of grade eleven, it was suspected that differences in Nonverbal Intelligence and Logical Mathematical Intelligence among subjects would influence the relation between instructional strategy and Problem Solving Ability in Physics. In the present study ANCOVA was used to remove statistically the effects of the extraneous cognitive variables (Non Verbal Intelligence and Logical Mathematical Intelligence) which would have an effect upon the dependent variable: Problem Solving Ability in Physics.

Data Collection Procedure

The investigator himself taught both the experimental group and control groups. The experimental group was taught through Schema Based Instruction. The students were taught the content of chapter 'Work, Energy and power' in the usual expository method of teaching and the problems were dealt in the Schema based method of instruction. The way of teaching Physics problems in the schema based instruction followed the same phases described in the design of schema based instruction. The control group was taught using the Direct Translation Strategy of teaching problem solving. The investigator himself taught the theory and problems of the content portion. The students were taught the content portion of the chapter Work, Energy and Power followed by the worked out problems. The very same set of problems given to the experimental groups were administered to the control group also; but in the usual way of Direct Translation Strategy of teaching problem solving. This would mean that the interventions in the groups differed only in the pattern of instruction of solving problems whereas the learning experiences employed to teach the subject matter remained the same in all the groups. Also the investigator could do justice to the experimental as well as the control groups by teaching them the very same set of problems for work out as well as for practice. The time taken for the entire treatment session was four weeks for each of the study groups. The standardized test for assessing Problem Solving Ability was re-administered in both groups after the completion of the treatment period.

RESULTS AND DISCUSSION

Effect of Schema Based Instruction on problem Solving Ability in Physics:

Table 1 gives the basic properties of the dependent variable Problem Solving Ability in Physics for the experimental and control groups.

Study group	n	Pretest		Post test	
		Mean	SD	Mean	SD
Experimental group	60	4.02	1.27	18.21	3.70
Control group	54	3.78	1.47	11.70	2.31

Table 1: Distribution of Pre-test and Post-test Problem Solving Ability in Physics

Table 1 shows that the mean and standard deviations of the pre-test scores of Problem Solving Ability in Physics among the study groups do not vary too much. But the mean post test score of Problem Solving Ability in Physics varies among the study groups. This is due to the effect of the intervention applied in the groups.

The effect of instructional strategy (Schema Based Instruction/ Direct Translation Strategy of teaching problem solving) with Non-Verbal Intelligence (NVI) and Logical Mathematical Intelligence (LMI) as covariates on Problem Solving Ability in physics for higher secondary school students was tested using one way ANCOVA. The results are presented in Table 2.

Source	Sum of squares	df	Mean square	F	Sig.	η^2_p
NVI	9.03	1	9.03	1.01	0.33	0.01
LMI	57.84	1	57.84	6.49	0.02	0.04
Instructional strategy	1134.69	1	1134.69	127.29	0.00	0.54
Error	980.58	110	8.91			

Table 2: Summary of ANCOVA of Problem Solving Ability in Physics for experimental and control groups

From Table 2 it is clear that the covariates - Non Verbal Intelligence and Logical Mathematical Intelligence - have no statistically significant effect on Problem Solving Ability in Physics for experimental and control groups at .01 level [for NVI: $F(1,110) = 1.01$, $p = 0.326$, $\eta^2_p=0.01$; for LMI: $F(1,110) = 6.49$, $p = 0.012$, $\eta^2_p = 0.04$]. There was a significant effect of instructional strategies on Problem Solving Ability in Physics, after controlling for the effect of Non Verbal Intelligence and Logical Mathematical Intelligence at .01 level [$F(1,110)= 127.29$, $p< 0.001$, $\eta^2_p = .54$]. The partial eta squared value indicates the effect size is large.

Comparing the estimated marginal means showed that the experimental group (which received Schema Based Instruction) has the higher mean of post-test scores in Problem Solving ability (M=18.29; CI=[17.50,19.07]); compared to control group, (M = 11.61; CI=[10.78,12.44]). Thus the ANCOVA result reveals that Schema Based Instruction is effective in increasing Problem Solving Ability in Physics compared to the Direct Translation Strategy of teaching problem solving.

CONCLUSION

In the present study the investigator attempted to validate a Schema Based Instructional strategy for its effectiveness on enhancing Problem Solving Ability in Physics among grade 11 students. It is ascertained that the Schema

Based Instruction significantly increases the Problem Solving Ability in Physics of grade 11 students, compared to the Direct Translation Strategy of teaching problem solving. Therefore the present study suggests the use of Schema Based Instruction for teaching problem solving. If a problem solving learning environment could be prepared by expert teachers using the elements of Schema Based learning, it could benefit the students to increase Problem Solving Ability in physics. This study clearly proves that the Direct Translation Strategy of teaching problem solving is not useful in improving Problem Solving Ability in Physics compared to Schema Based Instruction. Schema Based Instruction takes care of teaching problem solving in a meaningful way.

REFERENCES

Bautista, R. (2013). Students' procedural fluency and written-mathematical explanation on constructed response tasks in physics. *Journal of Technology and Science Education, 3*, 49–56. Retrieved from https://doi.org/10.3926/ jotse.68

Brown, J. D. (1996). *Testing in language programs.* Upper Saddle River. NJ: Prentice Hall Regents.

Chi, M.T.H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of Physics problems by experts and novices. *Cognitive Science, 5* (2), 121–152.

Fang, H. L. (2012). *The effects of simplified schema-based instruction on elementary students' mathematical word problem solving performance.* ProQuest LLC.

Fuchs, L. S., & Fuchs, D. (2005). Enhancing mathematical problem solving for students with disabilities. *The Journal of Special Education, 39*(1), 45–57. Retrieved from https://doi.org/10.1177/00224669050390010501.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences.* New York: Basic Books

Gentner, D. (1983). Structure mapping: A theoretical framework for analogy. *Cognitive Science, 7 (2)*, 155–170.

Jitendra, A., DiPipi, C., & Perron-Jones, N. (2002). An exploratory study of schema-based word-problem solving instruction for middle school students with learning disabilities: An emphasis on conceptual and procedural understanding. *Journal of Special Education, 36*, 23–38. Retrieved from https://doi.org/10.1177/00224669020360010301

Jitendra, A., Star, J. R., Dupuis, D. N., & Rodriguez, M. C. (2013). Effectiveness of schema-based instruction for improving seventh-grade students' proportional reasoning: A randomized experiment. *Journal of Research on Educational Effectiveness, 6(2),* 114-136. doi: 10.1080/19345747.2012.725804

Jitendra, A. K., & Star, J. R. (2011). Meeting the needs of students with learning disabilities in inclusive mathematics classrooms: The role of schema-based instruction on mathematical problem-solving. *Theory Into Practice, 50(1),* 12–19. Retrieved from https://doi.org/10.1080/00405841.2011.534912

John, Raven J. (2003) Raven Progressive Matrices. In: *McCallum R.S. (eds) Handbook of Nonverbal Assess-*

ment. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-0153-4_11

Jonassen, D. H. (2004). *Learning to solve problems: An instructional design guide.* Retrieved from https://www.pdfdrive.com/learning-to-solve-problems-an-instructional-design-guide-d18930675.html

Jonassen, D. H. (2010). *Learning to solve problems: A Handbook for Designing Problem- Solving Learning Environments.* Routledge Taylor&Francis group

Lucangeli, D., Tressoldi, P. E., & Cendron, M. (1998). Cognitive and metacognitive abilities involved in the solution of mathematical word problems: Validation of a comprehensive model. *Contemporary Educational Psychology, 23 (3),* 257–275.

Marshall, S. P. (1995). *Schemas in problem solving.* Cambridge: Cambridge. University Press.

Praveen, M. (2017). *Preparation and validation of a schema based instructional module with MOODLE to foster problem solving ability in physics at higher secondary level.* (Post Doctorial thesis), Farook Training College, Research Centre in Education, Calicut, Kerala, India.

Riley, M. S., & Greeno, J. G. (1988). Developmental analysis of understanding language about quantities and of solving problems. *Cognition and Instruction, 5(1),* 49-101. http://dx.doi.org/10.1207/s1532690xci0501_2

Rumelhart, D. E., & Ortony, A. (1977). The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, R. J., & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge* (pp. 99–135). Hillsdale, NJ:Lawrence Erlbaum Associates.

Wilson, J. W., Fernandez, M. L., & Hadaway, N (2001). *Mathematical problem solving.* Retrieved from https://staff.tarleton.edu/brawner/coursefiles/507/Problem%20solving%20article%20by%20Wilson.pdf

Young, H. D., Freedman, R. A., Ford, A. L., & Sears, F. W. (2004). *Sears and Zemansky's university physics: With modern physics.* San Francisco: Pearson Addison Wesley