"Understand It First!" Pedagogical and Assessment Practices with SOLO Taxonomy: An Overview on an Experimental Research Study

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*Abstract- SOLO Taxonomy, where SOLO stands for **Structure of Observed Learning Outcomes** is a five layered framework ((i)Pre-structural, (ii) Uni-structural, (iii) Multi-structural, (iv) Relational and (v) Extended Abstract) and a constructive approach advocated as to encourage and enhance learners' understanding from surface level to deep level. It was developed by an Australian educational psychologist and novelist **John B. Biggs** for assessing the quality of learning outcomes and the model of 'Constructive Alignment' for designing teaching and assessment. With these studies, the author-cum-researcher was intended to conduct an experimental research study and to experiment this taxonomy with Mathematics of secondary level. As Mathematics is a very logic based subject where understanding based learning is more essential rather than the mechanical learning or rote memorization or drill based learning. Also, it was learnt by the researcher that the Mathematics at secondary or higher secondary or higher education level is more theoretical learning and having very less practical approach or activities based learning compared to primary level. Thus with this concern, the researcher had developed the SOLO Taxonomy (with Constructive Alignment and SOLO Hexagon) based Instructional Strategy comprised with lesson plans, activities as well assessment tools (all based on SOLO Taxonomy) for the Mathematics of grade-IX and implemented through teaching learning processes in terms to measure the learnings as well as understandings of the learners as their achievements and their reactions/feelings about the new way of learning/creativity/thinking. With this focus, this paper has been developed by the researcher based on her Ph.D. research study. (As looking to the mentioned length of the paper, activities or lesson plans have not been illustrated here but it will be shown in the presentation if appropriate required time-duration will be provided for the presentation.)*

Key Words: Mathematics, SOLO Taxonomy, Constructive Alignment, SOLO Hexagon, Teaching-Learning

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Introduction

The nature of Mathematics according to the National Council of Educational Research and Training **(NCERT) (2010)** is that Mathematics reveals hidden patterns that help us to understand the world around us. Much more than arithmetic and geometry, Mathematics today is a diversified discipline, which deals with data, measurement, observations, deduction & proof, mathematical models, natural phenomena, human behaviour and social systems. Thus, Mathematics has occupied key part of an education system of any country.

From the literature reviews, it is learnt that Mathematics is the logic based subject where mastery or the grip on this subject can be acquired by better understanding and the thinking. Perhaps, **Gandhi and Varma (2007)** stated as it is important to note that present status of the Mathematics is the 'rote memorization (of the examples also)' and the 'traditional way of teaching' which are responsible for the poor performance of the children as well as for lowering the standard of Mathematics education. Also stated as, a large number of students have rarely understood Mathematics in its right perspective and meaning. Learning to think mathematically involves a great deal more than having large amounts of knowledge. But this notion should get reflected in the pedagogy being practiced by teachers in Mathematics classes. Apologetically, the roots of the tragedy lie in the structure of how Mathematics is taught. One understands how to think Mathematically when one is resourceful, flexible and efficient in one's ability to deal with new problems in Mathematics. The available research suggests that there may be better ways for students to learn Mathematics than mere listening to their teachers followed by drill. The perfunctory process that undergoes in the teaching of school Mathematics according to **Schoenfled (1987)** is: (i) A task is selected by the teacher to introduce a technique or skill, (ii) The technique is illustrated, (iii) More exercises are provided for practice in the illustrated skill.

The lifelong learning is necessary and meant to stress on the actual understanding (i.e. relational, not the instrumental) of the concepts and progressively leads to the higher thinking. To deal with such issues, new strategies or approaches are always required to research or to apply in order to avoid mechanical or boredom practices and to inculcate the active and constructive practices. With these perspectives and thoughts, the said research study was intended to try-out the experiment for the Mathematics teaching-learning within the structural levels of **SOLO**

Taxonomy developed on **'structure for increasing complexity in Understanding'** with the view as, "Teachers must actively cultivate the learner's intellectual skills rather than just to impart knowledge. Likewise, teachers need to assess their learners' intellectual skills, not just their capacity to memorise information".

Taxonomies of Learning: The Mean and Means

In general ways, the purpose or intention of any taxonomy is to provide a common understanding, on the part of the users, of what to teach and learners what to learn (often by using specific verbs, such as 'identify' or 'analyse'). This greater clarity about what students must be able to know and do is intended to: (i) ensure that learners learn – and not just to pass examinations and (ii) improve the efficiency and effectiveness of the assessment or

examining process by making sure that the assessment is directly related to the purpose of learning. Taxonomies can be used to: (i) define the syllabus or course for teachers so that they know what needs to be taught and to what extent, (ii) give clear objectives to learners for their course of learning, (iii) ensure that learners are not set over-simplistic or over-complicated assessment tasks for their course of learning, (iv) facilitate assessment of learning, (v) facilitate the grading of learners.

There are various Taxonomies used in framing educational or learning objectives. Following is a figure presenting an overview on some of the taxonomies while some more were searched by the researcher are mentioned here as: (a) Robert Gagne's Learning Taxonomy; (b) Bloom's Taxonomy; (c) Harrow's Taxonomy of The Psychomotor Domain; (d) Simpson's Taxonomy OfThe Psychomotor Domain; (e) Thomas' Taxonomy of The Psychomotor Domain; (f) Krathwohl's Taxonomy of The Affective Domain; (g) Anderson And Krathwohl (BloomRevised); (h) Marzano's New Taxonomy; (i) Fink's Taxonomy of Significant Learning; (j) Structure of The Observed Learning Outcome (SOLO); (k) Scottish Credit and Qualifications Framework and (l) Framework of Achievement.
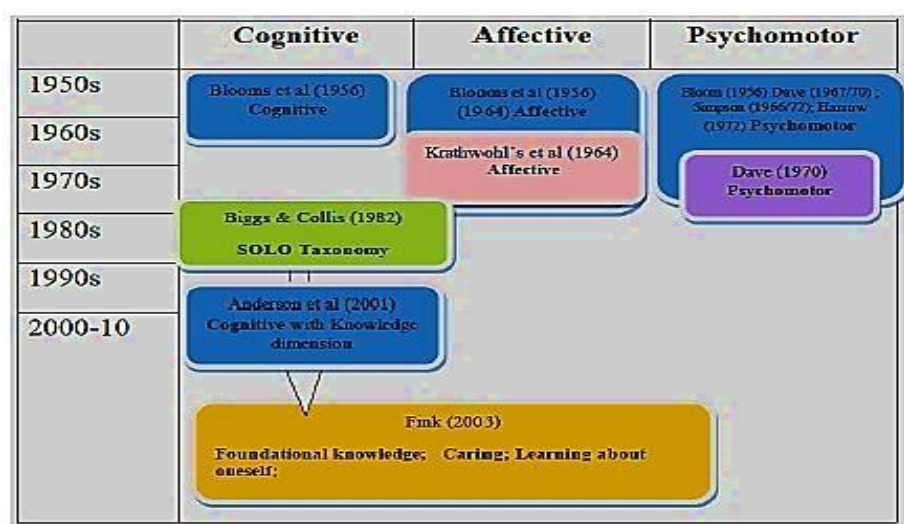
Figure – 1: Overview of development of Taxonomies and heir domains

(Source: http://www.ucd.ie/t4cms/taxonomies3.pdf)

After studying the mentioned taxonomies, the researcher found the 'SOLO Taxonomy-the framework mean to enhance the understanding from surface to deep level' as an appropriate approach to experiment its practices with Mathematics through a research study.

S.O.L.O. Taxonomy, Constructive Alignment and S.O.L.O. Hexagons
Let's have briefs on these three terms one by one.

SOLO Taxonomy

As per the **Biggs and Tang (2007)**, the SOLO is the short form of 'Structure of Observed **L**earning Outcomes'. It was developed by an Australian educational psychologist and novelist **John B. Biggs** for assessing the quality of learning outcomes and the model of 'Constructive Alignment' for designing teaching and assessment. It describes level of increasing complexity in a student's understanding of a subject through five stages as (i) Pre-structural, (ii) Uni-structural, (iii) Multistructural, (iv) Relational and (v) Extended Abstract. Also, it is claimed to be applicable to any subject area. Not all students get through all five stages, of course, and indeed not all teaching is designed to take them all the way. Below are the explanation and diagrammatic presentation about the five stages (levels) of SOLO taxonomy.
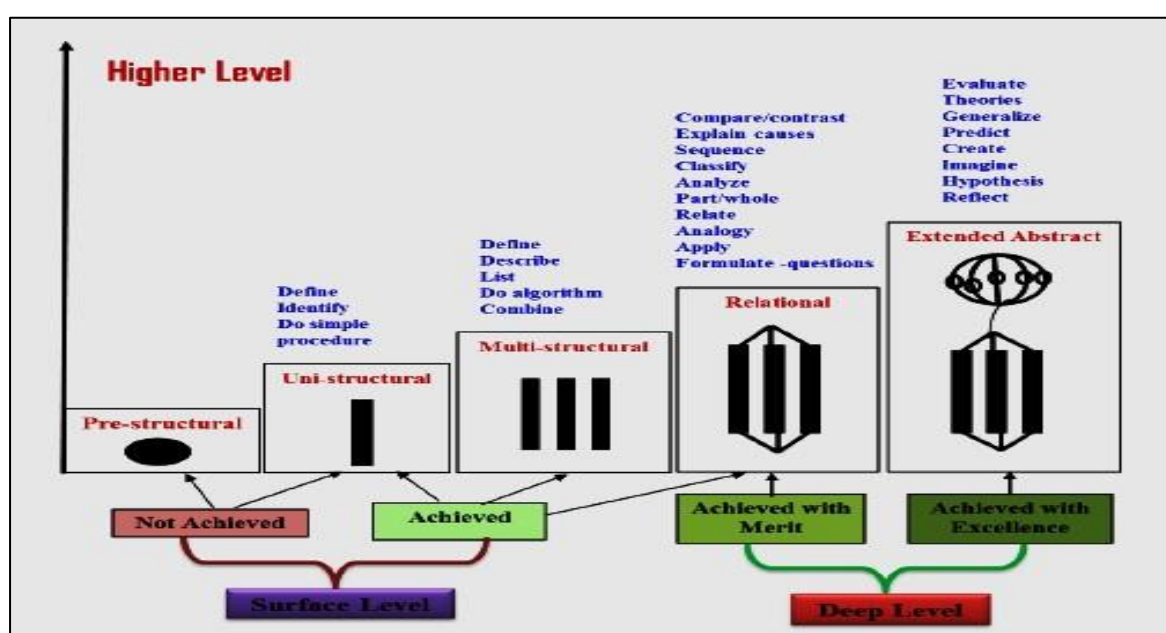

Figure   - 2 :   Levels of SOLO Taxonomy
(Source: http://pamhook.com/wiki/The_Learning_Process   )

Level – 1: The Pre-Structural Level
Here the student does not have any kind of understanding but uses irrelevant information and/or misses the point altogether. Scattered pieces of information may have been acquired, but they are unorganized, unstructured, and essentially void of actual content or relation to a topic or problem.

Level - 2: The Uni-Structural Level
The student can deal with one single aspect and make obvious connections. The student can use terminology, recite (remember things), perform simple instructions/algorithms, paraphrase, identify, name, count, etc.

Level - 3: The Multi-Structural Level
At this level the student can deal with several aspects but these are considered independently and not in connection. Metaphorically speaking; the student sees the many trees, but not the

forest. He is able to enumerate, describe, classify, combine, apply methods, structure, execute procedures, etc.

Level – 4: The Relational Level

At level four, the student may understand relations between several aspects and how they might fit together to form a whole. The understanding forms a structure and now he does see how the many trees form a forest. A student may thus have the competence to compare, relate, analyze, apply theory, explain in terms of cause and effect, etc.

Level – 5: The Extended Abstract Level

At this level, which is the highest, a student may generalize structure beyond what was given, may perceive structure from many different perspectives, and transfer ideas to new areas. He may have the competence to generalize, hypothesize, criticize, theorize, etc.

Constructive Alignment

According to the **Biggs and Tang (2007)**, Constructive Alignment is a principle used for devising teaching and learning activities, and assessment tasks that directly address the learning outcomes intended in a way not typically achieved in traditional lectures, tutorial classes and examinations. Constructive alignment was devised by Professor John B. Biggs, and represents a bonding between a constructivist understanding of the nature of learning, and an aligned design for outcomes-based teaching education. Constructive Alignment is the underpinning concept behind the current requirements for programme specification, declarations of Learning Outcomes (LOs) and assessment criteria, and the use of criterion based assessment. There are two basic concepts behind Constructive Alignment:

- Learners construct meaning from what they do to learn.
- The teacher makes a deliberate alignment between the planned learning activities and the learning outcomes

SOLO Hexagons: Graphical Organiser For Concept Arrangements

Hexagon is the geometrical figure consists of six sides/phases. With the sense of graphical organiser, this figure is meant to use as to represent a concept has chances to elaborate or expand or extend or widen or connect its meaning at most six ways or other six adjacent hexagons that also consist of relevant concepts or sub-concepts. This way of learning or practice helps learners to broaden their views or thinking.
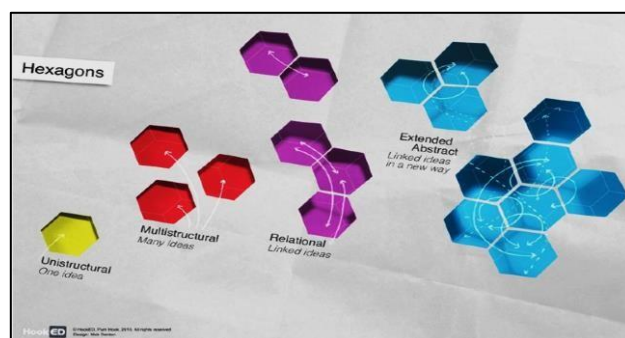
Figure-3: SOLO Taxonomy in the form of SOLO Hexagons

Why S.O.L.O. Taxonomy!

In short, it would be pointed as: (i) SOLO is the new theory basically leads to consistent thinking and understanding. (ii) Also**UNICEF (2005b)** stated as SOLO is a true hierarchic taxonomy – increasing in quantity and quality of thought. (iii) It is a potent instrument in differentiating curriculum and provides cognitive challenge for learners. (iv) Use of SOLO allows us to balance the cognitive demand of the questions that we ask and to scaffold students into deeper thinking and meta-cognition. (v) It also allows teachers and learners to ask deeper questions without creating new ones. (vi) Also, the feature of 'Constructive Alignment' intends towards the constructive approach and outcome based instructional designs in terms to encourage the studentcentred teaching-learning processes.

According to **Spady (1994)**, few points highlighted as (a) There is always an expectation that a learners' response/s can be improved through instruction and/or experience. (b) This notion of `capacity for continual improvement' is consistent with one of the basic principles of OBE (Outcome Based Education) is that - all learners can succeed if they have appropriate opportunities and time to learn and (c) The SOLO taxonomy enables teachers to make inferences about the depth of learners' understanding by examining the way they structure their oral or written responses to open-ended questions (A response may be anything from a short oral answer to a lengthy essay).

Research Reviews

All the research studies reviewed for the said study were divided in to five sections which are presented in the below table-figure with relevant details. Table-1

From the review of studies, the researcher found the gap or problem of 'the need of systematic or stepwise development of understanding in Mathematics'. Thus to proceed further in the same direction and it was also understood by the researcher that the levels of SOLO Taxonomy advocate the constructive approach and helps to organise the responses as well as the understanding of the learners. Also, the researcher didn't come across any SOLO Taxonomy based academic practices or researches in India. With these considerations, the researcher was proposed to conduct the research on the implications of the SOLO taxonomy for the Mathematics teaching-learning. Hence, the researcher had used the SOLO taxonomy in designing and developing the instructional strategy as well as in the assessment criterions of said experimental research study.

Distribution Of Reviewed Research Studies

Sr. No.	Category and Area of Mathematics	Years of the studies (From – To)	No. of Studies
I	Reviews on Misconceptions in learning of Mathematics	1979 - 2012	Total = 24 (03+21=24)
a)	Arithmetic	1991 - 2012	05
b)	Measurement	1979 - 2000	03
c)	Geometry	1988 - 2000	06
d)	Algebra And Calculus	1997 - 2012	05
e)	Probability And Statistics	1990 - 2000	02
II	Reviews on other Attributes concerned with Mathematics Education	1975 - 2013	Total = 42
a)	Attitudes	1979 - 2005	06
b)	Problem Solving	1985 - 2004	05
c)	Interactions And Responses	2000 - 2005	02
d)	Manipulative	2000 - 2013	07
e)	Constructivism	1999 - 2010	08
f)	Assessment And Achievement	1975 - 2012	14
III	Reviews on Instructional Strategies For Mathematics Education	1978 - 2010	Total = 10
IV	Reviews on Conceptual Understanding or In-depth learning in Mathematics	1980 - 2013	Total = 06
V	Reviews on SOLO Taxonomy	1987 - 2012	Total = 24
Total studies			106

Statement of the Problem

Developing And Implementing Instructional Strategy On The **S**tructure Of **O**bserved **L**earning **O**utcomes (SOLO) Taxonomy For Mathematics Of Class–IX

Objectives of the Study

- To develop the SOLO Taxonomy based instructional strategy for Mathematics of Class-IX.

- To implement the developed SOLO Taxonomy based instructional strategy in Mathematics of Class-IX.

- To study the effectiveness of the developed SOLO Taxonomy based instructional strategy with respect to the chapter-wise achievement of the group studied through developed instructional strategy.

- To study the effectiveness of the developed SOLO Taxonomy based instructional strategy with respect to the overall achievement of the group studied through developed instructional strategy.

- To study the effectiveness of the developed SOLO Taxonomy based instructional strategy with respect to the SOLO Level-wise achievement of the group studied through developed instructional strategy.

- To study the effectiveness of the developed SOLO Taxonomy based instructional strategy with respect to chapter-wise reactions of the group studied through developed instructional strategy.

- To study the effectiveness of the developed SOLO Taxonomy based instructional strategy with respect to the overall reactions of the group studied through developed instructional strategy.

Hypotheses

For the said study, there were total seventeen hypotheses from H_1 to H_{17} framed to meet with all the objectives stated above.

Delimitation of the Study

The said study was delimited in the manner as: (a) Only English medium secondary schools of theVadodara city those following the syllabus of the Central Board of Secondary Education (CBSE). (b) The experiment of the research study was conducted during an academic year of 2014-2015**. (c)** The study was also being delimited to the selected five chapters of Class-IX Mathematics. Selected Chapters were (i) Heron's Formula, (ii) Linear Equations in Two Variables, (iii) Quadrilaterals, (iv) Statistics, and (v) Probability.
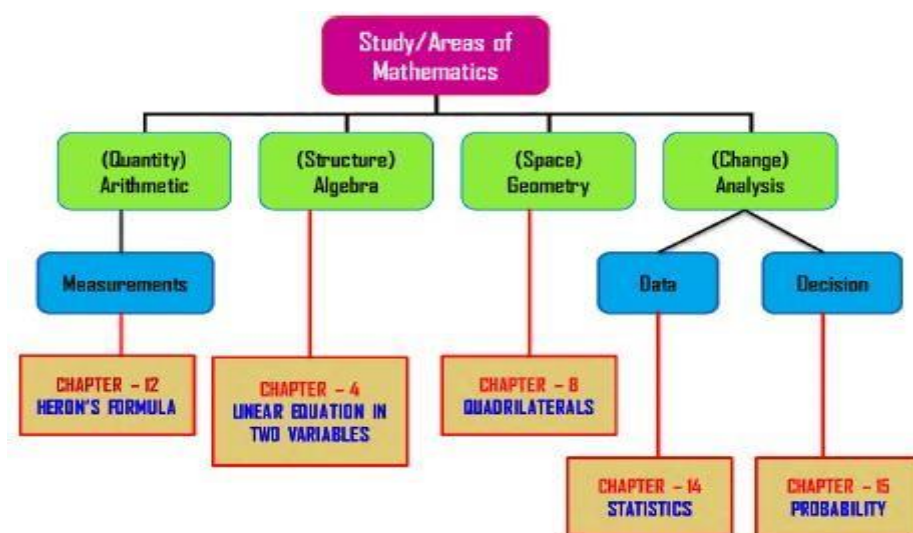
Figure-4: Selection for the chapters of class-IX Mathematics for the experimental study

Methodology

Research Design

This research study is the Experimental research study. The research design for a study is the 'Non-Equivalent Control Group Posttest Only', is one of the 'Quasi-Experimental-Designs'. Quasi-experimental designs are commonly employed in the evaluation of educational programs when random assignment is not possible or practical.

Variables

Independent Variable was The SOLO Taxonomy based Instructional Strategy developed by the researcher and the Dependent Variables were The (i) Achievements as well as the (ii) Reactions of the group studied through the SOLO based developed instructional strategy.

Population

The students of the thirty CBSE English medium secondary schools of the Vadodara city were constituted as the Population for the present research study, (source: CBSE website on 10/01/2013-some were affiliated and some were in pipeline to affiliation).

Sample

Two schools out of thirty CBSE English medium secondary schools were selected randompurposively with respect to the permissions of the schools in terms to be a sample of the said research study. Those two schools were selected as sample for the present experimental research study based on the following criterions as the researcher had set according to the need of the study: (a) Selected CBSE schools having secondary section that is at least having Class-IX. (b) A School whoever ready and permit to conduct experiments for the said research study for the longer duration as well to provide flexibility, liberty and necessary facilities as per the requirements of the research study. (c) After matching process, at least to get or have 25-40 students for a sample of the study.

Developed and ImplementedInstructional Strategy
Tools for Data Collection

Mainly two tools were used as, (i) Achievement tests and (ii) Reaction Scale were designed and developed by the researcher as well taken for the actual analysis in terms to draw out the findings and to make conclusions from it for this research study. Other tools were used as Field notes; Observation notes and the Reflection notes.

Techniques of Data Analysis

For the Data-analysis, various techniques were used as: (i) Descriptive Statistics; (ii) Graphical Presentations; (iii) Non-Parametric Method-MWW U Test; (iv) Rasch Analysis; (v) Frequency and Percentage; (vi) Chi-Square Test and (vii) Content Analysis
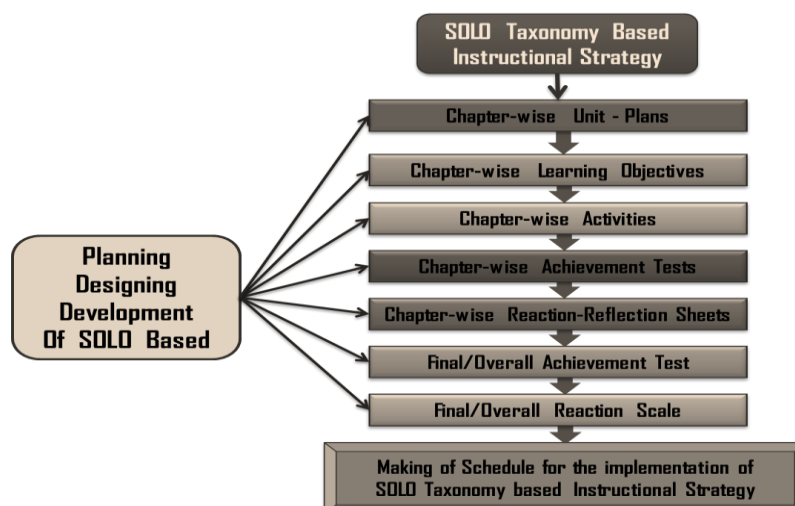
Figure – 5: Overview of SOLO based (complete) Instructional Strategy

Major Findings

Major Findings as in the forms of the Hypotheses testing as done by various Statistical analyses are presented in the following tables.

Table – 2: Data Analysis On Chapter-wise and Overall Test-scores Using Mann-Whitney U-Test

Table – 3: SOLO Level-wise Data Analysis On Overall Test-scores Using Mann-Whitney U-Test

Table – 4: Summary on testing of Hypotheses framed for the Chapter-wise and Overall Reactions   by using Chi-Square method

Table-2

Sr. No.	SOLO Levels	Sum Of Ranks		Max. RankSum	Calculated (R_x using)	Hypothesis Testing At Levels	
		R1	R2	R_x	U	0.05	0.01
1	Chapter - 12	1306	524	1306	59	H_1 Rejected	H_1 Rejected
2	Chapter - 4	1168.5	661.5	1168.5	196.5	H_2 Rejected	H_2 Rejected
3	Chapter - 8	1275	555	1275	90	H_3 Rejected	H_3 Rejected
4	Chapter - 14	1362.5	467.5	1362.5	2.5	H_4 Rejected	H_4 Rejected
5	Chapter - 15	1355	475	1355	10	H_5 Rejected	H_5 Rejected
6	Overall/Final	1365	465	1365	0	H_6 Rejected	H_6 Rejected

Table-3

Sr. No.	SOLO Levels	Sum Of Ranks		Max. RankSum	Calculated (R_x using)	Hypothesis Testing At Levels	
		R1	R2	R_x	U	0.05	0.01
1	Prestructure	1185	645	1185	180	H_7 Rejected	H_7 Rejected
2	Unistructure	1350	480	1350	15	H_8 Rejected	H_8 Rejected
3	Multistructure	1357	473	1357	08	H_9 Rejected	H_9 Rejected
4	Relational	1349	481	1349	16	H_{10} Rejected	H_{10} Rejected
5	Extended Abstract	1365	465	1365	00	H_{11} Rejected	H_{11} Rejected

Table-4

Sr. No.	Reaction Tools For	Frequency on Options for Reactions (in favor of)				χ^2	df	Hypothesis Testing At Levels
		Total	Positive	Neutral	Non-positive			
1	Chapter - 12	48	22	08	18	6.50	2	H_{12} Rejected**
2	Chapter - 4	40	16	05	19	8.17	2	H_{13} Rejected**
3	Chapter - 8	40	21	04	15	11.18	2	H_{14} Rejected*
4	Chapter - 14	40	20	07	13	6.37	2	H_{15} Rejected**
5	Chapter - 15	40	21	02	17	15.09	2	H_{16} Rejected*
		Total	Happy	Normal	Unhappy			
6	Section-II of Overall Reaction	2730	1224	664	842	179.96	2	H_1 Rejected*
7	Section-III of Overall Reaction	850	466	188	196	176.78	2	

*Rejected at Significance levels of 0.1, 0.05 and 0.01 // ** Rejected at Significance levels of 0.1 and 0.05

Interpretation

From the above major findings, it reveals that the developed SOLO based instructional strategy was effective as observed with reference to all the Chapter-wise Achievement Tests as well Reactions and Overall Achievement test as well Reactions conducted at Post-test level and had a substantial effect of progressive learning or understanding in Mathematics of the experimental group students studied through the developed instructional strategy compare to control group students studied through the conventional mode.

Graphical Presentation on Overall Achievement Test

Experimental Group   Vs.   Control Group
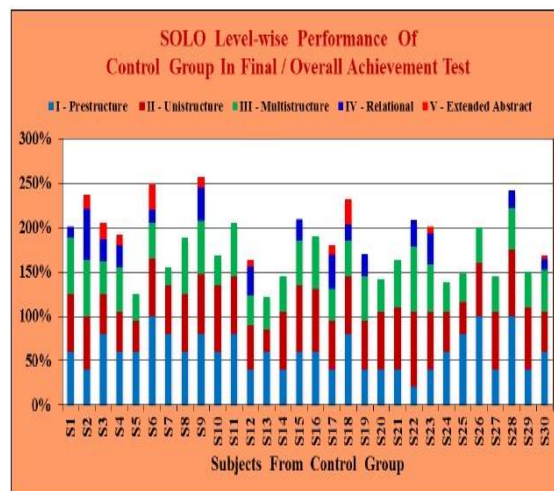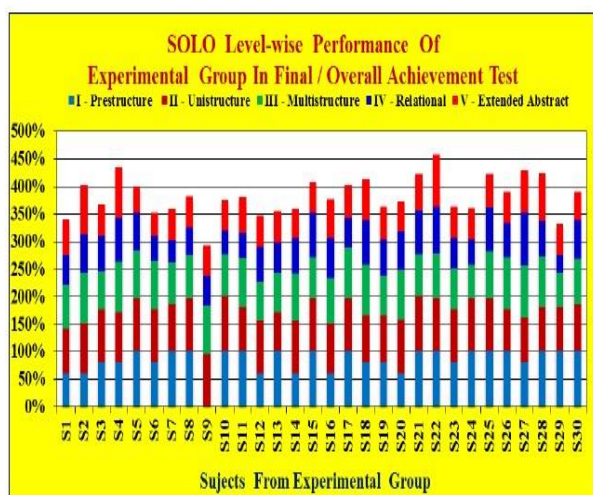
Conclusion

From the experimental research study conducted on SOLO Taxonomy, the researcher found the fair and favourable findings. Also, it was learnt as a suitable framework to practice the Constructivism in terms to carry the understanding level of the learners from surface to deep level. As well there is a scope to observe or measure the misconceptions or achievements through all the five levels of SOLO Taxonomy. This Taxonomy could be practiced at any grade level or even higher education level and for any subject or discipline. Authors of this paper also suggest to inculcate such innovative approach and practices in terms to bring practicum aspects to for learners to structure their knowledge. Teachers should be trained or updated with this taxonomy as a tool whenever needed to practice in terms to maximise the learning achievements.

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