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The Conceptualization, Theorization and Functional Structuring of SOLO Taxonomy in the Teaching of Science: An Anecdotal Description by a Researcher

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Key Words	Educational Objectives, Educational Taxonomy, SOLO Taxonomy, Levels of Understanding, Lesson Template, Infographics, Frequently Asked Question Generation Session				

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Abstract

Education primarily centers on the targets or goals, which are outlined by educational objectives, focused on the realization of fruitful learning experiences through instruction. Educationalists and mentors intend to cultivate distinct behavioural attributes in students, which are productively achieved through educational taxonomies. Taxonomies are cataloging structures based on a logistic pattern, which signify a group of thoughtfully conceived and precise terms, well-arranged from simple to complex and from concrete to abstract. Educational taxonomies are categorization frameworks to systematize educational goals and decide the suitability of particular learning outcomes in a simple and reasonable manner within the classroom. Various distinctive educational taxonomies have developed with the objective of extending the teacher-pupil collaboration beyond the four walls of the classroom. This paper is an upshot of the insightful scrutiny and analysis of the major educational taxonomies defined and developed by renowned educators. Among the chief educational taxonomies, the SOLO Taxonomy developed by Biggs

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ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

and Collis in 1982, which organized objectives in five levels of understanding as Pre-structural, Unistructural, Multistructural, Relational and Extended Abstract, was carefully studied, and an infographics on the SOLO Taxonomy was created. The investigator framed the phases as well as constructed lesson templates based on these phases, for each of the major educational taxonomies, including SOLO Taxonomy, in order to make them appropriate for classroom instruction. The investigator also spotted the struggles encountered in the real-life application of the SOLO Taxonomy in classroom scenario by way of a Frequently Asked Question (FAQ) Generation Session.

I. INTRODUCTION

Plentiful distinctive educational taxonomies had been propositioned by well-known educators, each of which is comprehensive in itself. Among them, Bloom's taxonomy has produced a noteworthy impression in the whole educational practices. But Bloom's Taxonomy had often been misemployed and misjudged by instructors. It fell short to recognize that learners might accomplish at unpredictable ability levels within each kind of higher order thinking skill. In realistic circumstances, it gave stress to the realization of the cognitive domain objectives only. These are all the difficulties with the application of Bloom's taxonomy in real classroom settings and not the theory itself. Sufficient educational taxonomies evolved after Bloom's taxonomy with the purpose of pushing the classroom instruction beyond memorization learning. Each one of them was exceptional regarding its marked attributes. They provide obvious illustrations of the shaping of the classroom instruction to satisfy the wants of the current generation. Furthermore, each of these taxonomies has a solid theoretical backing and is significant. Some of the existing major taxonomies of educational objectives developed till now, which were subjected to extensive review and analysis, are indicated below:

1. **Bloom's Taxonomy (1956)** developed by Benjamin S. Bloom, R H Dave Etal
2. **Experiential Taxonomy (1979)** developed by W. Steinaker and M. Robert Bell
3. **SOLO Taxonomy (1982)** developed by Biggs and Collis
4. **Mc Cormack and Yager's Taxonomy (1989)** developed by Mc Cormack and Yager
5. **Revised Bloom's Taxonomy (1990)** developed by Anderson and Krathwohl
6. **Jonassen, Peck and Wilson's Taxonomy (1999)** developed by Jonassen, Peck and Wilson
7. **Marzano's Taxonomy (2000)** developed by Robert Marzano
8. **Fink's Taxonomy (2003)** developed by Dee Fink
9. **Bloom's Digital Taxonomy (2007)** developed by Andrew Churches

1.1 SOLO Taxonomy in a Nutshell

SOLO (Structure of Observed Learning Outcomes) Taxonomy delivers a simple, dependable and strong model for the three levels of understanding – surface, deep and conceptual. As learning progresses, it becomes more complex. The SOLO taxonomy

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

was developed by Biggs and Collis in 1982. The biographies of Biggs and Collis are given in Figures 1 and 2 respectively.

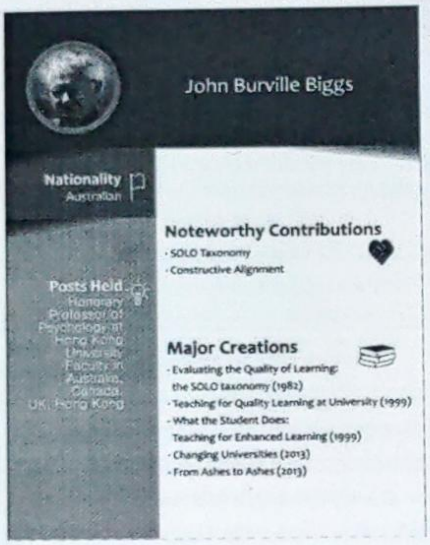

Figure 1: The biographies of Biggs

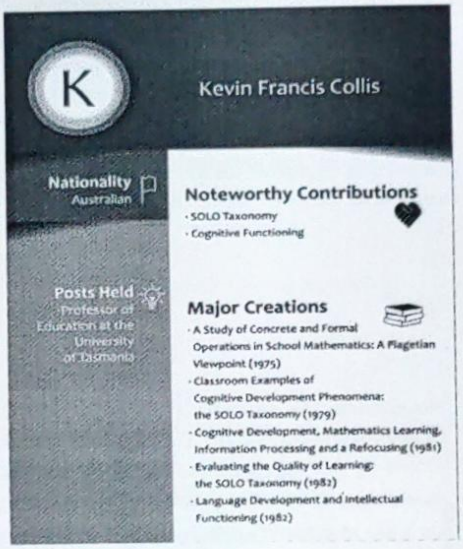

Figure 2: The biographies of Collis

The SOLO taxonomy, which indicates the Structure of Observed Learning Outcomes taxonomy, is a system of categorizing learning outcomes in terms of their complexity, facilitating us to evaluate students' work on the basis of its worth or quality, and not of how many bits that they got correct.

The five levels of understanding, as per the SOLO taxonomy are described below.

1. **Pre-structural:** At the pre-structural level of understanding, the task is inappropriately confronted, and the student has failed to notice the point or requires help to start. Here students are just obtaining bits of isolated and unconnected information, which have no organization and make no significance. The succeeding two levels, uni-structural and multi-structural are related to acquire information (surface understanding).
2. **Uni-structural:** At the uni-structural level, one feature of the task is grasped, and student understanding is disconnected and incomplete. The student is able to make simple and clear associations, but their significance is not understood. The leap to the multi-structural level is quantifiable.
3. **Multi-structural:** At the multi-structural level, numerous features of the task are identified, but their interactions to each other and the whole are missed. A number of connections may be made, but the meta-connections between them are missed, as is their implication for the whole. The advancement to relational and extended abstract outcomes is qualitative.
4. **Relational:** At the relational level, the features are interconnected and unified, and contribute to a deeper and more reasonable understanding of the whole. The student is now able to value the significance of the parts in relation to the whole.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

5. **Extended Abstract:** At the extended abstract level, the new understanding at the relational level is thought about at another conceptual level, dealt with in a new way, and used as the basis for extrapolation, simplification, reflection, or invention of new. The student makes connections not only within the given subject matter, but also ahead of it, generalizes and transmits the principles and ideas causing the particular occurrence.

The SOLO taxonomy portrays levels of increasing complexity in a student's understanding of a subject, by means of five stages, and it is found to be applicable to any subject area. Not all students pass through all the five stages obviously, and certainly not all teaching is intended to take them all the way. The uses of SOLO taxonomy are shown below.

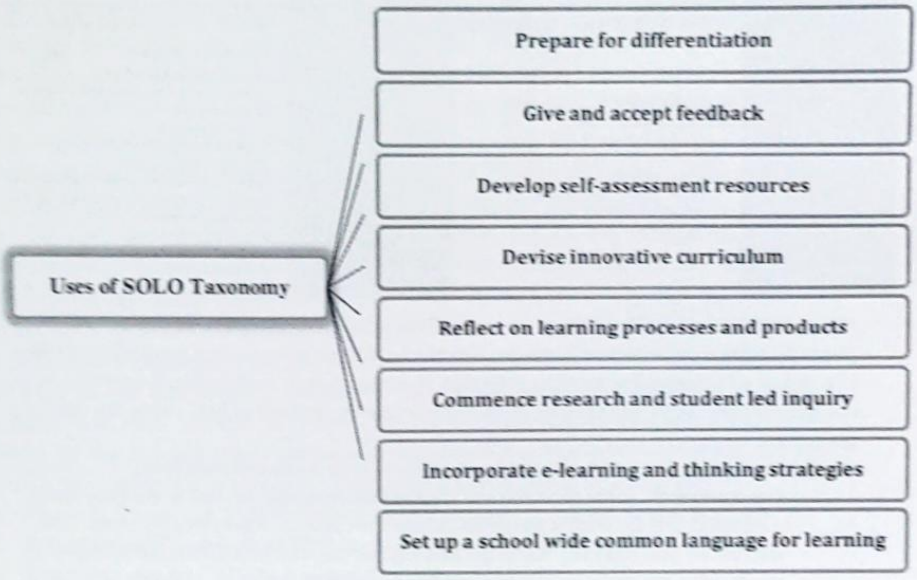

Figure 3: Uses of SOLO taxonomy

2. STATEMENT OF THE PROBLEM

The Conceptualization, Theorization and Functional Structuring of SOLO Taxonomy in the Teaching of Science: An Anecdotal Description by a Researcher

3. OBJECTIVES OF THE STUDY

1. To create and develop a fundamental structure in the form of phases for the SOLO taxonomy, so as to make it compatible to compose lesson transcripts for classroom instruction.
2. To design an infographics based on SOLO Taxonomy.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

3. To develop a lesson template on the SOLO Taxonomy based on the phases developed.
4. To identify the practical difficulties in the implementation of the SOLO taxonomy in actual classroom situations, leading to amicable way out predictions.

4. METHODOLOGY

The concept of SOLO Taxonomy has been theorized since 1982. But the practical application of this concept in actual classroom situations it rarely tracked. In this study, the investigator categorizes the methodology into the following heads:

4.1 Document Analysis
4.2 Peer De-briefing and Expert Consultation
4.3 In-house Design Studio Sessions (Self as well as technically supported)
4.4 Frequently Asked Question (FAQ) Generation
4.5 Way Out Prediction Exercise

4.1 Document Analysis

By means of an intense analysis of the theory of SOLO Taxonomy, the investigator created and developed a fundamental structure for the SOLO Taxonomy in the form of phases, which facilitates its implementation in the real classroom settings.

4.2 Peer De-briefing and Expert Consultation

Based on in-depth peer de-briefing and expert consultation of the investigator with the mentor, a sample lesson template on the SOLO Taxonomy was constructed to illustrate the model on the topic 'Conduction of Electricity' in Science, based on the phases developed.

4.3 In-house Design Studio Sessions (Self as well as technically supported)

By amalgamating the essence of the SOLO taxonomy, an infographics of the SOLO Taxonomy was designed by means of in-house design studio sessions by the investigator herself and also with a firm technical support. This created infographics includes the five levels of understanding, along with the specifications.

4.4 Frequently Asked Question (FAQ) Generation

A Frequently Asked Question (FAQ) Generation Session was conducted to identify the practical difficulties in the implementation of the existing major educational taxonomies. The session aimed at creating awareness about different educational taxonomies among the student- teachers and to extract maximum genuine doubts in the form of Frequently Asked Questions (FAQs). It was conducted among the student- teachers of the three teacher training institutions in Thiruvananthapuram, Kerala, namely Department of Teacher Education, Government College of Teacher Education and Mar Theophilus Training College.

4.5 Way Out Prediction Exercise

This part comprised a self-reflective session of construct building aimed to propose suggestive solutions to the difficulties identified in the implementation of SOLO Taxonomy through the FAQ Generation exercise.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

5. FINDINGS AND DISCUSSION

SOLO taxonomy turns out to be a dominant mental model for students and is efficient enough to change the way they reflect about their own learning outcomes. With SOLO, students are competent and encouraged to scrutinize their own progress in a learning task and to make intelligent judgments on their next steps. It also helps to represent levels of understanding that can be developed into the anticipated learning outcomes and to create the assessment criteria or rubrics.

5.1 Phases constructed for the SOLO Taxonomy

Through document analysis, the phases constructed by the investigator for the SOLO Taxonomy of educational objectives are described below:

Phase 1: Confrontation

In this phase, the teacher presents the concept to the students through a video or thought provoking questions. The students exhibit a curiosity to find out the missing points in the bits of unconnected information acquired.

Phase 2: Elucidation

The teacher asks the students to perform an activity related to the concept, and to identify the variables involved. Here, the students make simple and obvious connections between ideas. Then they describe their observations based on the variables identified. Here, more connections are being created, but lacks the meta-connections between them.

Phase 3: Association

The teacher asks the students to repeat the activity under different conditions and note down and explain the observations in each case. The students then compare and contrast their findings in the form of a table or chart. Here, the students see the significance of the various pieces of information and develop relationships between them. The teacher asks the students to use the information gained about the concept to enumerate the properties of the concept and find examples for it by relating the findings to real life experiences.

Phase 4: Generalization

In this phase, the students re- think the new understanding at another conceptual level, look at in a new way, and use as the basis for prediction, generalization, reflection, or creation of new. The students make connections not only within the given subject area, but also beyond it, generalize and transfer the principles and ideas underlying the concept.

5.2 Lesson Template Creation on SOLO Taxonomy

The sample lesson template constructed on SOLO Taxonomy based on peer de-briefing and expert consultation to illustrate the topic 'Conduction of Electricity' in Science is attached as APPENDIX 1.

5.3 Infographics Designing on SOLO Taxonomy

The infographics designed by the investigator, which includes the five levels of understanding, along with the specifications, by means of in-house design studio sessions, is as shown below.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

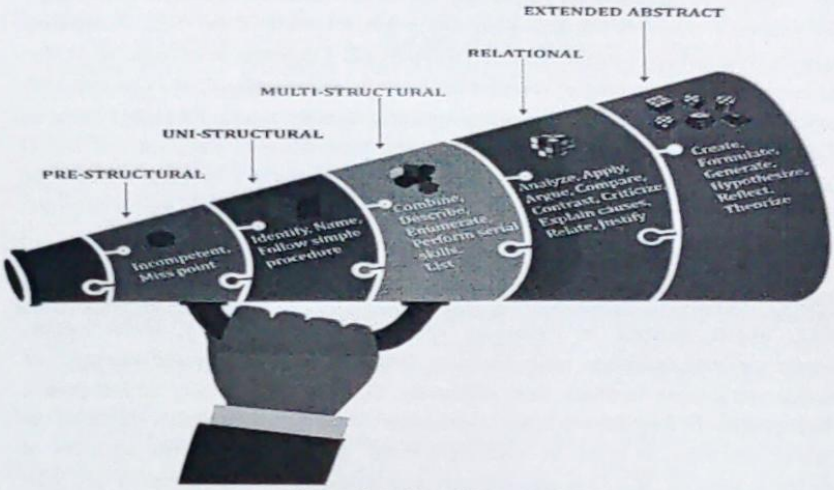

Figure 4: Inofgraphics on SOLO Taxonomy

5.4 Difficulties Identified in the Implementation of SOLO Taxonomy

Through Frequently Asked Question (FAQ) generation sessions, the difficulties identified in the implementation of SOLO Taxonomy is diagrammatically represented as follows

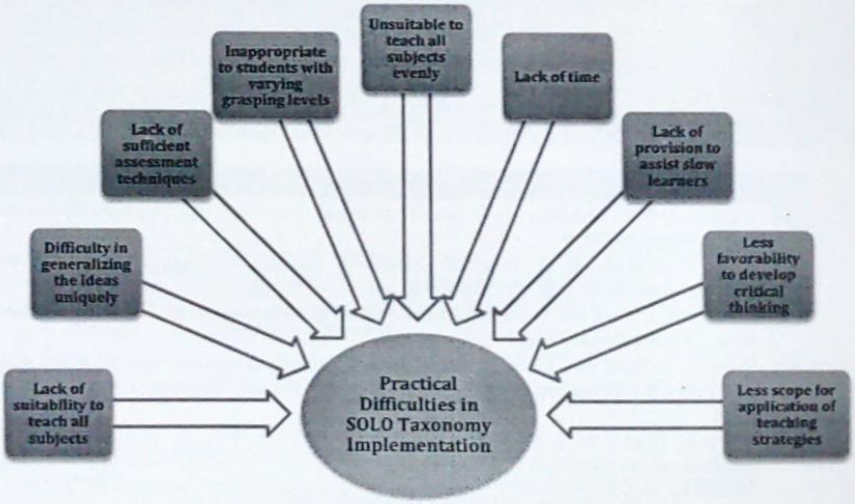

Figure 5: Difficulties Identified in the Implementation of SOLO Taxonomy

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

5.5 Suggestive Solutions for Improving the Implementation of SOLO Taxonomy

The proposed way out for improving the implementation of the SOLO taxonomy includes field testing of lesson templates using SOLO Taxonomy in multiple subjects of the curriculum, redesigning of school time table to accommodated study periods with varying period duration, designing of appropriate evaluation rubrics for classes based on SOLO Taxonomy as a follow-up to this study, remodeling of the phases of SOLO Taxonomy composed to suit with varying speeds of learners to accommodate the principle of inclusion etc. The Way out Prediction really offers much in the investigation to be carried in future.

VI. CONCLUSION

SOLO assists students in fashioning self-control, self-efficiency, metacognition, commitment and resilience while learning. Using SOLO, students and teachers can provide and discuss feedback more efficiently. SOLO is a supremely modest model, which progresses from idea to ideas to associate to extend. By explicitly depicting the learning outcomes, it gives the students a better understanding of the objective of everything they do. SOLO is educationally and rationally strong, supportive and well recognized. It is also highly dependable in that teachers and students manage to agree on what SOLO level the students have attained. SOLO challenges students to reflect more intensely by offering them a framework for thinking about unfastened ideas, coupled ideas and extended ideas. Thus the implementation of the SOLO Taxonomy in the appropriate manner could resourcefully be capable of grooming students for the future lives. Since the current theoretical compulsions bring about significant changes in the students' needs, they need to develop their knowledge and skill through need- based learning opportunities. Consequently, the taxonomies implemented today require an upgrade and facelift. As years pass by, the classroom picture transforms still more, along with the students' needs. In this context, it is indispensable to modify and upgrade the existing taxonomies.

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ISSN: 2347-1697
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Volume - 4, Issue -11, July 2017
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APPENDIX 1

SOLO TAXONOMY
(1982,Biggs and Collis)

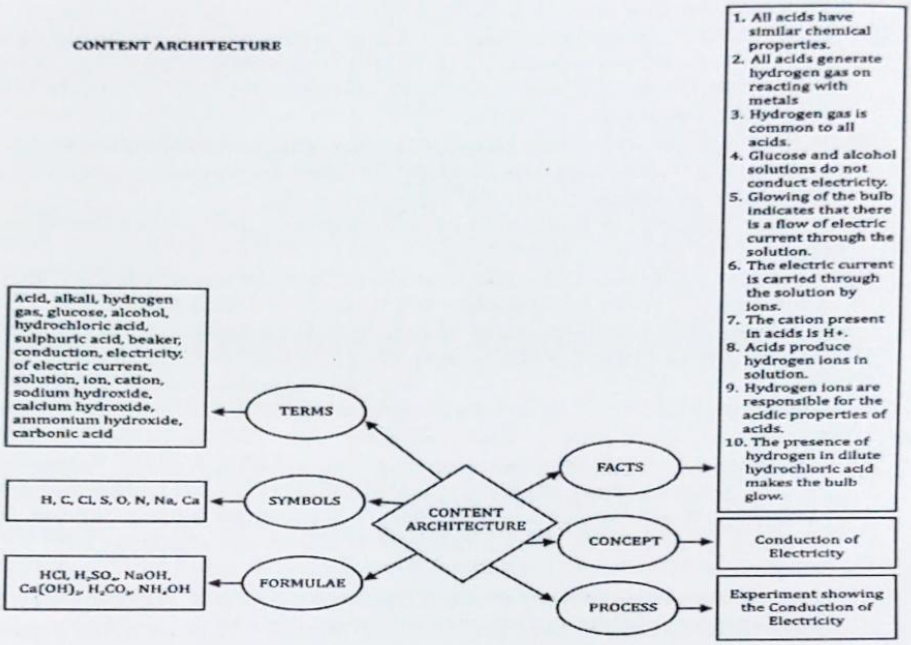
Name of Teacher	:	Name of School	:
Subject	: Science	Standard & Division	: X
Unit	: Acids, Bases and Salts	Duration	:
Subunit	: Conduction of Electricity	Date	:

STATEMENT OF CURRICULAR APPROACH

Through pupil centered, activity oriented,thinking stimulated, outcome based approach , the students exhibit increasing complexity levels in understanding about the conduction of electricity.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

CONTENT ARCHITECTURE



LEARNING OBJECTIVES

Phases	Learning Outcomes				
	Intellectual Skills	Cognitive Strategy	Verbal Information	Attitude	Motor S kills
Confrontation	✓				
Elucidation	✓	✓	✓		✓
Association	✓	✓	✓	✓	✓
Generalization	✓	✓	✓	✓	

(Note: The learning objectives are represented in the form of a grid with the phases of the SOLO taxonomy along the vertical axis and the expected learning outcomes along the horizontal axis. The list of the five learning outcomes advocated by Robert Gagne are given in the following reference: http://www.theoryfundamentals.com/gagne.htm)

SUPPORTING RESOURCES

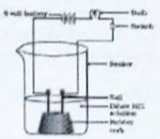
Two nails, cork, 100 ml beaker, 6 volt battery, bulb, switch, dilute hydrochloric acid, dilute sulphuric acid, ammonium hydroxide, sodium hydroxide, carbonic acid

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

SPECIFIC PROCESS SKILLS TO BE ATTAINED
Observing, communicating, classifying, using space/ time relations, inferring, predicting, formulating hypotheses, interpreting data, experimenting

PRE REQUISITES
The students already know that all acids have similar chemical properties, they generate hydrogen gas on reacting with metals and so hydrogen seems to be common to all acids.

	Phases Involved and Procedural Details	*Expected Pupils' Response*
Set Induction, Meaningful Verbal Learning	***Phase 1*: Confrontation** The teacher presents the flow of electric current through a solution to the students by asking some thought provoking questions as follows: * Do all acids have similar chemical properties? * What leads to this similarity in properties? The teacher discusses with the students on the conduction of electricity of acids and bases.	The students answer the questions as follows: * All acids have similar chemical properties. * All acids generate hydrogen gas on reacting with metals, so hydrogen seems to be common to all acids. The students express the commonly prevailing misconception that acids conduct electricity while bases do not, and exhibit a curiosity to find the missing points in their understanding.

	Phases Involved and Procedural Details	*Expected Pupils' Response*
Co- operative Learning, Multi- sensory Approach, Learning by Doing, Induced Thinking Principle	***Phase 2*: Elucidation** The teacher divides the class into small task groups and asks each group to fix two nails on a cork in a 100 ml beaker, connect the nails to the two terminals of a 6 volt battery through a bulb and a switch, pour some dilute hydrochloric acid in the beaker and switch on the current, as shown below:  He/ she asks the students to note down the observation. The teacher asks the students to tell the reason behind the observations.	The students perform the experiment in groups, and note the observation as the bulb starts glowing. The students describe their findings as the presence of hydrogen in dilute hydrochloric acid, which makes the bulb glow. The electric current is carried through the solution by ions. Since the cation present in acids is H+, this suggests that acids produce hydrogen ions in solution, which is responsible for their acidic properties.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume - 4, Issue -11, July 2017
Continuous 47th Edition, Page No.: 8117-8128

Phases Involved and Procedural Details	Expected Pupils' Response
Co- operative Learning, Multi- sensory Approach, Learning by Doing, Creative Construction of Knowledge	
Phase 3: Association The teacher asks the students to repeat the activity with dilute sulphuric acid, ammonium hydroxide, sodium hydroxide and carbonic acid and, describe the observations in each case, and compare and contrast their findings.	The students repeat the activity with dilute sulphuric acid, ammonium hydroxide, sodium hydroxide and carbonic acid. They note down the observations as sulphuric acid and sodium hydroxide solutions conduct electricity whereas ammonium hydroxide and carbonic acid solutions do not conduct electricity. Glowing of the bulb indicates that there is a flow of electric current through the solution. The students compare and contrast their findings in the form of a table as shown:

Solution	Nature	Glowing of bulb
Hydrochloric acid	Strong	Bright
Sulphuric acid	Strong	Bright
Ammonium hydroxide	Weak	Dim
Sodium hydroxide	Strong	Bright
Carbonic acid	Weak	Dim

Phases Involved and Procedural Details	Expected Pupils' Response
Co- operative Learning, Creative Construction of Knowledge, Correlation, Induced Thinking Principle	
Phase 4: Generalization The teacher asks the students to generalize the learned things and generate examples of conduction of electricity in everyday life.	The students generalize the ideas as follows: A strong acid or base, which contains a large number of ions, strongly conducts electricity and a weak acid or base, which contains less number of ions, weakly conducts electricity. They also generate examples of conduction of electricity in everyday life as follows: * The wires in our house conduct electricity and allow lights to come on when the switch is flipped. * Salt water has properties that allow for excellent conducting of electricity. * Dirty water conducts electricity much better than clean water. * Some gases, like oxygen, nitrogen and carbon dioxide, become good conductors when they are exposed to different elements. During an electrical storm, barometric pressure drops and the atmosphere become denser and these gases become conductors.

CLASSROOM EXTENSION
Do acids produce ions only in aqueous solution? Explore.

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