



## THE RELEVANCE OF DIAGRAMS IN SCIENCE TEACHING AND LEARNING

**Rajesh Kumar<sup>1</sup> & Gaurav Rao<sup>2</sup>, Ph. D.**

<sup>1</sup>*Research Scholar, Sr. Secondary Science Teacher, Kanhai Inter School, Nawada (Bihar) 805110.*

<sup>2</sup>*Assistant. Professor, Department of Education, C.S.J.M.UNIVERSITY, Kanpur.-208024-U.P.*

### Abstract

*Since time immemorial, the educational process debatably involves a mediated communication between teachers and learners to add sense or meaning making for both the stakeholders. The diagrams and various illustrations are the meaningful resource to mediate the educational journey. Diagrams can break out of the linear and systemic nature of printed text to show non-linear and systemic feature. In Science teaching and learning process, the use of diagrams is more relevant to make the representations of complex systems. Presently the pedagogy of Science is becoming modified from Linguistic methods to a mixed-visual methods supplemented with new techniques. Diagrams and diagramming are features of teaching and learning practices both as a means of Instruction and as a means of training learners in the use of diagrams that are features of many working and practicing teachers. There is also seemingly important need to make diagrams accessible and meaningful to students, quite contrary to the mechanical manner in which it is perceived and used by them. This paper discusses the Diagrams and their relevance in Science teaching and learning since they have different purposes and are required for understanding and communication.*

*Key words: Linguistic, Mixed-visual methods, Diagrams, Non-linear.*



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### Introduction

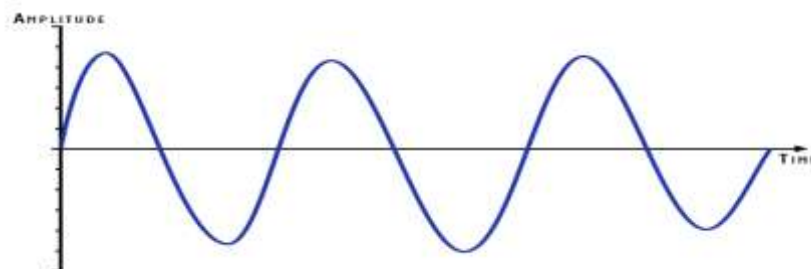
This paper attempts to justify the relevance of the diagrams in Science teaching and learning. Both teaching and learning requires the manipulation and communication of data and Informations. The manipulation involves the structuring of the data and Information into meaningful patterns by teachers and/or learners that are understandable to both teacher and learners. The communication involves the way and form in which that structured data and Information is conveyed from the teacher to the learner and vice-versa. The full educational process arguably involves a mediated discourse between teachers and learners to aid sense or meaning making for both parties and in which the data and Information involve combinations

of words, numbers, symbols and diagrams of varying type. All representations can be seen as sense making models of messy situations or complex system (**Lane-2002**).

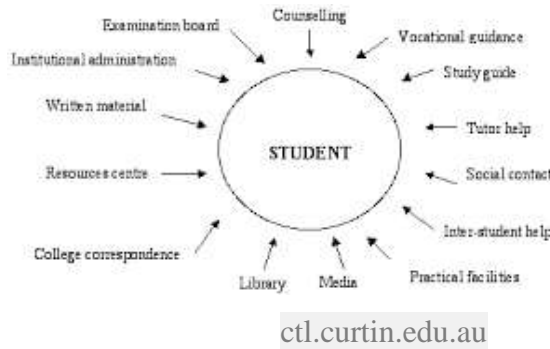
From the long tradition, the visualization of the objects is being done in the process of teaching. The educational community is generally agreed on visualization as an effective teaching tool. Current applications of visualization are found in many teaching contexts, including mathematics, reading, science and technology. With the advent of techniques, the tools for visual representations of the objects in the process of teaching have been replaced with Diagrams. Presently the diagrams are frequently appearing in textbooks and research publications.

Diagrams are representations of reality as seen or perceived by the persons creating them, mental constructs given a physical form to aid thinking, communication and action. Diagrams have been used since ancient times, but have become more prevalent during the enlightenment. In the words of **Anderson(1997)**, the Diagrams are pictorial, yet abstract representations of information and maps, line-graphs, bar-charts are all examples except the photographs and videos. On the other hand, *Lowe* (1993) argued Diagrams as specific abstract graphic portrayals of the subject matter they represent. However, *Hall* (1996) suggested Diagrams as simplified figures, caricatures in a way, intended to convey essential meaning/s. There are a number of ways Diagrams can be categorized. **Lane (2002)** has distinguished between four types of representations that goes beyond their use in teaching and learning to also cover the professional uses of Diagrams.-

- 1.) *Analogue Representations*- Here the Diagram looks like similar to the object it portrays. Such Diagrams play little part in most systems studies but are widely used in much scientific and technological work.



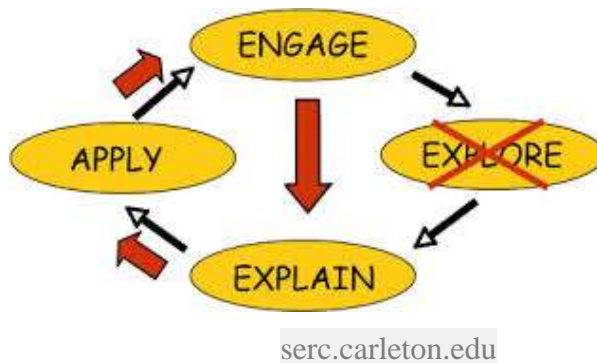
- 2.) *Schematic Representations*- Here the Diagram represents the essence of real world's objects or phenomena but do not look similar to them. These Diagrams are not commonly used in system studies but they are and can be extremely valuable where they are used for debating and negotiating land use and planning issues.



3.) *Symbolic Representations*- Here the Diagrams portrays relationships between numbers or quantities of things or processes. These Diagrams are a main stay of all science subjects including many systems studies, because they are central to the dynamic modeling of processes as much as the static representations of them.

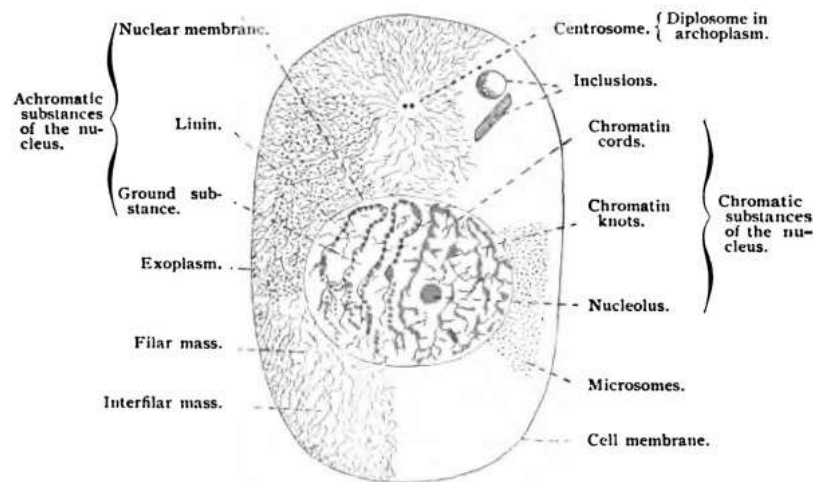


4.) *Conceptual Representations*- Here the Diagrams usually try to describe inter-relationships between ideas or processes that cannot be readily observed or depicted as ‘things’ but put forward as a model for acceptance by others. It is conceptual diagrams that feature most strongly in System work, even where the components are seen as fairly real.



In all these cases, and particularly conceptual diagrams, the creation of Diagrams requires learning the nature and purpose of diagram and practicing its use and getting feedback from others both on the skill involved in following the ‘rules of construct’ of the diagram (the practice)as well as how the diagramming process aids learning about the topic of the diagram.

**Trajectories of Diagram development within a concept:** The commonly observed trajectory of diagrams in the journey of understanding a concept is from depictive to more schematic representations. The reasons could be many and varied as we have seen from the need to project a particular view point and focus to the difficulty with conveying abstract ideas not only in a depictive form but also in words. **Maienschein (1991)** recounts the journey of E.B.Wilsons' diagrams of the cell from presentation to representation: from photographs to line diagrams, and suggests that this was perhaps a result of an increased understanding of the concept of the cell. The line drawings which he used in his later work were specific, and indicative of enhanced understanding. The diagrams also changed to draw the readers' attention to the specific features and processes being communicated.



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There have also been other trajectories in the history of theoretical sciences such as Neurosciences, Biophysics, Chemistry (**Abraham-2003**). Here the movement is from schematic diagrams to richer, detailed diagrams with the availability and inclusion of more information or content. **Butcher (2006)** suggests that Diagrams that are designed to support the cognitive processes required for deep comprehension may prove more effective. The level of ability of the learners and the sophistication of the Diagram must be aligned if a picture is to enhance learning.

Based on review of researches, **Davenport et.al (2011)** proposed a framework that uses three factors to determine the effectiveness of Diagrams,

- 1.) The specific learning objectives,
- 2.) How the diagrams makes key Information salient? and
- 3.)The learners' Cognitive processing and prior knowledge.

**Different Types of Diagrams:**

Different authors have classified Diagrams variously. The Educational Community generally agreed on three different types of the Diagrams (**Perini-2013**), used often in the process of teaching, characterized in the table below:

**Table 1 showing Types of Diagrams.**

<b>Diagram Type</b>	<b>Form-Content Relations.</b>	<b>Content omitted</b>	<b>Advantage</b>
<b>Pictorial or Images</b>	The visible details of the diagram represent specific details.	Specific Details.	Focus on details relevant to study. Less replete representational form allows
<b>Compositional or Depictive</b>	Characters denote system components. Spatial relations among characters represent relations among system components.	Intrinsic properties of system components.	Effective way to convey content involved in functional explanation. Makes it possible to non-committal about properties of system components can strengthen the argument. Closely resemble the objects. Allows for generalization about shared properties in cases where the individuals that share the generic properties differ in the details of how that property is instantiated.
<b>Schematic</b>	Generic visible properties of the figure interpreted to convey information about generic properties.	Information about detailed ways in which generic properties are instantiated.	

**Use of Diagrams in teaching and learning:**

Diagrams have always featured to some extent in teaching and learning but they have not been used as much as either the spoken or written word. The widespread formalization of teaching and learning within schools, Colleges and universities occurred at a time when level of literacy and access to books for reading and notebooks for writing is very limited. Accordingly, much of teaching and learning embraced an oral form of communication which might be supplemented to a small degree by printed diagrams in scarce text-books or on classroom walls or more ephemeral diagrams created by teacher on black boards.

**Relevance of Diagrams in Science teaching-learning process:**

There are now several studies available that address the use of Diagrams in Science Education. **Griesemer (1991)**, for example, asks whether- and why- Diagrams might be necessary for Science. Others have Discussed Diagrams used to convey metaphors and facilitate analogical reasoning (**Taylor and Blum-1991, Ruse-1991**), to convey theoretical

content (Lynch-1988, Maienschein-1991, Abraham-2003). Larkin and Simon (1987) compared Linguistic and Diagrammatic representation and showed that while some Diagrams are informational equivalent to linguistic description, this does not imply computational equivalence. Diagrams can be more efficient platforms for drawing inferences than informational equivalent linguistic representations. Clark and Mayer (2003) have suggested that the students can learn more if verbal explanations and visual representations are combined in presentation. This supplementary visual representations (Diagrams) may reduce the cognitive load on the students and hence increase learning. Mathai (2013) observed various reasons for the birth and sustenance of the schematic diagram which lends enough credence to its inclusion along with depictive diagrams in pedagogical practice. Often the depictive and schematic diagram exist together or are used together to serve different purposes even within a discipline like taxonomy where exact depictions are often the norm. The Concept Map is a Schematic Diagram representing the conceptual structure of a subject discipline as a graph in which nodes represent concepts and connections represent cognitive links between them. The use of concept maps in teaching and research has been widely used in Science education (Novak-1990, Wolf and Lopez-1993) and in Mathematics education (Park and Travers-1996, Lanier-1997). Catley, Novick and Shade (2010) discussed in detail the specific interpretations elicited by the diagrams and scenarios used in the two studies and how well these interpretations aligned with scientifically accepted views on the process of speciation. They also conclude that the non-cladogenic diagrams often represented in the college text books on evolutionary concepts, are educationally un appropriate. Yarden and Yarden (2010) attempted to examine the contribution of dynamic versus static visualizations to students' understanding of molecular processes like Polymerase Chain Reaction (PCR) methods and finds dynamic visualizations, by the use of the animations, more successful in particular. Grayet.al (2010) studies the utility of using students-manipulated physical models and modeling activities in large-enrollment, college-level courses by comparing the pre-model concept test and the post-model concept test and by classroom observation and interview. In this study, they valued the use of the models and diagrams as an aid to understand the underlying concepts and as a visual reference for recalling them, evidence in favor of overcoming the logistical barriers for 'hands-on' model and diagrams use in large enrollment classrooms. Chang, Quintana and Krajick (2010) attempted to investigate the effect of participation in a sequence of modeling activities, on middle school students' understanding of the particulate nature of matter, on the three contexts namely- **Treatment-1**. As part of a combination of activities in which students



constructed, interpreted and peer evaluated; **Treatment-2**. As part of construction and interpretation activities only; and **Treatment-3**. As part of viewing and interpreting teacher-generated animations. The study revealed that significantly positive impact of the **Treatment -1** on the student's achievement in Chemistry as compared to that of **Treatment-3** and respectively. **O'Day (2007)** analyzed the value of animations, in Biology teaching, on long-term memory retention whereas **Dahmani, Schneeberger and Kramer (2009)** and **Harris, Peck, Morris, Neto and Kallio (2009)** studied the effect of imaging programs on understanding of the student in a development intermediate algebra course and found a wide divergence in the quality of thinking process developed by remedial algebra students using graphing technology. In another study, **Morgan (2009)** assessed the role of Diagrams in communication of Mathematical activity among Teachers and finds it more valuable as perceived in out of the context.

**Conclusion:** Diagrams are well established to be more useful in the process of teaching and learning of Science. The relevant Diagrams have the power to significantly enhance learning. The conceptual component of working memory may explain many findings that the efficacy of Diagrams depends heavily on the prior knowledge of the learner as well as the conceptual Information available in the Diagram. The efficacy of Diagrams may be affected by the Specific Learning objectives, salient Key Information and the learners' cognitive processing and prior knowledge. In Science teaching and learning, the Schematic Diagrams seems more appropriate due to its pro-constructivist nature.

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