Epistemological Narrative Framework: A Narrative based approach for designing Secondary School Science content

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Abstract

Narratives have played an integral role in development of human communication. Knowledge dissemination is one of the reasons why humans communicate. It is also known that traditional societies before the renaissance relied heavily upon Narratives for cultural knowledge dissemination from one generation to another in the form of Mythologies. The rise of reasoning, logic, justification and the domain of Epistemology at large reduced the reliance (especially in the western world) upon use of mythological narratives as means of scientific knowledge dissemination. However, in recent years, use of stories for Educational purpose has gained impetus. General Science Education at Secondary School level has not been untouched from this movement. Arthur Stinner, Yannis Hadzigeorgiou and Stephen Klassen have shown how historical information can be used to create narratives as a supplement for science learning. The philosophical foundation supporting the use of historical information for science education was first proposed by Thomas Kuhn in his book "The structure of scientific revolutions". Kuhn's argument was that a science textbook only publishes the final outcome or conclusion of a discovery or theory, however, the essence of scientific tradition exists in the series of events that lead to the formulation of a theory or invention. The series of events go beyond the work of an individual scientist; many people working on same problem are involved in it. Scientific tradition exists in the process by which a concept evolves over time.

We believe that the process of development of scientific concepts that lead to advancement of science is of a structured nature, a structure that resembles with that of a particular type of Narrative schema. Understanding the Epistemological[1] relationship between narrative structures and a scientific inquiry event can help in developing Narratives that capture the essence of science which exists in the process that lead to development of a concept. Based upon the

[1] Epistemology is defined as the study of knowledge and justified belief. It is about issues related to creation and dissemination of knowledge in particular areas of inquiry (Steup, Epistemology, 2010). In simpler words we can explain Epistemology as a branch of philosophy which questions the justification for holding a belief. For example if someone makes a claim that "Sun rises in the east", then one can ask, what is the justification for believing this? Why should a group of people believe this statement to be true? These are the questions that epistemology deals with. Such questions have a direct relation with issues of Knowledge creation and its dissemination.

understanding of this relationship and integrating certain aspects of Theory of Knowledge, Theory of Narrative and Theory of Learning, we develop the Epistemological Narrative Framework to assist in the design of Narratives for Secondary School Science textbooks. A series of textbook chapters were designed using the Epistemological Narrative Framework, used as part of control group experiments with secondary school students. The results showed significant difference in the recall of students who were delivered lesson in the story form versus those who were taught with their current textbook approach. The Final implication of this research is the possibility of restructuring the Secondary School Science curriculum centered on the Epistemological Narrative Framework.

Organization of chapters

Chapter 1: Introduction

This chapter explains the reasoning behind formulating the research questions and the significance of these questions in resolving problems related to designing Narratives for teaching science? A reason for building a link between Epistemology and Narrative structures is elaborated in this chapter.

Chapter 2: Literature review

Literature survey begins with the current works of researchers who have talked about the notion of using historical narratives of science as a base for creating content for secondary school science textbook. Thomas Kuhn has talked about it in his Structure of scientific revolution. John Dewy has pointed to it in his book “Nature of inquiry”. Recent researchers who have proposed the rewriting of science curriculum in Narrative form are Arthur Stinner, Yannis Hadzigeorgeoue Aaron Isabelle and Stephen Klassen. The first section of literature review chapter contains a review of works of these researchers. In the next section literature review from the domains of Theory of Knowledge, Theory of Narrative and Theory of Learning is presented. From Theory of Knowledge we understand what is valid knowledge, what is it that can be known and in what way does science progress, which is the domain of Epistemology, Ontology and History of Science respectively. From Theory of Learning, we understand how learning is constructed, in which Piaget compares a student’s learning process with that of a scientist and introduces the concept of schema development through “Accommodation” and “Assimilation”. We also look at Vygotsky’s theory of social constructivism in which he builds upon the fact that knowledge acquired by a person is a function of the social environment in which he/she is nurtured. More recent Educational theorists like Roger Schank and his philosophy of learning by making mistakes is also referred to understand the narrative schema of a learning process. From Theory of Narrative, we learn about story structures explained by Propp, Chatman and Bal to find out common elements between story structures and the structure of scientific progress and the process of learning. The premises from these three domains, helped in developing the Epistemological Narrative Framework or ENF.

Chapter 3: Research methods

This chapter gives detail of Literature on Research methods used in the course of this research. They are under three broad categories of Deduction, Induction and Historical method.

Within Deduction, we use the argument building approach for finding points of similarity in Theory of Knowledge Theory of Narrative, Theory of Learning and integrating them to form the ENF approach. Under Induction, we use statistical methods for finding effectiveness of the ENF in a classroom environment. Historical Method has also been used to collect historical accounts associated with science discovery events to develop Narratives as demonstrative examples for ENF.

Chapter 4: Development of Epistemological Narrative Framework (ENF)

This chapter elaborates upon how certain key concepts from Theory of Knowledge, Theory of Narratives and Theory of Learning were integrated to form the Epistemological Narrative Framework. The process of scientific inquiry seems to have a structure that can be mapped as a particular type of Narrative. Each element in the scientific inquiry Narrative is given a distinct symbol. The different symbolic events are combined to form the schema or structure called The Epistemological Narrative framework. This framework is then used to develop four narratives as examples. The step by step process of developing a narrative using ENF is also discussed.

Chapter 5: Field experiments

This chapter gives detail about the experiments conducted to test effectiveness of Narratives designed using ENF in actual classroom situation. The theoretical notions were tested by exploratory experiments with secondary school students at various schools in Mumbai. The feedback from students helped in introducing improvements in the framework. Using the ENF approach, narratives were developed to explain science concepts from NCERT science textbook of class 6^{th} and 8^{th} class. Finally, control group experiments were conducted to compare the results of the lessons taught using ENF approach versus those taught using their current science textbook. The results show significant difference between the achievement score on the parameter of "recall value" of Control and Experimental group. Although, we believe that the ENF approach and the current textbook may not be comparable because they are two separate paradigms. The current textbook is centered on explanation of the final conclusion of a long discovery process. The claims in textbook appear to be final declared facts about the world on which inquiry is closed. For example the atom model is explained as a final and absolute structure of atom as if the structure is absolutely true. The ENF paradigm on the other hand explains the development of a concept. For example the current notion of atomic structure is explained using Dalton and Rutherford's model and how they came to a particular conclusion.

But, Dalton would not have been able to develop his ideas unless; Priestly and Lavoisier had discovered that air is a mixture of various gasses. So the chapter of discovery of various gases present in air need to be placed before the chapter on atomic structure. The reasoning for this arrangement is simply that, that is the order in which the discoveries have actually happened in history. It is true that there can be many arguments about who discovered a particular phenomenon but the chronological order of discovery of different phenomenon are related in such a way that one phenomenon cannot be discovered unless a certain other phenomenon is known. For example, Lavoisier could not have discovered oxygen unless Joseph black had found a way of capturing Vapors released during experimentation. Galileo could not have discovered the celestial motions unless the invention of telescope, which is connected with history of magnifying, glasses.

The chapters chosen for control group experiments were those which showed to some extent evolutionary development of an idea. For example, the chapter on Fiber to Fabric in class 6th NCERT textbook shows how clothing has evolved from animal skin, leaves and grass drapes to weaving of Cotton , Jute and Woolen clothes after the discovery of materials like cotton, Jute and wool, hence this chapter was chosen for the experiment. Similarly chapter on evolution of batteries was chosen for another experiment.

Chapter 6: Conclusion

This chapter summarizes the work in previous chapter and explains to what extent the hypothesis statements formed in response to the research questions were answered in the due course of this research. The implications of the research in secondary school science content development are discussed. Limitations and future possibilities of the ENF approach are also outlined in this chapter. Chapter concludes with a note on how narrative can play a role in building the relationship between learning of science and the legacy of scientific tradition embedded in development of scientific thinking ability. Possibility of how secondary school science curriculum can be re-organized in Narrative form is presented in this chapter.

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Abbreviations

ENF: Epistemological Narrative Framework

HBCSE: Homi Bhabha Centre for Science Education

KVIIT: Kendriya Vidyalaya Indian Institute of Technology

LCP: Large Context Problem

NCERT: National Centre for Educational Research and Training

ZIET: Zonal Institute of Education and Training

Chapter 1

Introduction

1.1 Introduction

This research work started with the purpose of finding answers to questions that emerged during an academic project which involved explaining science concepts to secondary school students with the medium of a comic book (Datt, 2005). The first comic book in series was meant to explain process of life formation on Earth. Second comic book in the series was meant to explain the concept of static electricity. We had chosen comic book medium because it allowed for representation of knowledge content in the form of a narrative. The underlying belief was that content represented in narrative form would be useful in drawing students' attention and their interest towards scientific subject matter. The idea of using comic book as a narrative medium for explaining science concepts was liked by students who were shown these books. However, when the project was presented to subject matter experts, although there was consensus on the point that students would find narrative depiction of science more interesting, they had doubts about whether the story depicted in the comic book corresponded well with scientific process of acquiring knowledge[2]. The immediate question one encountered was; how does one know that the story correlated well with facts associated with the process of a scientific investigation? The characters in the comic narrative solve problems and in the process, learn something. However, the very process of problem solving and knowledge acquisition by characters in the story was ambiguous. It was not based upon an understanding of the process of learning as enumerated in the literature on learning or Theory of Knowledge. A story written for learning purpose if deprived of human learning process may not be epistemologically correct.

It was observed in the comic book that in the process of making the narrative imaginative, some key aspects associated with facts of scientific process of gaining knowledge or conducting a scientific inquiry were overlooked. Similar problem has been articulated by Hadzigeorgiou and Stefanich:

> The first thing that comes to mind when considering science and its relationship to storytelling is that the former has nothing to do with the latter. Why? Because scientific knowledge has become synonymous with objectivity and truth, while a story has been associated to the imaginary and the unreal. And yet, a relationship between these two does appear to exist (Hadzigeorgiou & Stefanich, 2000).

This contradictory aims of science and narratives give rise to following research questions.

1.2 Questions

The problem mentioned above causes a hindrance in the design of epistemologically correct narratives. The first step in resolving this problem was to identify the main question which needed to be addressed, anticipating that finding answers to these questions would resolve the problem at hand. Following questions appeared to be lying at the heart of the problem of designing narrative informed from epistemological aspects of science:

[2] The basic structure of stories in comic book project was simple. There is some problem encountered by some agent. In order to resolve the problem, the lead character (hero) has to acquire some knowledge. The knowledge the character gets is by asking question about things to a learned person. However, this is same as gathering information. The aspect of reasoning process and experimentation which is at the heart of scientific knowledge is missing from this structure, hence a better narrative structure was required that encompassed the scientific reasoning process and experimentation in its schema. The scientific reasoning process is elaborated in the domain of Epistemology hence our search began in the Theory of Knowledge to develop a narrative schema suitable for developing narratives for teaching science or more specifically for teaching the process of a scientific inquiry.

1) What is the relationship between Narrative structures and knowledge creation/acquisition process in the context of Science education? Is there a specific narrative schema underlying the process of a scientific inquiry?

2) Is the relationship between Narratives and Knowledge acquisition patterned in such a way that a general Narrative framework can explain knowledge creation/acquisition in all domains of Natural Science[3]?

3) How can a Narrative based Epistemological framework be used to design narratives for secondary school science lessons?

4) And, what is the effect of Narratives created using the above Narrative Framework on student's learning in the context of Secondary School Science curriculum?

For the first three questions, we found answers by correlating information from literary sources mainly from the domain of Theory of Knowledge, Theory of Narratives and Theory of Learning. The fourth question was answered by empirically testing lesson plans designed using the Epistemological Narrative Framework (ENF[4]) with secondary school students and comparing their achievement scores with students taught using lessons plan from their existing curriculum textbook.

1.3 Search for answers

In order to find out if there was any inherent relation between Narrative structure and Knowledge creation/acquisition process, we reviewed the literature on educational narratives and found many authors who have asserted that such a relation does exist. A study of prehistory also revealed that stories have existed in the human civilization since prehistoric times. They have been used for various purposes, knowledge dissemination being one of them (Mello, 2001).

3 This research is limited to finding relation between narrative structures and scientific inquiry to gain knowledge in subject matter in natural sciences. Social sciences and mathematics are outside the scope of this research.

4 Epistemological Narrative Framework is the approach developed in the course of finding answers to the hypothesis questions. This approach helps in organizing secondary school Science curriculum in the form of Narratives.

Schank and Abelson state:

> For thousands, maybe millions of years, people have been telling stories to each other. Whatever the means and whatever the venue, storytelling seems to play a major role in human interaction (Schank & Abelson, 1995, p. 89).

It seems stories have a primordial relation with a human being's natural way of making sense of the world. This point is asserted by Bell, who states that:

> The nature of narrative has for several decades now aroused speculation extending beyond the literary realm into a variety of disciplines concerned with the fundamental construction of meaning. The shaping of experience by Narrative, indeed the very impulse to tell stories, may suggest primordial, but subliminal, processes underlying even the apparently independent planes of reason (Bell, 1991, p.177).

Without a narrative experience, humans could not express their knowledge or thought (Mello, 2001). Traditional cultures of the world from Greek civilization to Indian, to Egyptian to American to Chinese, all have their roots in narratives embodied in their cultural mythology. It is a fact that generations after generations have grown listening to the stories from their respective cultures, from The Ramayana, The Mahabharata, The Jataka tales, The Panchatantra, Aesop's fables, Stories from the Bible, Stories about Mohammad, Zen Stories, and the list goes on and on. These stories played the role of knowledge transfer from one generation to another, knowledge about the culture in which they originated. They help the listener make sense of the cultural world they live in. Bock explains that there exists a relation between narrative structure and organization of knowledge.

> Since forms of storytelling and narrative organization of knowledge seem to be common to all known cultures, we may conclude that narrations are not merely accidental cultural artifacts, but rather necessary by - products of the evolutionary process (Bock, 2009, p.2).

This is true not only for the mythological traditions of ancient cultures, but story and narration in general are one of the primary means by which humans communicate and make sense of the world. It is established that Narratives play an important role in cognition which has lead them to acquire an important role in education (Mott & Lester, 2006). S E. Worth has expressed something similar regarding how narratives help in making sense of the world:

> Storytelling is one of our primary forms of communication with other people. Narrativity is the principle way that human beings order their experience in time. It is also one of the primary ways that humans make coherent sense out of seemingly unrelated sequences of events. Thus, an account of how this ordering works is essential to understanding one of the many ways of knowing used by humans (Worth, 2008, p.42).

Schank and Abelson maintain that stories are basic constituents of human memory, knowledge and social communication (Schank & Abelson, 1995).

In recent years there has been a revised interest in stories as a tool for knowledge dissemination. Storytelling has gained significance as an educational tool in various domains like Medicine[5], Management[6], Leadership[7] and Education[8]. The focus of this research is in the field of education and more specifically, Science learning[9]. Avraamidou affirms that stories are a means of transferring not only cultural knowledge but also it is useful in explaining scientific description of reality (Avraamidou, 2008). Avraamidou states that:

> In a book aptly entitled *Teaching as Storytelling*, Egan makes the case that stories form a natural vehicle and means of educating students not only about their cultural and historical roots but also the scientific descriptions of reality (Egan, 1986)(Avraamidou, 2008, p.87).

In what way stories can be used to explain scientific description of reality? For that we needed to understand what does scientific descript of reality mean and how does it relate to Narrative structures?

1.4 Theory of Knowledge and its relationship with Narrative structures

A brief introduction to Kuhn's notion of how advancement in science happens is presented here. According to Kuhn, Science must be seen as a whole enterprise with a certain

5 Works of Jeffrey M Borkan, William L Miller

6 Works of David Snowden, Muayyad Jabri, Deborah Sole, Daniel Gray Wilson

7 Works of Steve Denning, Doug Stevenson, Douglas A. Ready, Scott Ferguson

8 Works of Janice Jerome Bruner, McDrury, Kieran Egan, Margaret Parkin

9 Works of, Yannis Hadzigeorgiou, Arthur Stinner, Stephen Klassen, Aaron Isabelle

tradition. He has explained how advancement of knowledge takes place within the tradition of science. His work implies that to really understand a scientific concept, the story of its development in history must be understood. Kuhn is not talking about the autobiographical stories of scientist. What he is referring to is a peculiar nature of the way science advances forward. His emphasis is on the structure of a discovery event. Science progresses with the efforts of many scientists almost linked in succession, trying finding solution to a problem formulated in ancestry because no one theory explains a phenomenon completely. Something remains unanswered, unclear that needs to be investigated and answered by a successive generation. For example, the concept of Gravitation that Newton proposed was the result of a series of investigations on the phenomenon of moving bodies in nature, which was started by Aristotle and continued by Galileo (Kuhn, 1962). Thomas Kuhn explains:

> Each of them (discoveries) necessitated the community's rejection of one time-honored scientific theory in favor of another incompatible with it. Each produced a consequent shift in the problems available for scientific scrutiny and in the standards by which the profession determined what should count as an admissible problem. Such changes, together with the controversies that almost always accompany them, are the defining characteristics of scientific revolutions (Kuhn, 1962, p.6).

It was here, that some connection between Science and Narratives was seen in the sense that a concept's development appears to resemble the process of development of a narrative that links propositions and counters propositions of many researchers together and culminates into formation of a theory or invention that tentatively satisfies the doubtful questions surrounding the phenomenon under study. Kuhn's notion of Paradigm shift focuses at large movements of change in scientific history which question fundamental beliefs about nature. Examples of such paradigm shifts are limited to only some concepts that brought whole new fields of study into existence like modern chemistry. We have used a lesser form of Kuhn's idea to look at evolution of objects and technology as well and their examples are much more in number and cover the whole science curriculum.

George Gale's explanation brings to light the tradition bound nature of science. That science is a growth of particular kind of tradition. But it is not the same as tradition in the religious sense. Scientific tradition is opposed to a religious tradition in fundamental ways (Gale, 1979). In the religious tradition, hero is one who upholds the beliefs of a particular religious culture. Anyone who propagates any thought that is not in agreement with the existing belief, is considered a heretic. However, the situation is exactly the opposite in Science. The person, who is termed as heretic in religious traditions, is actually the Hero of science because scientific tradition outlines conditions of falsifiability of its own ideas and methods. George Gale explains:

> An individual is said to be a member of the Catholic tradition only insofar as that person accepts the paradigm represented by the statements of dogma[10]. Someone who publically rejected some notion which is an element of dogma would be automatically ejected from practice within the tradition. Such a person is called a "heretic," and the set of alternate beliefs which he or she proposes the new concept structure is known as heresy…we can usefully compare scientific and non-scientific tradition. Contradictory to religious revolutionaries, revolutionaries in scientific tradition are always accorded the status of heroes by the entire scientific community at some later date (Gale, 1979, p.77).

The question that follows from above discussion is, 'Through what means can such a Tradition of Science be transmitted to students?' The works of Arthur Stinner (Stinner, 1993) also attempt to provide answers to this question. It appears that Narrative centered approach of organizing scientific knowledge; keeping in mind the history of science can provide an answer to this question. Narrative by virtue of its nature of being provides the right possibility of passing the tradition of science from generation to generation. The idea of passing knowledge from generation to generation may appear dogmatic if looked only on the surfaces. What is being talked about here is that the knowledge of the "process of science" rather than particular subject content is what is aimed at be passed on from generation to generation. The 'process' of arriving at new knowledge in science is common to all domains of science whether physics, chemistry of biology. What is the underlying narrative of the scientific process of knowledge creation and acquisition is what the aim of this research work is.

1.4.1 The notion of Continuity and Discontinuity

An important aspect on which we find clear relation between narrative structure and organization of knowledge is the concept of continuity. It is one of the most important concepts in science. C.S. Pierce explains the significance of the notion of continuity in science:

> Now continuity, it is not so much to say, is the leading conception of science. Now it occurs into every fundamental and exact law of physics. The few laws of Chemistry which do not involve continuity seem for the most part to be very roughly true. This is the

10 Gale has explained earlier in the same reference that a dogma is defined as a set of concepts that characterize a religious tradition (Gale, 1979).

> leading idea of differential calculus and of all the useful branches of mathematics; it play a great part in all scientific thought, and the greater the more scientific that thought is; and it is the master key which adepts tell us unlocks the arcana of philosophy (Peirce, 1974, p. 27).

Continuity is opposed to things that are discontinuous or broken. The continuity we are talking about is the continuity in development of ideas in the history of science. C.S. Pierce has associated continuity with the idea of evolution. It can be termed in other words as growth. Pierce quotes spencer and explains growth as a movement from the homogeneous to the heterogeneous (Peirce, 1974). The evidence about presence of continuity (evolution or growth) is clearly visible if we study the evolution of scientific thought in western theory of knowledge. Thales was the first philosopher in western world who asked "what is the substance that pervades all existence?" This question in turn emerged from his observation that things change from one state to another. Thales thought that for one thing to become something else, something must be common between them and if that is so, there must be something that was common in all material things. According to Thales, that substance was Water (Asimov, 1965). This thought did not end here. Subsequent philosophers answered the same question by pointing to other aspects of nature. For example Anaximander pointed at the quality of oppositional forces in nature to be pervading all existence. Aneximenes declared Air to be the fundamental substance in all things while Heraclitus stated Fire to be the essential substance present in everything (Harris, 1968). The thoughts of Thales, Anaximander, Anaximenes and Heraclitus form a continuous line connected by one question, what is that substance which pervades all existence?

Such linking of thought is also the essence of Deductive and Inductive logic. In Deduction when two premises are linked, they result is the production of a third statement which is the conclusion, the premises and conclusion is in continuity because conclusion follows from the premises.

In any domain of science at any point, one can see a continuous chain of thought that has precedence before it. Scientific thought develops on an existing knowledge base and builds it further. Let us take the notion of positive and negative electric potential. It was earlier believed that there were two type of electric fluids, resinous and vitreous and that light objects charged with same electric fluid repelled each other and those charged with opposite fluids, attracted each other. But later Benjamin Franklin discovered that there was no such thing as resinous and vitreous, it was only one fluid, present in different quantity. Where it was more, he called it positive and where it was less he called it negative. And Like charges repelled each other and unlike charges attracted each other. This idea of positive and negative electric charges is only a continuation of the two fluid theory of electricity proposed by Du Fay.

This type of continuous development is there in Physics, Chemistry as well as Biology. Aristotle believed that the force of gravitation acting upon a heavier body is greater than the one acting upon a lighter one, hence, if the two are released simultaneously, the heavier one will fall first, but Galileo showed through demonstration by throwing a heavy and a light ball from the top of Leaning tower of Pisa, that the same amount of force acted upon both resulting in both touching ground at exactly the same time. This continuity is not just visible in evolution of objects but also of beliefs, for example, the discovery of Oxygen by Anthon Lavoisier. His work was preceded by Priestley who himself followed the work of Joseph Black (Spangenburg R. M., 2006). The idea of evolution of scientific thought was elaborated upon by Thomas Kuhn in his "Structure of Scientific Revolutions". He proposed the development of science through large periods of normal science to the period of paradigm shift when a fundamental belief is replaced by another belief. He gave the example of replacement of Phlogiston theory by Lavoisier and the advent of modern chemistry. Kuhn proposed that the culture of science can only be known by tracing development of thought from one scientist to another because he believed discovery to be the result of workings of many minds rather than one (Kuhn, 1962). Probably, this is what Newton meant when he said that:

> If I have been able to look far, that is because
> I have stood on the shoulders of Giants (Surendran, 2002)"

Newton, here may be referring to the work of Kepler, Galileo and Aristotle. A similar line of thought can be seen in Jerome Bruner's following statement:

> An individual's working intelligence is never "solo." It cannot be understood without taking into account his or her reference books, notes, computer programs and data bases, or most important of all, the network of friends, colleagues, or mentors on whom one leans for help and advice. Your chance of winning a Nobel Prize, Harriet Zuckerman once told me, increases immeasurably if you have worked in the laboratory of somebody who has already won one, not because of pull but because of access to the ideas and criticisms of those who know better (Bruner, 1991, p.3).

This continuity in thought is maintained by coming in contact of one scientist/philosopher with another, either as teacher or friend or a fellow researcher. Because it involves transfer of ideas from one human to another and modification in the original idea, it becomes inherently a narrative of change, of evolution of an idea. The transition from one set of belief or idea to another set itself is a narrative with a Beginning, Middle and an End. The beginning is the existing paradigm, the middle is the anomaly and subsequent search for an alternative belief and end is the replacement of the old paradigm with new one in light of new experiences. The new paradigm itself becomes the beginning and the narrative cycle continues endlessly without a permanent beginning, middle or end. The narrative continues with the end of one becoming the beginning of another. John Dewey explains the very essence of reflective thinking which is at the heart of scientific development in the following statement:

> Reflection involves not simply a sequence of ideas, but a consequence – a consecutive ordering in such a way that each determines the next as its proper outcome, while each in turn leans back on its predecessors. The successive portions of the reflective thought grow out of one another and support one another; they do not come and go in a medley. Each phase is a step from something to something – technically speaking; it is a term of thought. Each term leaves a deposit which is utilized in the next term. The stream or flow becomes a train, chain, or thread (Dewey, 1910, p.2-3).

It is very clear from Dewey's explanation that knowledge advances in a consequent series of progression with one following or built upon another piece of knowledge. However, it is also important to consider the opposite of continuity i.e. discontinuity. The notion that scientific advancement essentially happens by termination of a one-time established paradigm to be replaced with another has been talked about Thomas Kuhn. It is discussed in detail in the next section.

1.4.2 Discontinuity in Scientific Paradigms

It is possible to produce a counter argument to the idea of continuity by bringing attention to Kuhn's notion of paradigm shift which specifically points at the discontinuities in tradition. The new paradigm spells the end of the previous paradigm. But Pitowsky points that the coming up of new paradigm does not destroy the old paradigm. He explains through the example of Newtonian Mechanics:

> Readers of *Structure (Kuhn's structure of scientific revolution)* are apt to gain the impression that Newtonian mechanics is a dead paradigm, of interest only to historians. Much is said about the replacement of the Newtonian paradigm by relativity (special and general) and quantum theory, implying that classical mechanics has faded away and subsided. However, a fairly superficial glance will disclose that thousands of scientific articles are written every year on topics directly associated with Newton's laws (Pitowsky, 2007, p.121).

Pitowsky adds further:

> From the picture painted by *Structure* we would expect that interest in Newton's theory would have declined after alternate paradigms emerged; in particular, problems that were part of Newtonian "normal science" would have been set aside. Here too the situation is quite different, classical mechanics continued to be a research topic throughout the twentieth century and beyond. The investigators included some of the leading lights of mathematical physics, who achieved new and important results, including some of the most important mathematical theorems of the twentieth century. What is more, as we shall see, the Newtonian paradigm gained a new lease of life in the 1980s (Pitowsky, 2007, p.122).

In the process of understanding the notions of Continuity and Discontinuity, an image appears before us which presents the advancement of science like a forward and branching movement. The rise of quantum mechanics does not discontinue the growth of Newtonian mechanics. They simply branch out in different directions addressing issues at macro and micro level respectively. Newtonian mechanics may be subsumed in Quantum Mechanics. We see then that that which binds narrative structures and knowledge acquisition is the idea of continuity, a chain of event linking one sequence of events with another. It may be noted that even the most traditional doctrines presented by Aristotle are not completely extinct. A lot of Aristotle's theories have been proven wrong especially in Mechanics and Logic, however in some areas they still are applied in limited sense for example the hypothetical syllogism. The syllogism itself is not completed useless. It is very much present and taken help of in development of the modern symbolic logic. In the words of Westerstahl:

> The amazing thing about Aristotle's logic is in fact how 'modern' it is…His results can easily be stated, understood and proved in a modern framework (Westerstahl, 1988, p.12)

Hence, one can believe with fair level of confidence that science progresses with a Narrative of continuous and discontinuous movement of thoughts in a domain. With these set of initial answers, it was clear that a further research into the matter was required. The next step in the research was to find the exact nature of the relationship between Narrative structure and knowledge creation/acquisition process. Rest of this thesis is aimed at finding the answer to this question and those emerging from it.

1.5 Objective of study

Following from the above discussion, two objectives emerge. One was to find if a general framework can be developed that provides an aid for representing science content in the form of Narratives. The second objective was associated with extension of the Narrative framework to the design of Secondary School Science curriculum.

Textbooks are the medium which invites students to the world of discoveries. Chapters contained in a science textbook are outcomes of conclusions of discoveries that happened in the history of science. The current secondary school textbooks contain chapters that catalogue these research outcomes in the form of concepts and theories. The arrangement of chapters in a textbook follows a certain manner. A set of chapter that fall under a family of concepts are grouped together, so that continuity is maintained. For example chapters like sources of food, Nutrition, Variety of food items and Growth process of a plant are grouped together under Health and Nutrition. Concepts associated with Force, Work and Energy are grouped together because they fall under principles of Mechanics. We can clearly see that categorization puts content into disconnected boxes. But in reality, the concepts are linked, with one depending upon development of the other. The understanding of Epistemological Narrative Framework makes it possible to not only design chapters in the form of narratives but also provides another logical method for organizing the textbook chapters in such a way that maintain continuity of scientific concepts in a better way than it is in the current science textbook.

1.6 Research Question

This leads us to our final research question:

How can a Framework be developed (based upon understanding of the relationship between Narrative structures and Knowledge acquisition process) that can be used to create Narratives suitable for secondary school science curriculum? And, what is the effect of Narratives created using the above Narrative Framework on student’s learning in the context of Secondary School Science curriculum?

Chapter 2

Literature Review

2.1 Introduction

Literature review begins with the survey of existing approaches of using Narratives in science learning. The recent authors who have discussed how stories can be developed and used for teaching science lessons are Yannis Hadzigeorgiou, Arthur Stinner and Isabelle, hence it was important to review their work. Examples of private publishers who are developing narrative content for science teaching are discussed.

The domains associated with science are, Theory of Knowledge or Epistemology and Theory of Learning. The domain associated with Narrative structures is Theory of Narrative. In the following argument we show how the three domains are related with each other:

1. Etymologically, the word '**to narrate**' has its roots in the word "gnarus" which means 'to know' or 'knowing' (Etymonline, 2001).
2. **Knowing** is defined as justified true **belief** (Steup, The analysis of Knowledge, 2008).
3. Essence of belief is the establishment of a **Habit** (Pierce, 1878).
4. A **habit** is a permanence of repetitive **behavior** (Merriam-Webster, Habit, 2011) and

5. A relatively permanent **change** in **behavior** is defined as **learning**[11] ("So what is learning", 2010).

6. From 1, 2, 3, 4 and 5, we can conclude that three terms, Knowledge, Narrative and Learning are related to each other. Hence, it was necessary for us to search the domains of theory of Narrative, Knowledge and Learning to know more about the nature of relationship between these domains which helped us in building the Epistemic Narrative Framework.

A more explicit explanation of the above argument can be given if we try to relate only the keywords Narrate, Knowing, Belief, Habit, Behavior and Learning. The linkage between these words is shown in figure 2.1:

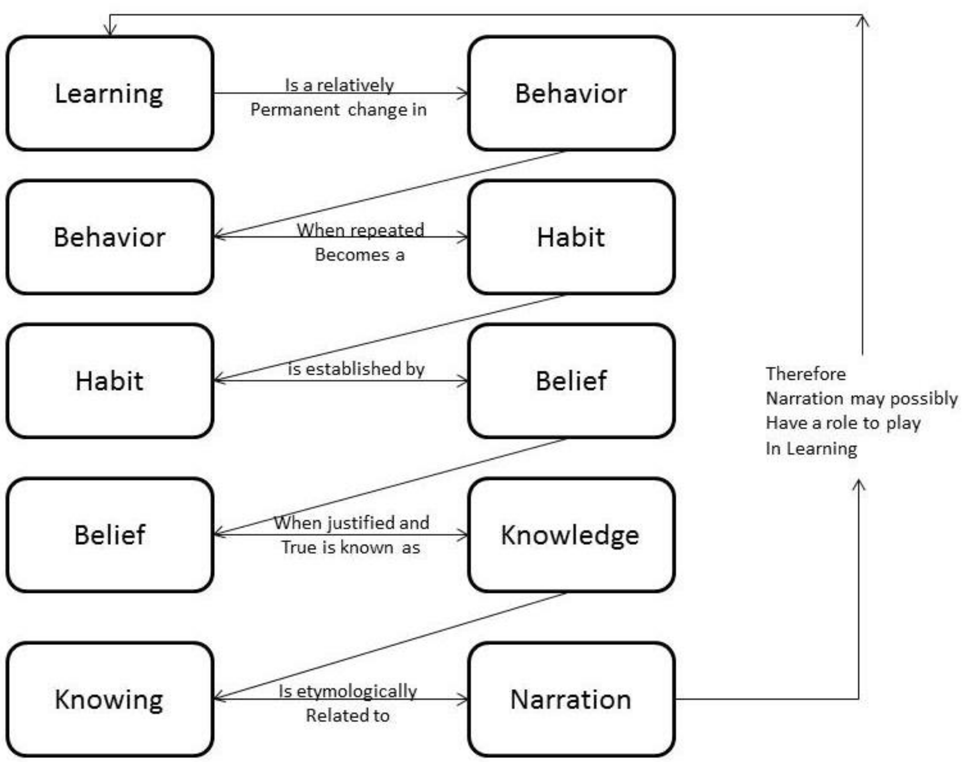

Figure 2.1: Diagrammatic representation of argument to show the link between the words Narrative, Knowing and Learning

In the above argument we have shown how the words narrative, Knowing and Learning are linked with each other. Before getting into the details of their interconnections between each

[11] There are several concepts related to theory of learning, but we have chosen only those which are relevant for present discussion.

domain, we will first review existing research that uses narrative as tool for knowledge dissemination in science learning.

2.2 Existing Literature on Narrative based knowledge dissemination in science learning

In this section, we will refer to existing research in the area of using narratives in science learning. The main researchers who have written about use of narratives in science education are Arthur Stinner, Yannis Hadzigeorgiou, Arron Isabella whose work we will describe are Yannis Hadzieorgiou, Aaron Isabelle, Arthur Stinner, Stephen Klassen and Bentley.

The approach of story construction by Yannis Hadzigeorgiou deals with historical account of a knowledge discovery event. He gives the example of Galvani, Volta and Michael Faraday for building the story of current electricity (Hadzigeorgiou, 2006). Yannis believes that oppositional points presented by different researchers of the same phenomenon inherently make an interesting story. Hadzigeorgiou's paper presents a particular incidence of discovery of current electricity in which the phenomenon of electric current was described as animal electricity by Galvani and contact electricity by Volta. Their arguments form an interesting dialogue between two protagonists trying to prove their interpretation of true nature of electricity. Yannis' story building guidelines for physics education are also centered around the idea of humanizing the experience of learning science which comes from the various efforts currently being made to connect science education to the idea of responsible citizenship, where it is recognized that science learning is not just about accumulating facts, but it is also about imbibing values of Objectivity, Curiosity, Pursuit of truth, Intellectual honesty, Humility and Commitment to human welfare (Hadzigeorgiou, 2006). The important point in Hadzigeorgiou's research is the idea of opposition between competing explanations of the same phenomenon. This idea, we have elaborated in detail in the development of our Epistemological Narrative Framework.

Another approach to story making is presented by Isabelle where again biographical accounts of a knowledge discovery event are narrated to students. This approach is part of the overall instructional strategy called the Launch, Explore, Summarize (LES) model of learning. In the first Launch phase, children are given actual physical object to activate prior knowledge of the subject matter, then in the second phase, they are told a story regarding the objects given to play with and in the third phase, connections are built between the story and the activity they did in the first phase. The story presented by Isabelle is partly fictionalized, after telling of the story the factual and the fictional aspects are discussed in the class (Isabelle, 2007). The story is that of the famous experiment conducted by Otto Guericke in which he demonstrated the power of air pressure by joining two hollow hemispheres without any adhesive. The joint was so strong that a series of horsemen pulling from both sides could not separate them. In this case also, we see a single story account from which generalizing to discovery events at large is not elaborated upon. The information is not sufficient for producing a conceptual framework because a conceptual framework requires a structure that can explain large number of discovery events in small number of key steps. However, the idea of fictionalizing the narrative to make it more suitable to fit in a narrative structure is what we have dealt with in detail in building our framework for constructing Narratives for knowledge Organization.

A similar approach that combines the historical, factual data with fictionalized story is introduced by Stephen Klassen. This approach, adds fictional element in a historically correct science story to connect the problem context with current environment of students. The story used by Klassen is modiefied by changing the name of the place where the experiment took place. Klassen has specifically put emphasis on writing a ‘good science story’ by integrating story design principles with design of Science Narrative. The story that Klassen chose to analyze was that of Louis Slotin, the scientist who was associated with the Manhattan project, who died while conducting experiment while assembling the first atomic bomb. The story was used with a science laboratory experiment to teach students the safety precautions required while handling radioactive substances. Klassen points out that the classroom exercise does not have a context, and context is what triggers the interest of students by giving them answer to the question ‘Why they should be doing a particular exercise’. Story provides such a vivid context for the exercise. It connects the knowledge with real life situations in which such knowledge comes in handy in solving a real life problem (Klassen, 2008). However, the approach shown by Klassen is only meant for literary criticism. It does not claim to be an approach for story construction, which is the prime focus in our research. But the idea of fictionalizing factual information is adopted by us from this research.

An example of improvisational drama in a learning context is provided by Bentley. He conducted an experiment in which students were asked to enact the controversy related to theory of Evolution. The goal of their research was to expose children to multiple points of view rather than giving a fixed definition of the concept. Their dramatization approach shows how the concept of Evolution, seen from Creationism's point of view is distinct from Darwin's theory (Bentley, 2000). Students perform a play based upon script co-created by the instructor and present it to the class which acts as an audience. Here again what is presented is a single example of story. A general framework which can help in creation of stories is not provided, which is what essentially we aim at doing in this research.

Stinner and Williams have combined the concept of large context problem (LCP) with the storyline approach to assist instructors in building Narratives for explaining science concepts (Stinner, 1993). Stinner explains the idea behind LCP with an example of the Atom model. If Atom model is to be taught as an LCP, then instead of teaching Bohr model of atom, the various ideas concerning discovery of atom starting from Ionians to Dalton are knitted in to a story that shows how the idea of atom has evolved over the ages (Williams, 1993).

> Learning could be well motivated by a context with one unifying central idea capable of capturing the imagination of the student (Stinner,1980, p.90).

Stinner's idea is to initiate a student's way of seeing with help of introduction to the concept's history, can be achieved by a storyline approach that the authors have proposed. The intension of using the storyline approach is to teach science as if the students have been inducted as a member in a culture (Williams, 1993). The authors have also presented a framework for assisting the instructors in weaving a story around a particular scientific context.

One of the successful examples of use of stories in primary school math teaching is of a series of storybooks called "Round the Rug Math: Adventures in Problem Solving". The books present a story in which the characters go on an adventure. On the way they come across various kinds of obstacles which are overcome by solving a math problem.

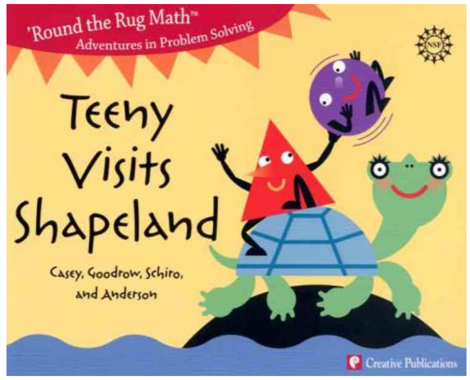

Figure 2.2: From website of Round the rug: Adventure in Problem solving (Casey, 2009)

Our research follows closely the research of Arthur Stinner and the concept of a Large Context Problem or LCP in which history of development of a scientific theory is explained rather than just explaining the final concept. This process focuses on teaching the essence of a scientific enterprise which is about development of idea from gross generalizations to specific details. It is possible to extend the missing elements in the work of Arthur Stinner if we are able to discretely see the general composition of a scientific inquiry event independent of specific cases. In order to be able to build tools for teachers who can build their own stories or content writers to create science books with epistemologically correct science stories, a more detailed level investigation of what exactly happens in each step of a scientific inquiry. Each step needs to be distinctly seen. For example, one discrete step is ‘Questioning’. Another discrete step is reasoning and within reasoning there are discrete steps. The attempt that is being made in this research is to establish the belief that all scientific developments may be unique episodes in the life of development of scientific domain however, there are certain indispensable common elements in all domains of science without which science is not possible. The idea is to be aware of these elements and see them working in a discovery event. The implication for learning in this would be to teach the process of science rather than only the outcome of the process. Now from what source can the process of science be learnt or acquired? The answer is Theory of knowledge or the world of Epistemology.

2.3 Theory of Knowledge

The main philosophical paths that are followed here are those started by Aristotle, John Dewey (Pragmatism) and Thomas Kuhn. Why these philosophical paths have been taken will become clear as we go forward in this section.

Learning is associated with the idea of Habit formation (Piaget, 1950). Knowledge is defined as justified true belief (Steup, 2008) and forming of a belief leads to establishment of a habit (Pierce, 1878). Therefore Learning is associated with Knowledge acquisition. To learn is to acquire knowledge[12]. But, what does it mean to acquire knowledge about something? When does one know that what one has acquired is knowledge and not some delusion of knowledge? We start with the subject matter of knowledge and other things associated with it.

The first question that comes to mind while attempting to understand knowledge acquisition is; what is knowledge? But before even attempting to answer this question, another important thing needs to be addressed first. When does the need to acquire knowledge about something arise? It seems that the answer to this exists in the act of **questioning**. The innate need to gain knowledge of some unknown thing may get expressed and articulated in the form of questioning. Questions like, what are the properties of water? Why do high tides occur? Which chemical solution is suitable for making paints? What is the capital of India? A question is the first step, a demand, asking to put some light on an unknown issue. Levi Strauss states:

> The scientific mind does not so much provide the right answers as ask the right questions. (McKenzie, 2002)

The act of questioning begins the process of reflection and insightful thinking in the mind of the questioner (McKenzie, 2002). The first question that started the culture of science in the western world was “What is that substance that pervades all existence?”(Harris, 1969). If we look at some of the popular theories in science, we see a fundamental question behind it. Newton’s famous question, why do things fall down instead of going up and Aristotle’s famous question on falling bodies that if two bodies of different mass fall freely in air then which of them will fall first are just a few examples about how new knowledge is preceded by questions, that exactly point at the heart of an unknown problem which needs to be answered. Finding answer to a question leads to

[12] Knowledge itself can be distinguished into various types, but all of them will some way or the other are learnt.

formation of new knowledge. Moving forward from arising of a question, how does one proceed to finding an answer? In other words, what really happens when knowledge of something is gained? Aristotle has written in poetics:

> "Recognition, as the name indicates, is a change from ignorance to knowledge"
> (Aristotle, 1989, p.20).

Simillar thought is confirmed in the words of Schlick:

> To know is to re-cognize or rediscover. And to rediscover is to equate what is known with that which is unknown (Schlick, 1974, p.15).

Similar thought is presented by Stroll in explaining Plato's position:

> Plato's explanation of what occurs when we seem to learn something is that we are not actually learning, but we are actually remembering or recollecting something we already know (Stroll, 1961, p.27).

Yolton has pointed to something similar when he says:

> By nature animals are born with the faculty of sensation, and from sensation memory is produced in some of them, though not in others. And therefore the former are more intelligent and apt at learning than those which cannot remember (Yolton, 1965,p.17).

Schlick has explained this with the help of a scenario. A man is walking in the street when he sees an unknown creature. A closer look makes him recognize the creature with what he had previously seen. It resembles the features of an animal. So, he comes to know that what he is presently seeing is an animal. And further, since he had seen specific type of an animal before, a dog and this particular animal that was present before him resembled the image of a Dog which already existed in his memory, he concludes that this animal is a dog. The person arrives at the knowledge that the animal before him is a dog (Schlick, 1974). The idea of knowledge of physical attributes of an object by recalling a previously stored memory image of it is also known as the concept of "Perception" in cognitive psychology (Kellogg, 2007).

The next question which emerges is, if knowledge is about recognizing something previously known, then what aspect of the object is recognized? What is it that is known or can be known? This is the question that Plato and his teacher Socrates inquired about: *"What can be known?"* (Stroll, 1961). By focusing our attention to this question, we now enter the subject matter of Ontology. This question was important because of the status of philosophy in Athens during the Greek times. Socrates's question was in response to the opinions of the Sophists, who believed that "nothing exists and if it did, nobody could know it, and if they knew, nobody could communicate it. Therefore men should not seek absolute knowledge for they would not find it (Stroll, 1961)." The world of Sophists was a world where the person's sole intention was to develop techniques for winning in arguments. The arguments were personal opinions of the sophists and they were happy with it as long as it helped them influencing people. They were not concerned about an argument's correspondence with truth as they thought knowledge of anything was not attainable (Stroll, 1961). Socrates response to this was that men could have definite knowledge of what they out to do and how they ought to live their lives. But Plato, his student put further light on this matter by giving a clear response to the question "What could be known?" He declared that only things that are permanent can be known, things that are constantly changing cannot be the objects of knowledge (Weber, 1925) (Stroll, 1961). Plato also developed an elaborate theory of Forms which was later developed and modified further by Aristotle. Here we introduce the idea of Universals and Particulars. Entities like people, places and things are Particulars, while Universals are their 'properties' or 'attributes' associated with them. Particulars are ever changing. For example a particular table is constructed, it will wear over time and will merge with earth when discarded, but the property of table-ness, let us say being rectangular, will remain forever as this property will be present in anything that is rectangular. Being rectangular is a Universal. Another example; Rahim is a person. He will grow old and die, but if Rahim had the property of being courageous, then this property is what can be attributed to other people independent of Rahim. So, according to Plato and also Aristotle, knowledge can only be of Universals because they are changeless, indestructible entities. And even the particulars can only be known through the knowledge of Universals attributed to them. Hence, when we say, knowledge is about recognizing something previously known, what is being recognized is the attribute or in other words, the Universal concept associated with the object of attention. Universals as properties are further classified into primary and secondary. Primary properties are associated with physical attributes of an object like shape, size, color. texture, smell etc. while secondary properties of an object come into operation when that object is observed to have certain effects on other objects. For example, iron when comes into contact with moisture, it gets rusted. This is one of the secondary properties of Iron. Kochiras explains John Locke's position on primary and secondary properties:

"I doubt not but if we could discover the Figure, Size, Texture, and Motion of the minute Constituent parts of any two Bodies, we should know without Trial several of the Operations one upon another, as we do now the Properties of a Square, or a Triangle. Did we know the Mechanical affections of the Particles of Rhubarb, Hemlock, Opium, and a Man, as a Watchmaker does those of a Watch, whereby it performs its Operations, and of a file which by rubbing on them will alter the figure of any of the Wheels, we should be able to tell before Hand, that Rhubarb will purge, Hemlock kill, and Opium make a Man sleep….The dissolving of Silver in Aqua Fortis, and Gold in Aqua Regia, and not vice versa, would be then, perhaps, no more difficult to know, that it is to a Smith to understand, why the turning of one Key will open a lock, and not the turning of another" (Kochiras, 2009, p.34).

It becomes clear from this explanation that things are recognized by their shape, size, texture, color (Primary property) and also by their behavior, which is the effect they have on other objects (Secondary property). In philosophical movements after the formulation of symbolic logic, the notion of primary and secondary properties has been replaced by the idea of a concept. Schlick explains that since knowing through recognition of sense data can never be precise and always susceptible to doubt, the precise way of knowing about something is through the Concept[13] related with that object. Schlick demonstrates this point in the following text:

If someone hands me a piece of metal, I won't know whether it is pure silver or not, so long as I am restricted to the perception obtained merely from seeing or touching the metal. My memory images of silver are not sharp enough for me to distinguish them clearly from images of similar metals, such as tin or certain alloys. But the situation is entirely different if I make use of the scientific concept of Silver. Then Silver is defined as a substance with the specific gravity of 10.5, an atomic weight of 108, a certain electrical conductivity, and so on. I need only see if the substance possesses these properties in order to determine, to within any desired degree of accuracy, whether what has been given me is silver or some other metal (Schlick, 1974,p.27).

The word Concept defines relationships between terms. A relation is that which builds connection between many terms and concepts. There can be many type of relations like causal relation, spatial relation, kinship relation etc. To know something is to know how that thing is related to something else.

13 We will use the word concept instead of Universal here because there is a transition of Formal Logic to Symbolic logic. Formal logic of Aristotle is based upon Universals' relation with Particulars in which Universals are absolute attributes of an object, while the idea of a concept is from symbolic logic (which is the modern form of logic). It is centered on the idea of relationships between various terms.

2.3.1 Aristotle’s theory of Substance, Essence and Causality

In order to understand the subject matter of knowledge further, we need to get into the details of the following terms introduced by Aristotle: **Substance, Essence, and Causality. Substances** are said to be beings or things that exist. To ask what is substance is the same as asking what is being. (Cohen, 2009). Some examples of substances can be bodies including plants, animals, the part of plants and animals, the elements, the heavenly bodies. Things more basic than bodies are also substances like surfaces, lines and points. Also included in substance are imperceptible things like mathematical objects (Cohen, 2009). Substance is the thing that becomes our object of attention when we wish to know about something. It is synonymous with the concept of a Particular.

The next question is that of ‘how a Substance is defined?’ A Substance is defined by its **Essence**. Essence is what makes a thing what it is. It outlines its Identity (Cohen, 2009). For example, if a Substance or a thing is stripped of its outward shape, it can continue to be something, but when a Substance is stripped of its Essence, it seizes to be (Cohen, 2009). If Essence is that which makes a Substance what it is then **Cause** is what makes the Essence exist. A cause can be explained thus:

> The answer Aristotle proposes is that the cause of being of a substance (e.g., of a house) is the form or essence that is predicated of the matter (e.g., of the bricks and stones) that constitute that substance. The essence is not always just a formal cause; in some cases, Aristotle says, it is also a final cause (he gives the examples of a house and a bed), and in some cases an efficient cause. But in any case ‘what we seek is the cause, i.e., the form, by reason of which the matter is some definite thing; and this is the substance of the thing’ and ‘the primary cause of its being’ (Cohen, 2009, p.).

In the above citation, the question that Aristotle is responding to is not What property X has or what is the essence of X? Aristotle is asking that; what is causing X to have that property? Aristotle finds it not important to ask what is a man for man is a man. A thing is defined by itself. The right question to ask, Aristotle suggests is what causes a man to be? Or more specifically what causes a man to have a certain quality? Or what causes a house to be strong?

Aristotle further divides cause into four types; Material Cause, Formal Cause, Efficient Cause and Final Cause (Cohen, 2009). Material Cause is the matter out of which a substance is made, for example a house is made of bricks and mortar. Formal Cause is the plan or the design according to which the house is to be constructed. Efficient Cause is the process or the technique of bringing together the pieces of a substance, in other words, Efficient Cause, causes the material to move and get joined in a certain manner according to the Formal Cause and Final Cause is the purpose for which a thing is to be made, for example, house is made for, comfort and security (Bodner, 2010).

Here it is clear that the knowledge of something is associated with cause and effect relation. We will see later that cause and effect is only one type of relation. There can be other type of relations. In the theory of Four Causes itself four different type of relations are mentioned. Material cause explains the relation between an object and the material with which it is made. Formal cause tells about relation of an object with its design plan. Final cause is a relation that connects an object with its purpose and efficient cause connects an object with a 'prime mover' or a force that initiates the actions that lead to consequences that result in formation of that object.

The next question encountered is, by what means can one know the relationship between two things or entities? The answer provided is by two schools in philosophy that of rationalism and Empiricism (Russel, 1980) (Weber, 1925) (Harris, 1969) (Dewey, 1955). These oppositional viewpoints are presented in the works of Descartes, Spinoza and Leibniz (the Rationalists) and Lock, Berkeley and Hum as the (Empiricists). Rationalists believed that knowledge was innate, it is born with us, and could be known independent of experience. Empiricists believed that Knowledge could only be attained by experience which is gained by information collected by the senses (Russel, 1980). Kant attempted to bridge the gap between the two schools by declaring that although the first step towards knowing something is experience but experience alone is meaningless if it is not connected in the right way by innate ideas in the mind (Harris, 1969).

The dichotomy between experience and reason is important to understand the process of knowledge. While it is true that only through the sense does one perceive the world, but after the senses have presented the information to the mind, it is by the innate constitution of the mind by which it draws inferences and conclusions. So, I believe that both are integral part of the knowledge acquisition process. Experience shows what appears to happen when something is going on. But it only shows an if- then relation. But, the if-then singular moment cannot reveal any underlying structure unless it is deductively related to some other set of general events. So, relation between terms is known by a collective action of Rationalism and Empiricism.

2.3.2 Methods of acquiring knowledge: Deduction and Induction

The two different schools of Empiricism and Rationalism give way two methods of acquiring valid knowledge, that of Deduction and Induction. Deductive logic has its base in combining two or more set of statements to form a conclusion. The set of minimum three statements form an argument (Kreyche, 1961). For example A is above B and B is above C therefore A is above C. Let us break this argument into three parts.

Premise 1: A is above B

Premise 2: B is above C

Conclusion: A is above C

The first two statements form a Premise and the third statement is a conclusion. The conclusion is new knowledge created by synthesis of two previously known facts. Here, no sense experience is required. Knowledge is arrived at purely by reasoning. The form of argument developed here is known as a syllogism. There are two type of syllogism, Categorical and Hypothetical. We will see in detail about these in the section on research methodology.

Now we turn to what it means to acquire knowledge by Induction. When we say that knowledge is recognition of what is now present with something similar that existed before, then there exists a dimension of time that separates past experience with the present one. The knowledge that is gained by connecting various pieces of data at different times and then finding if there is anything similar in the instances, is acquiring knowledge by way of Induction. It is to form general principles from particular singular events. Most knowledge that humans acquire is by Induction (Schlick, 1974). Schlick explains with the following example:

> I have never seen my window decked out with frost except when the temperature outside is quite low; hence whenever the window panes are covered with beautiful crystals, I may definitely expect to have a feeling of intense cold when I leave the house. The proposition that ice can exist only in the cold I have obtained through Induction (Schlick, 1974).

Three things have been established so far: that to know is to recognize it with something previously known. What is known is a relationship of one thing with another. Knowledge of relationship between things can be gained by method of Deduction and Induction. So far, aspects of knowledge which are permanent and static are discussed, in the next section, we introduce temporal aspect of knowledge associated with things that are constantly changing**.**

2.3.3 John Dewey and the Narrative nature of a scientific inquiry

Now we move on to another aspect of knowledge on which light was thrown by John Dewey. We have seen earlier in the works of Greek philosophers that knowledge can only be of things that are permanent, static and persist through time. But after considerable development in modern philosophy and science which was specifically observing phenomenon that change, it came to the notice of John Dewey, that not just static, but knowledge is also of dynamic phenomenon that are constantly changing. The space-temporal relation of knowledge acquisition is explained in detail by John Dewey. The following statement clearly explains this:

> "Existential Subject –Matter as transformed has a temporal sense. Linguistically, this phase is expressed in Narration" (Dewey, 1955, p.220)

Dewey emphasized the need to reform the subject – Matter of Logic both formal and symbolic in his book *Logic: the Theory of Inquiry*. The main point that Dewey makes is that as methods and means of science develop, it has a direct impact upon the field of Logic as has been the case in transition from Classical Aristotelian Logic to the modern 'Symbolic Logic' and that if in future, methods of inquiry change that will effect further change in Logic (Dewey, 1955). Aristotelian metaphysics gives fixed essences to substances. Dewey explains Aristotle's position:

> "Nature in its most emphatic and eulogistic sense consisted of unchanging substances with their fixed essential characters or natures. The distinction and relation of the permanent, the fixed, from and to the variable and changing, was the ultimate problem of science and philosophy. The philosophy of Aristotle is a systematic exposition and organized solution of this problem carried through all subjects with which inquiry was then concerned" (Dewey,1955, p.88)

And further it is elaborated that Greeks believed that true knowledge can only be of things that never change and are permanent. Things that are constantly changing cannot be truly known (Dewey, 1955). This belief is reflected in the system of formal logical syllogism which is the form of complete enclosure and permanence (Dewey,1955). The advancement of modern science has destroyed the notion of fixed essences. Now, change itself is a category that is considered as an object of knowledge (Dewey, 1955). Dewey devices a new way of answering the question: “What is an object if it is not defined by its fixed essence?” The answer is presented in the following explanation:

A) “The conjoined properties that mark off and identify a chair, a piece of Granite, a meteor, are not sets of qualities given existentially as such and such. They are certain qualities which constitute in their ordered conjunction with one another valid signs of what will ensue when certain operations are performed (Dewey, 1986, p.132).”

B) A chemical Substance is represented not by enumeration of qualities as such, but by a formula which provides a synoptic indication of the various types of consequences which will result. (Dewey, 1955, p. 129)

These two points mentioned here become clearer when we view them in the worldview of Pragmatism as elaborated by C.S. Pierce:

> “Consider what effects, that might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object (C.S. Pierce,1872, p.2).”

The same point has been reiterated by William James who is also associated with the creation of Pragmatism, as follows:

> “Grant an idea or belief to be true,” it says. “What concrete difference will its being true make in anyone’s actual life? How will the truth be realized? What experiences will be different from those which would obtain if the belief were false? What, in short, is the truth’s cash-value in experiential terms?” (James, 1978, p.1)

This point we have attempted to represent diagrammatically in figure 2.4.

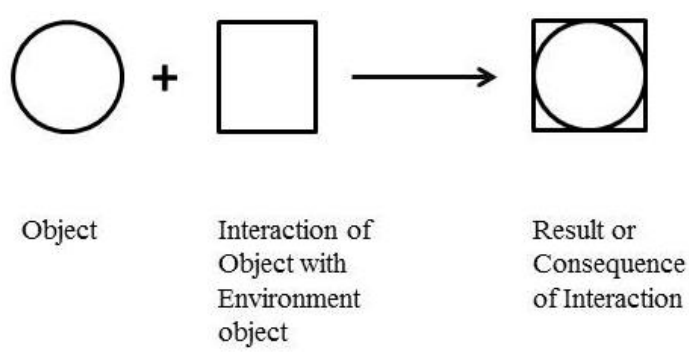

Figure 2.3: A is the Object of focus, B is when it is affected or effects another object or when it interacts with other objects which Dewey refers to as operations and C is the outcome or consequence or result of the interaction.

When a scientific enquiry is concluded, it leads to the identification of the object as the one which produces certain effects into its environment objects (Dewey, 1955).

This process essentially involves a temporal change in events and situation that happen before and after a gap of time interval. At this point we move to the worldview that Dewey has constructed and which essentially describes knowledge of reality as a Narrative.

C) In present science, on the other hand, such transitory events as lightening and such variable things as the weather become subjects of scientific judgments when they are determined as constituents of a systematic set of changes… (Dewey, 1955, p. 130)

D) Change is characterized in terms of direction-from something to something (Dewey, 1955).

E) The "from which" and "to which" that determine the subject-matter of any particular narration-description are strictly relative to the object intent set to inquiry by the problematic quality of a given situation (Dewey, 1955).

F) To a layman a flash of lightening comes close to being an isolated instantaneous occurrence. A scientific account of it is a narration of a prolonged history of which the flash is one incident; with the growth of scientific knowledge the tale becomes longer. On the other hand, a mountain, which to a layman is a standing symbol of permanence, is to the geologist the scene of a drama of birth, growth, decay and ultimate death. (Dewey, 1955, p. 222)

The points above mentioned clearly states that changing phenomenon in nature are described by narration because they are inherently a drama or a tale of one thing turning into another. Having established this, we now move on to the details of knowledge. An event, whose outcome is knowledge, will have its beginning point, an inquiry (Dewey, 1955).

> An inquiry is defined as the controlled or directed transformation of an indeterminate situation into one that is so determined in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole (Dewey, 1955, p. 104).

Dewey has described the pattern of inquiry in the following steps:

The indeterminate Situation: Inquiry begins with questioning. This questioning arises in a situation where certain aspect of the situation is doubtful. Doubt arises out of questioning some aspect of the situation. To remove the doubt inquiry is commenced. The situation may be unique and hence since it is encountered for the first time, doubt will give rise to question and that will begin the process of inquiry (Dewey, 1955, p. 105).

Institution of a Problem: This is partial determination of situation as the key problem of a given situation is outlined. The inquiry is directed towards the problem (Dewey, 1955, p. 106).

Determination of a Problem Solution: Contemplation upon the problem statement produces a solution in an intuitive way. Problem situation is broken into its constituents. All the aspects are considered and then there is a flash of solution in the form of an idea. Along with the idea comes the possibility of predictions like what will happen or commence when certain idea is implemented, how the situation will turn (Dewey, 1955, p. 108).

Reasoning: In the beginning, the idea is vague and unclear. It has to be put to test through various arguments till it is chosen with confidence to be the right approach towards dealing with the problem (Dewey, 1955, p. 109).

Operational Character of Fact-Meanings: This is where actual, physical experimentation is conducted to test the validity of solution in factual terms. Here the response from facts is taken which may lead to further questioning and inquiry. This is when idea is actualized and given a concrete shape (Dewey, 1955, p. 110).

So far we have seen that knowledge arises as a result of inquiry in a problem situation. A problem situation is that in which something is indeterminate or unknown. This is the dynamic aspect of knowledge acquisition in contrast with static aspect. In the next section we see another aspect in which there is a synthesis of the dynamic and the static aspect of knowledge acquisition. This is related to change in established belief about relations between terms.

2.3.4 Kuhn's Structure of Scientific Revolutions

Dewey's 5 stages of inquiry clearly resemble the structure of a Narrative which we will see in the section on Theory of Narratives. However, it is also noted that routine problem – solving activity cannot constitute a story (Livingston, 2009). In fact, narrativity increases with divergence from stereotypical behavior (Livingston, 2009). If it is so that mere problem solving set of events cannot constitute a meaningful Narrative, then what aspect of knowledge acquisition can be considered as a narrative? To find an answer to this question, we need to look into another aspect of inquiry which is associated with the advancement of science. This aspect was dealt with by Thomas Kuhn in his book *Structure of Scientific Revolutions*. Kuhn divided the advancement of science in two distinct phases; that of Normal Science and Paradigm Change (Kuhn T. S, 1962).

> "In this essay, 'Normal Science' means research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." (Kuhn, 1962, p.201)

Kuhn also introduces a new term, Paradigm to describe the work that goes within normal science tradition. A paradigm is synonymous with the various scientific traditions that have got established from classical to modern scientific development. Terms like Aristotelian dynamics (or Newtonian), Corpuscular optics (or wave optics) capture the picture of a paradigm (Kuhn, 1962)

> "By choosing it, I mean to suggest that some accepted examples of actual scientific practice-examples which include law, theory, application and instrumentation together provide models from which spring particular coherent traditions of scientific research." (Kuhn, 1962, p.10)

What Kuhn pointed in his work was that progress in science is marked by movement from one paradigm to another. But these periods of change, known as scientific revolutions are preceded by routine scientific work within a Normal Science paradigm. Novelty is the last thing for which a scientist working in a given Paradigm aims at (Kuhn, 1962). The main work of a scientist within a paradigm that has got well established as normal science is to work out the details by making more precise instruments for precise measurements, to improve the established norms. The outcome of such work is fixed, only their means change (Kuhn, 1962). This routine activity Kuhn has termed as puzzle solving and the scientist who achieve this are puzzle solvers (Kuhn T. S., The structure of Scientific Revolutions, 1962). This description of routine Normal Science resembles the pattern of scientific inquiry mentioned by John Dewey.

If we further look into Kuhn's Structure of Scientific revolutions, we will see a striking resemblance between advancement of knowledge and Narrative structure. What triggers the beginning of a new Paradigm from an existing one is the observation of an anomaly. It is an incidence that is like a mistake which is not supposed to happen given the conditions of the existing paradigm.

> Discovery commences with the awareness of an anomaly, i.e. with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science. It then continues with a more or less extended exploration of the area of anomaly. And it closes only when the paradigm theory has been adjusted so that the anomalous has been adjusted and that the anomalous has become the expected (Kuhn, 1962, p.52).

It is also stated that the change in paradigm is essentially faced with resistance from existing paradigm.

> By ensuring that the paradigm will not be too easily surrendered, resistance guarantees that scientists will not be lightly distracted and that the anomalies that lead to paradigm change will penetrate existing knowledge to the core (Kuhn, 1962, p.65).

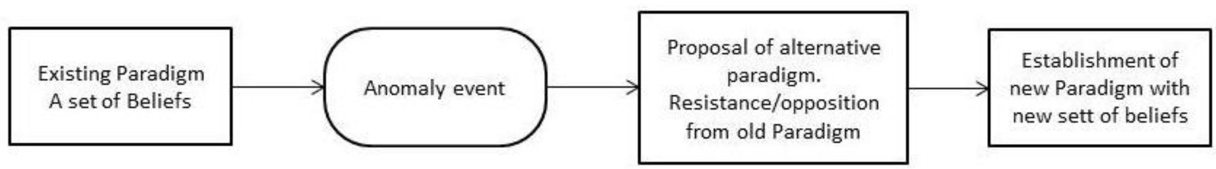

Figure 2.4: Diagrammatic representation of Kuhn's structure of scientific revolution

The period of peak tension is marked by the term Crisis. The anomalies in certain scientific tradition become so strongly recognized that it requires an urgent solution and till the point it is done, the crisis in the old paradigm mounts. The crisis is also the point where the old paradigm begins to break down, that's when the new paradigm slowly begins to take over.

Another feature of a discovery pointed out by Kuhn is that it is impossible to associate one single person and one single incidence that lead to a paradigm change. It is a series of events in which many scientists and competing propositions are involved. Contribution to a discovery comes from many diverse fields (Kuhn, 1962). Unexpectedness is the mark of a paradigm change because what induces the change is an event that does not fall into the domain of what is already known. When something which is not known is encountered, it invokes surprise. This is what makes this event as an interesting narrative. We will elaborate upon this in the section on Framework development for Narrative Knowledge Learning Synthesis.

The question or rather a paradox one encounters now is, if Knowing is associated with recognizing something previously known, then how can new knowledge be possible, because what we see is what we already know? This is the paradox that was raised by Plato (Stroll, 1961).

We will find the answer to this question in the subsection on theory of Learning. In the next subsection, we will look into how the transition from traditional logic to modern and then toward a narrative turn has happened through the history of philosophy.

2.3.5 Understanding Kuhn through Paradigm change from traditional to modern philosophy

In order to understand Kuhn's work, we need to look at the shifting paradigms in the Theory of knowledge itself[14]. For which we need to look at the historical transition from Greek to modern period in philosophy and the schools of thought that have affected the change. This is not the exact interpretation of Kuhn's notion of paradigm shift. However, we have attempted to apply it in more situations. We call these situations as Conceptual Shift. The cases of Paradigm shift presented by Kuhn are few and they work at very large scale. However the cases of conceptual shift are more. We give a few examples of conceptual shifts in history of philosophy. It may be noted that after the scientific revolution, philosophy and science acquired distinct roles, one became enquiry into knowledge and other into scientific knowledge. However when historians write history of specific subjects like chemistry or mechanics, it begins with reference to pre-science era of Greek philosophers because then it becomes clear to trace the logic of how conceptual shifts have occurred in development of science.

The first trace of scientific inquiry in the western world dates back to the Greek philosopher Aristotle as he is considered the founder of western logic (Weber, 1925). Aristotle was part of a long chain of developmental thought. Before him was his teacher Plato and his teacher's teacher, Socrates. Not just that, even before Socrates there were great many schools of philosophy like the sophists, the Pythagoreans and even before them lived Anaximander, Parmenides and the first one was Thales (Harris, 1969). It is also true that the credit of the first systematic study of science goes to Pythagoras (Kneale & Kneale, 1962), but that was limited to mathematics.

It is important to know the primary questions that the classical philosophers tried to answer. Thales was the first philosopher to provide a scientific answer to the question; what was it which pervaded all existence? And the answer he provided was Water. This was refuted by

[14] These examples are not provided by Kuhn, but we have attempted to see the history of science though Kuhn's structure

Anaximander who postulated an infinite boundless that was the cause of all existence. That boundless is constantly in vibration and produces various opposing qualities by its motion. It produces the opposing qualities of Hot and Cold, Wet and dry etc. (Harris, Fundamentals of philosophy, 1969). Anaximenes then proposed that the Air was the primary substance. Pythagoras found numbers to be the cause of existence. Then Heraclitus again followed Thales' line of thought by inferring Fire to be the one substance of which all other forms are born through a process of transformation. This fire caused all things to change from one state to another and because of this substance alone that the universe was in constant flux, ever changing (Harris, 1969) (Gale, 1979). However to this proposition Cratylus objected with the argument that if everything was changing and impermanent than how could anything be described? Because as soon as anything is described, it would change within the next moment so the description would be untrue. All statements about anything will be false. This line of thought was also supported by Herecliteans who followed that only the statement which is true can qualify as true knowledge (Harris, 1969). This is where the concept of Knowledge's association with truth comes into the picture. Then the philosopher Parmenides clarifies that change is only an apparent condition. The truth underneath reality is permanent and fixed, it never changes (Gale, 1979). All variety is an illusion. After this, there was a period of sophistry who debated about existing philosophies. Then Socrates came into the picture and proposed that the only thing one can truly know is oneself (Weber, 1925). Nothing can be certainly said about the outside world. Only the content of our own mind can we be certain about. He introduced the idea of developing personal virtues and character to guide once conduct as these were the things worth worrying about rather than the cause of the external material world. Plato took these thoughts further formed the distinction between opinion and knowledge. He suggested that the object of knowledge is reality. Plato also tried to resolve the confusion of how changeable things can be known. He explained that an object is a mixture of what is and what is not. He further elaborated that change is only present in relativity, when one thing is compared with another. And the most important point that Plato introduced which connected all the arguments of previous philosophers was idea of the Universal. His explanation was that there are many figures that can be called as triangles. They individually may be different but as a group they have something common, the concept of 'triangularity', which is a Universal truth about all triangles. This common attribute is termed as a Universal. These Universals which are the attributes of the particular never change, they are fixed. Hence, they alone can be the subjects of true Knowledge (Harris, 1969). Only Universals are real, particulars are an illusion. Plato's work was taken further by Aristotle and he created a practical tool for testing the validity of philosophical ideas against known truths. This tool is what we know as Logic. Aristotle's categorical syllogism was the first scientific way of arriving at knowledge through self-evident truths. The syllogism helped in finding the validity of an argument. Thus, an argument could be scrutinized in a purely objective way free from personal biases of individual. This was the first scientific way of arriving at new knowledge with valid justification.

> "The scientific study of logic began with Aristotle in the fourth century B.C. His impressive work, combined with other influences, the foundation of a long tradition of logic that still continues." (William Thomas Perry, 1991, P. 3)

The transition from Traditional to Modern Logic started with the introduction of Descartes' method of arriving new knowledge by systematically doubting each and every impulse of thought that passes by in one's mind. Descartes was single mindedly focused in search of things that one can be absolutely certain about. He found out the only thing one can be certain of is that 'one exists' because even to doubt this, one needs to have a mind to doubt. Therefore the fact that Descartes's mind exist is absolutely certain. And since the whole of Descartes as the world knows is nothing but the mind of Descartes in which all his doubts exist, therefore Descartes exists[15] is an absolute certain truth.

John Lock introduced a further classification of properties into Primary and Secondary. Primary properties tells us about the physical appearance of an object while secondary properties come into picture when the object comes in contact with other and what affects happen from this interaction. Objects have properties and these properties are distinct from one object to another and that is what forms their unique identity (Denkel, 1996). A clear view of matter around us from ontological philosophy is given by Bertrand Russel. According to Russell, matter is made up of Things and Truths. Things are particulars like proper nouns. They are names of objects, people and places like Table or Mr. Rajen or New Delhi. Truths are about universals which are properties or relation common among many Particulars (Russel, 1980). For example the property of malleability may be common among many elements like Aluminum, Copper, Gold and Silver.

[15] Exist at that moment when he would have asked the doubt.

All these elements are part of a category called Metal. All metals share some common properties. These properties or qualities are called Universals. Other kind of universals is relationships between many Particulars or Universals. For instance, A Loves B. Love is the ‘relation’ that exists between A and B. A ‘relation’ is the connection that binds many Particulars or Universals together (Russel, 1980)

Emanuel Kant furthered the work on qualities by dividing them into 12 categories (Sion, 2008). Of all the categories, that of relation, being the highest and all being the subset of it. Subsequently through the works of other philosophers the idea of defining an object by its relations to other replaced the idea of defining objects by its fixed unchanged characteristics. Philosophers in the late 19^{th} and the early 20th century were not satisfied by the use of natural language as a vehicle for carrying operations of Logic. They found Natural language confusing and not good for correct communication of ideas. There were search for a more accurate language which captured ideas with exactness and without any ambiguity. On this basis was a new language of Logic developed called the symbolic logic whose pioneers were Bool, De Morgan, Whitehead and Wittgenstein (Weber, 1925). Consider an example that explains relations. A is the father of B. Here A and B are terms and Father of is the relation which connects the two terms together (Russel, 1980). The difference between formal and symbolic logic is that while former attributed universal, unchanged properties to Objects and rigidly classified them as such and such a thing with a particular property, symbolic logic is built upon developing relations between terms, which are valid only in a system which is overall defined by the network of **relations** within that system (Langer, 1953) (Schlick, 1974). Under symbolic logic, the question is not what are the properties of X? But rather, how is X related to Y and under what conditions?

By understanding change in development of philosophical notions associated with natural science, it is possible to understand Kuhn’s theory of scientific revolutions because it throws light on the overall nature of the scientific subject matter. At this point it may also be useful to look at views counter to kuhn’s structure of scientific revolutions.

2.3.6 Feyerabend’s opposition of structure in scientific method

A counter view about the advancement of science was presented by Paul Feyerabend. He was a philosopher of science who had views contrary to those who believed in any ordered development of ideas in advancement of science. He believed that there was no method or structure present in development of ideas in history of Science. If at all there was any method it was a method he called “anything goes”. According to Feyrabend:

> Aesthetic criteria, personal whims and social factors have a far more decisive role in the history of science than rationalist or empiricist historiography would indicate (Preston, 2009).

Feyerabend introduced a kind of epistemological anarchy because he believed history of Science to be so complex that there could not be any possibility of existence of a general methodology which can explain any structured pattern in scientific revolutions (Feyerabend, 1975). Awareness of Feyerabend’s point of view helps in keeping a check on believing that all scientific discoveries follow a strict pattern based upon fixed scientific methods.

Learning from Feyerabend’s philosophy, it can be said that the ENF approach developed in this research presented does not claim that scientific discoveries follow this pattern. What it does is to assist in looking for certain narrative elements in a historic discovery event. Each discovery event is unique in its own way, however within that uniqueness, there does exist certain commonalities. The elements may not be arranged in the exact chronological manner as is shown in this research, but they may have a different order of arrangement which makes each discovery event a unique episode in the history of science.

2.3.7 Summary of Theory of Knowledge

We summarize all the points mentioned so far in understanding the theory of knowledge:

1) Knowledge is defined as justified, true belief (Sosa, 1991).
2) A belief is the perceived ‘relation’ may appear to exist between two or more terms (Russel, 1955).
3) Knowledge is gained in the process of finding an answer to a question (Dewey, 1955)
4) A question is encountered when there is something doubtful about some aspect of a given situation (Dewey, 1955).

5) The answer to a question is in the form of recognition. To know is to re-cognize or rediscover. And to rediscover is to equate what is known with that which is unknown (Schlick, 1974).
6) The recognition provides an answer to the question, but the answer is only a tentative suggestion. It needs Justification (Dewey, 1955).
7) Theories of justification form under the categories of Rationalism and Empiricism (Russel, 1980) . The methodical tools using which theories are justified are Deduction and Induction.
8) There is not a single person or a specific time in history in which a discovery can be placed. A discovery is an outcome of many minds working on the same problem, developing on the works of a previous generation (Kuhn, 1962).

These are the key points which will be integrated in developing the framework for Narrative Knowledge Learning Framework.

2.4 Theory of Narrative

Bruner suggests two modes of cognitive functioning; the narrative and the argumentative. Narrative deals with the particular aspect of existence namely human intentions, the other deals with causes and procedures to verify truth through empirical means (Herman, 2007). Narratives can be viewed from various perspectives and authors have defined them in innumerable number of ways. For the purpose of constructing a framework for narrative organization of knowledge we have restricted our search to basic elements that constitute a narrative. These elements were later used to model the framework for narrative organization of knowledge. The terminology in describing the elements of a narrative may be confusing as each author has used a different term for each element. We will attempt here to draw a common terminology for the various aspects that have the same essence. What this means will become clear in a few paragraphs from now. We will look at the various elements from perspective of authors like Seymour Chatman, Mike Bal, Edmund Burke, Vladimir Propp, Levi Strauss and Roland Tobias. Quoting Herman to begin with in understanding the elements of a story:

> Scholars may not agree that a story must have a beginning or an end, but there is little dispute that a story is composed of action (an event or events) and characters (more broadly existents or entities) and that it always proceeds in time (Herman, 2007,p.41).

Story refers to actions, events, goals, or other mental object as against words, sentences of linguistic objects (Herman, 2002). We start our literature with a review of Aristotle's work on elements of narrative.

2.4.1 Aristotle

Aristotle laid down the structure of narratives (especially Tragedy) in his Poetics. Aristotle believes the purpose of Epic poetry is imitation and what it imitates is the behavior or character of men (Aristotle, 1989). He has suggested every tragedy to be composed of six elements: Character, Plot, Diction, Thought, Spectacle and Song. He further elaborates these and explains that:

> Character is that which reveals moral purpose, showing what kind of things a man chooses and avoids. Speeches therefore, which do not make this manifest, or in which the speaker does not choose or avoid anything whatever, are not expressive of character. Thought, on the other hand, is found where something is proved to be or not to be, or a general maxim is enunciated (Aristotle, 1989,p.13).

Plot, according to Aristotle is imitation of action that is unified into a Beginning, Middle and an End. The beginning does not follow from a cause, but something commences after it. An end is what necessarily follows something, but it is not followed by anything and a middle is that which follows something as it is followed by something else (Aristotle, 1989). Aristotle has also pointed out some essential things that necessarily need to be present in a good tragedy, that the character must be good i.e. any speech an action manifesting moral purpose is expressive of that character, secondly it should have propriety. Third, it should be true to life and fourth that there should be consistency, even a character that is confused and unclear must be so throughout maintaining his confused nature (Aristotle, 1989). Another aspect of Tragedy mentioned by Aristotle is recognition. Aristotle explains recognition as a change of state from ignorance to knowledge. Best form of recognition is associated with a reversal of situation (Aristotle, 1989). Recognition in the plot is generally of persons. It may happen in four ways, by recognizing a sign or by bodily marks or scar or an object evoking memory of a feeling associated with the object or recognizing through reasoning and last is by making a discovery (Aristotle, 1989). The flow of action in tragedy is further explained by Aristotle to be composed of:

1) Complication

2) Unraveling or Denouement

A complication is that part which mars a change of fortune from the beginning and unraveling is that which begins from the beginning of change of situation to end (Aristotle, 1989). It can be represented in the following diagram.

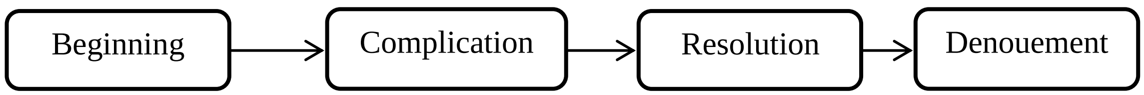

Figure2.5: Representing stages in the development of a story plot.

Aristotle’s Narrative plot graph is represented in the following graphical way by Riedl and Young (figure 2.7):

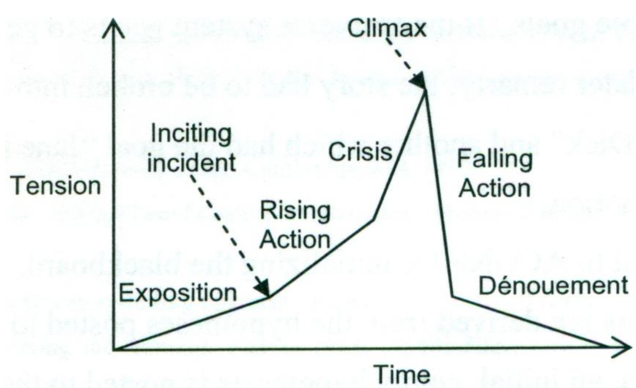

Figure 2.6: Aristotle’s dramatic arc as interpreted by Riedl and Young (Riedl, 2002)

This dramatic arc has been employed by computer based narrative generation systems (Riedl, 2002).

The general definition of a plot composing of a Beginning, Middle and End is still very much present in popular writings in various mediums like novels, children’s illustration books, and animation.

A similar structure of a story plot was presented by Gustav Freytag. His plot structure contained five basic elements; Exposition, Rising Action, Complication/Conflict/Climax, Falling action and denouement (Wheeler, 2004). Freytag’s plot model is given in figure2.7. Exposition defines the theme and setting of the story along with introduction to the main characters and may sometime give clues to a future conflict. Rising action is a situation in which the protagonist faces a conflict or tension. Complication and climax are the highest point of conflict in the story, when uncertainty is maximum. Falling action reveals the outcome or complication when the result of the tensions manifests and finally all the questions that arose in the complication begin to get resolved in the final Denouement which literally means unknotting of the plot. If it is a tragedy, it may end in death of the protagonist in case of a comedy the situation of complication is resolved (Freytag's Pyramid, 2011).

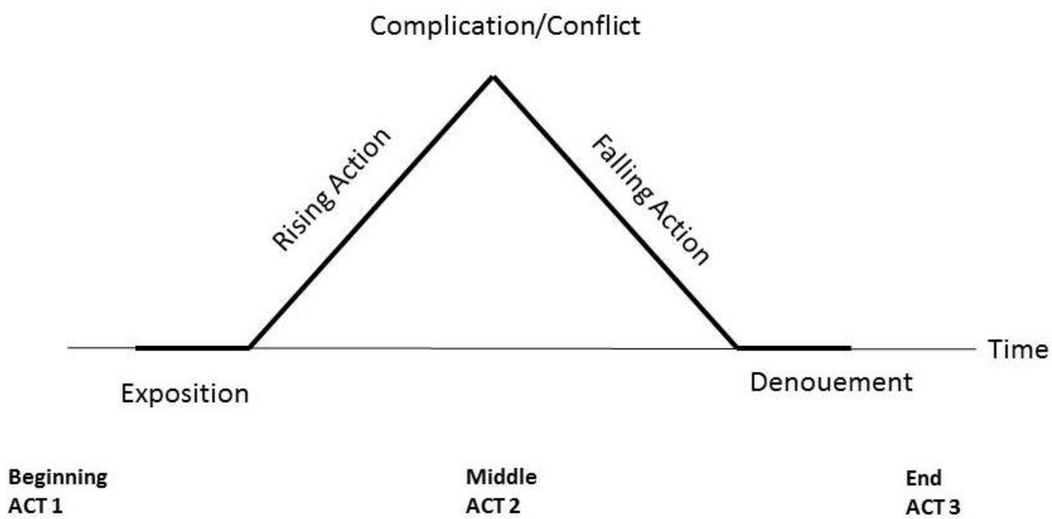

Figure 2.7: Freytag's plot structure of Drama

We now move on to a study of Chatman's view on elements of a narrative.

2.4.2 Seymour Chatman

Seymour Chatman divides Narrative text into Story and Discourse. Story, he further divides into Events and Existents. Events are subdivided to Actions and Happenings. Existents are divided into Characters and Setting (Chatman, 1980). Chatman makes these distinctions based on the idea of Form and essence of an entity. Here story refers to the Form and Discourse refers to the content of a narrative text. Story is the relationship between the various conceptual elements like character, setting and events while Discourse is the expression, the delivery medium in which the story is communicated. The medium can be a book, a movie, a song or a performance (Chatman, 1980).

2.4.3 Mike Bal

A narrative text is defined as telling of a story in a particular medium which could be language, images, sounds or any object like a building. This narrative text constitutes of a Story, A Fabula, Event, Actors and Act. Mike Bal describes each in the following way:

> A story is a Fabula presented in a certain manner. A Fabula is a series of logically and chronologically related events that are caused or experienced by actors. An event is the transition from one state to another state. Actors are agents that perform actions. They are not necessarily human. To act is defined here as to cause or to experience an event (Bal, 1997, p.83).

We observe that what Chatman refers to as Story, Mike Bal calls it as Fabula and What Chatman labels as Discourse is termed by Bal as Text and Story. But the essence of Chatman's Story and Bal's Fabula is the same that is a sequence of events causally related. Our focus is on Fabula or discourse because this helps in understanding the logic of events that compose the skeleton structure of a story. Elements of a Fabula distinguished by Bal are, Events, Actors, Time and Location. Event is characterized by a change from one state to another.

> The structure of Fabula is determined by confrontation. Two actors or groups of actors are confronted by each other. Every phase of the Fabula – every functional event – consists of three components: two actors and one action… (Bal, 1997)

Actors are either the cause of something or they undergo an event caused by some other entity. With actor are connected two more terms namely Function and Actant. For example in the sentence "Marxists want to bring a classless society" Marxists is Actor, Wants to bring is Function and Classless Society is Actant. As it is clear from the example presented by Mike Bal, Actor is the person doing the action or causing the event. Actant is that which is affected by the action of the actor. Function is what actor performs on the actant (Bal, 1997). Time is what connects the events together because every change presupposes succession in time. Location is the place where events happen. Place is also divided into Inside space and Outside space.

2.4.4 Edmund Burke

Krishna Kumar has used Burke's dramatic arc in analysis of stories in Indian textbooks and its comparison with Canadian textbooks. He explains that Burke proposed 5 basic elements in his Dramatist Pentad, they are (Kumar K. , 1989):

Agent (the person, or the kind of person, who performed the act depicted in a story), Act (what took place in thought or deed),

Scene (the situation in which the act took place),

Agency (the means used in the performance of the act),

Purpose (to what aims or person the act was addressed)

These are explained by Burke in the following passage:

> We shall use five terms as generating principle of our investigation. They are: Act, Scene, Agent, Agency and Purpose. In a rounded statement about motives, you must have some word that names the act (names, what took place, in thought or deed), and another that names the scene (the background of the act, the situation in which it occurred); also, you must indicate what person or kind or person (agent) performed the act, what means or instruments he used (agency), and the purpose. Any complete statement about motives will offer some kind of answers to these five question: what was done (act), when or where it was done (scene), who did it (agent), how he did it (agency), and why (purpose) (Burke, 1969).

Burke's Dramatistic worldview draws a distinction between motion and action. Motion is the property of things and objects while action is that of humans where the motive to act plays an important role. Burke's epistemological assumption stems more from his intention to study motivated behavior of how conscious being performs action rather than how they seek knowledge or understand the world (Kimberling, 1982).

2.4.5 Vladimir Propp

Propp did structural analysis of Russian Folktale and found out 31 functions that formed their basic structure. The tales he proposed are combination of a set of functions among the ones described by him (Propp, 1968). These are the following conclusions of Propp's study

> The functions of characters serve as stable, constant elements in a tale, independent of how and by whom they are fulfilled. They constitute the fundamental components of a tale. The number of functions known to the fairy tale is limited. The sequence of functions is always identical. All fairy tales are of one type in regard to their structure (Propp, 1968, p. 21).

Propp's study is significant because it helps us see the actions and events of a story as prototypical. By defining a few set of functions, it may possible to build narratives for specific purposes if, one can outline the schema of the environment or community in which a particular narrative is to be positioned. The other element of Russian folktale defined by Propp is the Dramatis persona. He associates the idea of spheres with the dramatis persona. A sphere is related with the influence of the actor within a certain set of Functions. The sphere of action is that of Villain, the Donor, the Helper, a Princess (a sought for person), Princess' Father, Dispatcher, The Hero and The False Hero. All the dramatis personae are associated with performances in a certain set of functions (Propp, 1968). The list of 31 plot functions of Russian folktale is given in the appendix 2.

2.4.6 Levi Strauss

He was a structural anthropologist who is known for his method of analyzing Myths of the South American natives. His hypothesis was that myths from not just red Indian communities but around the world followed a certain logical structure have an internal structure. The logical structure of the myths was the presence of a binary oppositional framework given by the form a: b::c:d which means *a* is opposed to *b* as *c* is opposed to *d* (Strauss, 1983). For example *cooking* is opposed to *hunting* as *eating* is opposed to *predating* (Strauss, 1981). Strauss showed that the oppositional relations present in the myths were also related to cultural codes and also to the geography and the overall ecosystem of the communities in which they originated. Strauss's work has its base in Structuralism which sees any system to be composed of relationship between primary units and to the whole structure. For example in language, a structural analysis will try to find relation between phonemes and morphemes and their relation to sentences and expression in a particular language (Hawkes, 2003). The idea of binary opposition presented by Levi Strauss stems from the roots of logic dating back to the Greek period when Parmenides attributed the creation of qualities in nature like hot and cold, Wet and dry to the oppositional motion of matter (Harris, 1969). The law of opposition forms the backbone of Formal logic presented by Aristotle. Levi Strauss has used the same principles to analyze myths. The extent to which Levi Strauss has taken the structure of formal logic is to connect myths with, not just the socio-cultural aspect but the whole biosphere of the community in which the myth is created which includes apart from kinship relation, the classification of flora and fauna and geographical divisions. The important learning we get from Strauss's work is to see a narrative as part of a larger system. The words written do not grow and die with the story, but they extend to the way life of a community is organized or structured.

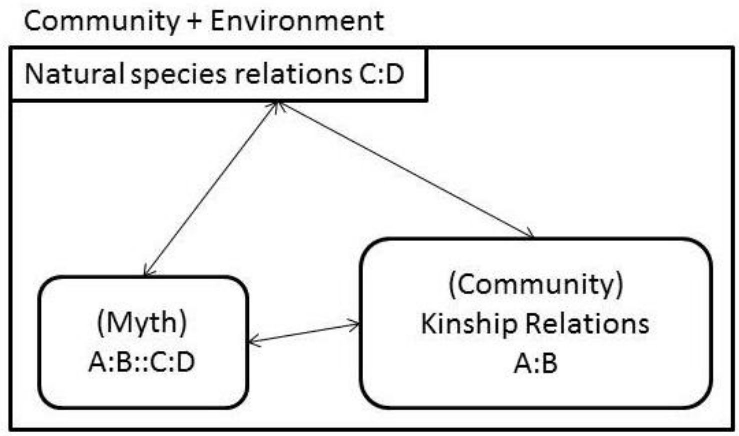

Figure 2.8: The oppositional relations present in the myth structure are reflected in the oppositional relations present in kinship relation and Natural Environment composing the savage community.

2.4.7 David Herman

David Herman refers to Gerard Genette's work and explains that there is a story when there is event or action because event involves transformation, a transition from an earlier state to a new state. The transformation is necessarily desirable. So, Gennette, according to Herman relates action, event state, transformation, expectation and interest as integral aspects of a story (Herman, Story Logic: Problems and Possibilities of Narrative, 2002). Herman's work lay emphasis on philosophy of action and draws its attention on its relationship with events in a story. He also refers to the work of Donald Davidson, Wittgenstein and W.V. Quine to draw parallels between structure of language and structure of the world. A distinction between nouns and verbs reflects a distinction between objects and events. Herman also presents Vendler's study on world configuring properties of language by drawing correlations between Objects, event (actions and processes) and Facts. Within action, there are further divisions as Activity, Accomplishment, Achievement and State. Example of Activity could be someone running or pushing a cart, of Accomplishment could be someone running a mile or drawing a perfect circle, of Achievement could be someone reaching a hill top, of State could be someone in debt or being a North American (Herman, 2002). Herman further clarifies the connection of a time dimension with achievement and accomplishment. Another important term that Herman introduces is Storyworld. He finds it better to look at story from the story world point of view because it provides a larger perspective in which the events of a story unfold because the actions of agents are motivated by a situation which is connected to larger issues which constitute the Storyworld as a whole. Hence, looking at Storyworld provides a better grip on the structure and Logic of a story. The same point is better explained by Herman:

> The term Storyworld better captures what might be called the ecology of narrative interpretation. In trying to make sense of a narrative, interpreters attempt to reconstruct not just what happened-who did what to or with whom, for how long, how often and in what order-but also the surrounding context or environment embedding existents, their attributes, and the actions and events in which they are more or less centrally involved. This surrounding environment, is not just temporally but spatiotemporally structured, although classical treatments of story tend to emphasize sequence over space. (Herman, 2002, p.13).

2.4.8 Joseph Campbell

Joseph Campbell is associated with elaboration of the mythical structures in ancient myths across the world and his structure is known by the name of the Hero's journey. The questions that Campbell have tried to find answers for are these:

> What is the secret of the timeless vision? From what profundity of the mind does it derive? Why is mythology everywhere the same, beneath its varieties of costume? And what does it teach? (Campbell, 1973, p.2)

The answer to such questions Campbell has provided by presenting a kind of structure on which the ancient myths are built. It is given by Separation>initiation>Return which can also be termed as the nuclear unit of a myth (Campbell, 1973). A myth is an elaboration of The hero's journey. For Campbell, the journey is a symbolic representation of an inner spiritual journey. The psychological significance of the various aspects of the Hero's journey we will deal with later, but first let us look at the basic elements of the Myth that Campbell has discovered. The broad division of the plot of a Myth comprising the Hero's journey is given by Departure, Initiation and Return. The subdivisions under each heading are given in the appendix2.

2.4.9 Robert McKee

We have chosen to review the work of Robert McKee because he looks at writing of stories as a design process with clearly laid down intentions and purpose. At the same time he distinguishes between story building based upon a formula and understanding the underlying Universal forms of story. It is here we see clearly laid down the purpose of a story. He quotes Kenneth Burk by saying that "Stories are equipment for living".

According to McKee:

> Story isn't a flight from reality but a vehicle that carries us on our search for reality, our best effort to make sense out of the anarchy of existence (McKee, 1997, p.12).

Some stories are centered on character, others are centered on action (Tobias, 1993), but for McKee the most important thing that creates the structure of a story is Event. An event is characterized by change. A thing must change from one state to another. Also a change must signify some meaning to a certain character. McKee explains:

> A STORY EVENT creates meaningful change in the life situation of a character that is expressed and experienced in terms of a value (McKee, 1997, p.33).

McKee further expresses these changes of state from positive to negative as composed of binary qualities from being alive to being dead, being truthful to being a liar, being courageous to being Coward. These values are not to be confused with moral qualities they merely represent to what end of the spectrum of experience is a character positioned at (McKee, 1997). There is another element that is part of event is conflict. If the event has a conflict centered on it then that makes an event more impactful.

Scene is also an event, but it has great emphasis on what values are at stake for the central characters. What will they gain or lose in the due course of actions. The values in a scene undergo a change of state from say freedom to slavery or justice to injustice. The purpose of scene is to create an exposition.

A **Sequence** is a series of scenes that lead into culmination of a bigger action. For example if we consider a protagonist's applying for and getting a dream job as a sequence, then it can consist of three scenes. Her getting ready for the interview is one scene. The second scene could be her leaving home to reach the hotel where the interview is being held. On her way, she may meet obstacles like a gang who she has to fight to make her way to the hotel in time. The third scene may be of the final interview where the interviewee hears about her adventures trip to the hotel and finally gives her a job for that's the kind of courageous and determined person they want. The next element is the **Act,** which is similar to scenes building up into sequence but the change that happens in Act leads to a major reversal of events. A series of acts built up the larger structure of a **Story**. And then there is a **Climax** which is just before the story ends, it brings about irreversible change. The other important aspect of story is **Setting** which itself is composed of Period, Duration, Location and level of conflict. Where Period is the time in which story is set. Duration is the length of the time. Location is the place or space where the story unfolds and level of conflict elaborates the hierarchy of human struggle (McKee, 1997). A story setting is what confines the limits and the possibilities of a story because within any world, however imaginary, only certain events are possible. McKee explains:

> A STORY must obey its own internal laws of probability. The event choices of the writer, therefore, are limited to the possibilities and probabilities within the world he creates (McKee, 1997, p.70).

And lastly, the story has the element of character. McKee defines character as:

> True Character is revealed in the choices a human being makes under pressure-the greater the pressure, the deeper the revelation, the truer the choice to the character's essential nature (McKee, 1997, p.101).

The attributes of a character that the audiences judge it for are hidden in the questions such as, is the character loving or cruel, is he Generous or selfish, Strong or weak, Truthful or a liar, Courageous or Cowardly? These attributes become visible when the character is seen making choices in a given situation which may be filled with different kind of pressures, his character is defined by what he chooses it do. The main character also, the Protagonist has a will which means it consciously desires something. It wants to bring about something for itself or for the world. The protagonist also must have its desire in coherence with its potentialities. It must have an opportunity to fulfill its desire. It is not necessary that it may succeed, but a protagonist has hope, that if such and such a thing happens, it will have chance of fulfilling its desire. The main elements of a story according to McKee are Events, Character and Setting.

Following is the summary of main points in the theory of Narrative that will be used in development of Epistemological Narrative Framework:

1) Aristotle's basic elements of a plot have the structure with a Beginning, Middle and End.

2) Chatman, Burke and Bal's basic elements of a story are Agent, Actant, Story (Plot), Setting, Time, Agency, Purpose, Place.

3) Propp's basic elements of a Russian folktale are dramatis persona, its sphere of action and Functions.

4) Levi Strauss's idea of binary opposition and relation of story to the community. The basic elements being Binary oppositional relationship between various elements of story at different levels.

5) David Herman's emphasis on specific type of actions and events as activities, achievements and accomplishments.

6) Joseph Campbell's plot structure describing the hero's journey to unknown worlds and connecting the known world with the unknown world.

7) Robert McKee's elaboration on story design with basic elements of the story, emphasis being on Character's motivation, desire and purpose for performing action.

2.4.10 Significance of Dialogue

Dialogue is not a narrative element that stands in itself. It is mostly a tool to enhance characterization. It also externalizes the character's thinking process and provides reasons for the actors' actions. It is a conversational exchange between two or more people. Dialogue becomes necessary in a problem solving situation as many characters are involved in attempting to resolve a problem. One of the main attempts in development of Epistemological Narrative framework is to represent an argument or syllogism in the form of a dialogue.

Table 2.1 shows a matrix of author and the associated element of the story they have talked about. This has been created by drawing inferences from each author's work.

2.4.11 Basic elements of a Story

After a literature survey of various structures of story building by various authors, a set of basic elements of a story were drawn. These basic elements are essential in a story. A story model can only be built by keeping these basic elements of a story in mind. These elements are given in table 2.1.

Philosopher	**Character**	**Event/Plot/ /Function**	**Setting/ World**	**Purpose**	**Agency**	**(Binary Oppositional)**
Aristotle	*	*				*
Kenneth Burke	*	*	*	*	*	
Mike Bal	*	*	*			
Seymour Chatman	*	*	*			
Levi Strauss			*			*
David Herman		*	*	*		
Vladimir Propp	*	*			*	
Joseph Campbell	*	*		*	*	
Robert McKee	*	*	*	*		*

Table 2.1: The primary elements of a story discussed by various authors

Table 2.1 summarizes the basic elements of a story by various authors. Aristotle has emphasized upon Character, Plot and Binary opposition, Kenneth Burke has talked about Character, Plot, Setting, Purpose and Agency. Mike Bal and Seymour Chatman states character, Plot and setting to be the main elements while Levi Strauss has looked at narrative mostly from setting and binary opposition point of view. David Herman considers Plot, setting and purpose to be the main elements. Propp finds the main story elements in Russian Folktales as Character, Plot, Purpose and agency. For Joseph Campbell Character, Plot, Purpose and agency are important while for Robert McKee Character, Plot, Setting Purpose and Binary Opposition constitute a story's main elements. We find that although there is a diverse number of scholars who have talked about various elements of a story, probably the most important element are only a few. There may be other elements but the elements of Character, Plot, Setting, Purpose, Conflict and Binary Opposition seem to be of primary importance.

2.4.12 Summary of Theory of Narratives

A review of theory of narratives helped us in outlining the basic elements of a narrative. These elements are as follows:

1) **Plot/Event:** This is a complex network of situations where many characters with their individual desires are trying to achieve something and are in conflict with each other. Conflict is an important aspect of an event, without which it loses its meaning and significance.

2) **Character:** Since stories are about 'what happened in the life of a being,' it is an essential component. Character is defined by its attributes or qualities. Further, their qualities come to light in their inner drives, motives and purpose of the characters that take the action of story forward.

3) **Setting/world:** The place or space and time where the events of a story unfold. It is extremely important in setting the limits to the kind of actions that can happen in a story.

4) **Opposition:** Opposition brings forth the main conflicting element of the story. Conflict or complication exists primarily because of conflict between various forces maybe between two or more humans, between human and nature, human and society or human in conflict with their inner thoughts.

5) **Dialogue:** The other elements of story like character, opposition and setting get expressed with the help of dialogue. In the Epistemological Narrative Framework, dialogue has been used to express a logical argument or syllogism.

In the next section we study the literature on Theory of Learning which is mostly used to reinforce certain point from Theory of Knowledge. There are also similarities between the three domains which will be discussed in chapter 4.

2.5 Theory of Learning

The spectrum of learning is vast. There are many aspects associated with it. There is of course the learner. There is the content to be learnt which can be either a skill or understanding of a concept. There are methods by which the learner learns, there are tasks and assignments associated with learning method and finally tests and evaluation for measuring if learning has taken place. But underlying all these aspects, there is an understanding of the learning process itself which tries to answer the question “how do humans or even animals learn?” This question has been addressed by various learning theories. Some theories associate the learning process with habituation while others relate it with meaning construction. What we have attempted is to build a schema of learning from the learning theories. This schema is represented as a narrative structure which can be applied to build narratives in which characters learn something.

The systematic method of studying learning process was first applied by Pavlov who introduced the concept of classical conditioning to the learning process (Houston, 1976). B.F. Skinner introduced the concept of Reinforcement (Kim Austin, 2001) which together with Pavlov’s concept of Conditioning formed the Learning theory known as Behaviorism. The concepts related to Behaviorism are discussed in more detail in section 2.5.2. Another learning theory that emerged after Behaviorism was Cognitivism, the main focus of which is to understand how the mind or brain processes information and uses it in specific situations (Kellogg, 2007). Cognitivism contrasts with the Learning process as described in Constructivism which associates learning process with a learner’s prior experience. It contrasts with Cognitivism’s view of mind as an information processing machine. Due to the effect of a learner’s prior knowledge, two people observing the same event can construct different meanings out of it. In the next section we discuss in detail Piaget’s notion of Constructivist learning approach.

2.5.1 Piaget’s theory of learning

At this point, we would like to deviate towards the Constructivist theory of learning. Piaget was one of the main proponents of this theory of learning. The main concept of this theory is based upon the idea of knowledge emerging by a disturbance in a balanced or equilibrium state. Matthew explains Piaget’s point on this:

> In both, theory of evolution and the constructivist theory of knowing, ‘viability’ is tied to the concept of equilibrium. Equilibrium in evolution indicates the state of an organism or

> species in which the potential for survival in a given environment is genetically assured. In the sphere of cognition, though indirectly linked to survival, equilibrium refers to a state in which an epistemic agent's cognitive structures have yielded and continue to yield expected results, without bringing to surface conceptual conflicts or contradictions. In neither case is equilibrium necessarily a static affair, like the equilibrium of a balance beam, but it can be and often is dynamic, as the equilibrium maintained by a cyclist. (Matthews, 1998, p.16)

The two main terms in Piaget's constructivist learning theory are 'Accommodation' and 'Assimilation'. These terms can be understood under a third term called Schema. A schema is an expected order in a set of events. A known schema can be understood as a state of equilibrium. For example the schema of a restaurant is composed of the order of events and its relation with the agents acting out those events. The relation between schema, Assimilation and Accommodation, we would like to explain by quoting Michael Matthews:

> An infant quickly learns that a rattle it was given makes a rewarding noise when it is shaken, and this provides the infant with the ability to generate the noise at will. Piaget sees this as the construction of a scheme which, like all schemes, consists of three parts:
>
> 1) Recognition of a certain situation (e.g., the presence of a graspable item with a rounded shape at one end) ;
> 2) Association of a specific activity with that kind of item (e.g., picking it up and shaking it);
> 3) Expectation of a certain result (e.g., the rewarding noise)
>
> It is very likely that this infant, when placed in its high-chair at the dining table, will pick up and shake a graspable item that has a rounded shape at one end. We call that item a spoon and may say that the infant is assimilating it to its rattling scheme […]Shaking the spoon, however, does not produce the result the infant expects: the spoon does not rattle. This generates a perturbation ('disappointment')…that development would be an accommodation (Matthews, 1998,p.17).

To reinforce Piaget's idea of Assimilation and accommodation, we would also like to quote

David Leonard:

> In Piaget's developmental learning theory, the key to the growth and maturation of the person is through a twofold learning process. Through the process of accommodation, existing cognitive structures change to make sense of the new events occurring in the environment. Through assimilation, the individual interprets environmental events based upon existing cognitive structures (Leonard, 2002, p.38).

We are now in a position to form a graphic representation of the learning process as suggested by Piaget's constructivist theory of learning.

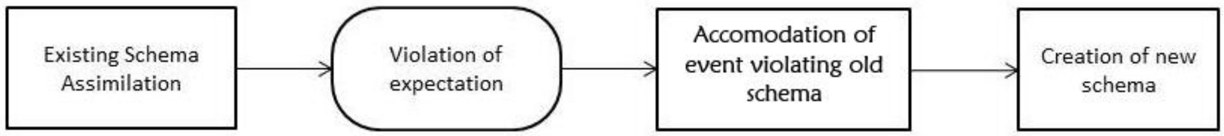

Figure 2.9: Representation of learning process according to Piaget's theory of constructivism

In simple terms if we try to describe this process we can say that an agent (a person) at any given instance of time will have a particular schema of the environment in which he/she has entered. Now two things are possible, either the structure of the environment matches the schema that the agent has in his/ her mind or it violates it. If it matches the schema, then things go normally and no new learning takes place in that case. However, if the schema does not match the Agent's expectation (schema) then there is a perturbation and that leads to accommodation to the new information and a new schematic structure of the new environment if formed.

For example, let us say an agent X is habituated to a certain routine in which at 7:00 AM every morning, he receives a bottle of milk from a local milkman. This routine is fixed as a schema for Agent X in which exists another agent who is a milkman, whose job is to deliver milk. This schema, the agent has *assimilated* through many prior experiences. Now consider that on a particular day, the Milkman does not show up at 7:00 in the morning. Initially, the agent X will ignore this incidence as just a onetime event. But what if milkman is absent even on subsequent days on a continued basis. This will dramatically affect the normal life of the Agent. He will be deprived from the consumption of milk. His body will become deficient of vital nutrients that milk provides. This perturbation or disturbance is the starting point towards the journey towards learning (if the agent chooses to do something about it). Now the agent may step out of his comfortable dwelling place to find out what happened to the milkman? This may lead him to have new knowledge about where the milkman lived, if he did not know it before. On arriving at the milkman's house, he may come to know that the Milkman has got a job at a new dairy farm which has recently got established in their locality. The Milkman may also inform the Agent that now he can get milk from a nearby milk station. This becomes new knowledge for the Agent as he accommodates it with the previous knowledge, which will permanently change his behavior. He may have to now step outside his house every morning to get milk for himself from the local dairy milk station. A new routine is established for the agent based upon new knowledge of how to get milk. This discussion is a simplistic adaptation of a very complex, and still incompletely understood processes.

2.5.2 Theories of learning preceding Constructivism

The constructivist theory of learning has itself evolved from other theories like Behaviorism and Cognitivism. There are many more theories and philosophies of learning but we are focusing on these as they are the main ones and we wish to compare them and present an argument about why of all these, we have chosen to focus our work on philosophy of constructivism.

According to Behaviorist, the learner starts off as a clean slate (i.e. tabula rasa) and behavior is shaped through positive or negative reinforcement. Both positive and negative reinforcement increase the probability of antecedent behavior repeated again. In contrast, punishment (both positive and negative) decreases the likelihood that the antecedent behavior will “not” happen again (Knowledgebase, 2011).

Cognitivism came into the picture after criticism to Behaviorism which assumed a human to be a black box. Also that most of the experiments done by Pavlov upon animals, especially dogs. Cognitivism is a theoretical approach in understanding the mind using quantitative**,** positivist and **scientific** methods, that describes mental functions on the basis of information processing models. Cognitivists divide cognitive functions of brain into a few categories; these are Perception, Attention, Memory, Reasoning, Problem Solving and Language (Kellogg, 2007). This view of associating learning process with mental cognitive process was found to have certain limitations by the Constructivists who were opposed to looking at human mind as an information processing system. The point at which the constructivists differed from Cognitivists was the construction of meaning.

The underlying idea in **constructivist** approach is that knowing or learning is an act of active construction by the learner. Learning is an active action that the learner performs. From this point, when a child is constructing knowledge, what becomes important is to understand what action is being done, when knowledge is being created. The action being done is the act of differentiation, how two entities are separate from each other. This helps in forming a schema of a world made up of differentiated things. A world in the beginning may appear homogeneous, but soon through the sense one begins to notice that there are different looking objects, there are different sounding sounds, there are different tasting tastes, and there are different feeling sensations. When we learn to describe how it is that what looks same is formed of different constituents, we learn to create knowledge from our own individual perspective that can also be shared by others. Bruner in his book study of thinking has shown that thinking involves forming distinctions and creating boundaries of categories. There can be fuzzy boundaries but that fuzziness itself is a unique property that when frozen becomes another category. There are endless possibilities of looking at the world and each learner discerns it in his/her own way based upon prior experiences (Bruner J. , 1956). One of the approaches in constructivism is breaking of expectation. For this, we need to understand the concept of a schema. A schema is like a mental map that any person builds regarding something. For example, the schema of a restaurant tells us what kind of behavior or events to happen in a restaurant or a hospital. Generally, things happen in repetitive way in these places. If this wasn't so, people would not be able to take spontaneous action. A schema of prior knowledge regarding the world around us is constantly being built up as we grow up and gain new experiences. When the person becomes comfortable with a certain schema, he/she expects that the next moment in time will contain the similar incidence which is stored in their schema, however if something happens that is unusual and strange, it disrupts the schema about something. This creates a situation when the old schema has to be assimilated with the new one. This leads to adaptation of the old with the new schema and new knowledge is constructed (Knowledgebase, 2012). This process is impossible unless the learner spots the distinction between the regular, expected event or schema and the new event that has occurred. Each individual has his/her own repository of schema built through prior experiences. The person's constructs meaning not by what the object is but by giving the object meaning in relation to his/her own life's past experiences.

2.5.3 Vygotsky's theory of Social Constructivism

While Piaget's Constructivist theory is centered on biological process of an individual's growth in his/her stages of mental development, Vygotsky on the other hand introduced a different form of Constructivism called Social constructivism. According to Vygotsky, a learner is not alone in the endeavor of acquiring knowledge. The learner, has a social and cultural environment which plays an equally important role in his/her learning as the individual's own efforts. Vygotsky showed through experiments that when learners at the developmental stage of 8 years were given certain tasks with the assistance and demonstration be a trainer, their ability for performing the task increased significantly as against those who received no assistance in performing the task. This insight of Vygotsky has had far reaching consequences in development of theory of social constructivism. Vygotsky's approach focuses on social environment of the learner. Rather than expecting the learner to have complete onus on her individual achievement, it focuses on building a relationship of learning between student and teacher as well as student and peers. At this point we would like to recall the historical process of development of concepts in western science. We speculate that it may be because of presence of such a social learning environment in the western world that may have been responsible for sprouting of so many ideas by scientist generation after generations. Such a social learning process was well developed in eastern cultures as well, but lacked the scientific method developed during renaissance. It is a well-known fact that each philosopher or scientist has studied either directly under a master or has got the chance to study their work indirectly. Plato succeeded Socrates and so did Aristotle, Succeeding Plato. And many philosophers, Succeeded Aristotle, translating and studying their work, their questions and solutions, and in the process modifying them or presenting a better alternative.

A researcher, philosopher, scientist or technician, finding the impetus of her work in the work of another contemporary scientist or a predecessor where inquiry into a phenomenon passes from one generation to another is one of the central ideas is at the core of Epistemological Narrative Framework.

2.5.4 Summary of Theory of Learning

Piaget's constructivist theory of learning outlines the process of learning in which an existing schema is disturbed by an event that contradicts expectation. The unexpected event leads to assimilation of the new situation which results in schema modification leading to new learning.

Vygotsky's theory of Social Constructivism states the social aspect of learning. A student's learning ability is affected by the presence of peer group which may include friends, parents and teachers. If an abled peer helps the learner in performing a task rather than leaving him/her alone to solve the problem, then the ability to learn and perform the task increases significantly. In this approach, the student learns along with the abled peer. The significant point learnt from Vygotsky was that since the social environment of child influences their learning capability, the important thing to focus on was to understand the social environment of the scientific community. Kuhn had specifically seen scientific development as the operation of community building forces where person's from a domain form a cohesive group. If a learning environment is to be created for teaching science, then that environment should emulate the structure of a scientific community and their operational schemas. In such a scientific culture, learning of student may become spontaneous. Here we see direct integration of ideas of Piaget, Kuhn, Dewey and Vygotsky. How these ideas are integrated methodically is explained in next chapter on research methods.

2.6 Narrative Schema of learning process

The learning schema according to constructivism has one of the components as violation of expectation. Expectation comes to form because of an existing schema. How does a schema get established in the first place? The clue to this is found in Behaviorism and Cognitivism. When a stimulus and response are present together in many instances that forms a schema:

If S then P > S > Therefore P.

This schema conditions the learner to expect only a certain output when a specific input is given.

During any new experience, memory recall enables to fit or match an existing perception into a storehouse of previous experiences. When this is established, various experiences are stored as schemas. Once this step is established, only then the next step of schema violation can take place. The strength of the existing schema enables the violating incidence to stand out in contrast against it and hence possibility of it becoming noticed or catching the attention.

Recalling Kuhn at this point, it is possible to compare Kuhn's notion of anomaly in an existing paradigm with the notion of Violation of expectation in constructivist theory of learning. Piaget's existing schema (or equilibrium state) is equated with the notion of a Paradigm in Kuhn's structure of scientific revolutions (Burman, 2007). Kuhn clearly explained that encounter with anomaly situation is directly dependent upon rigidity of existing paradigm. Novelty is never the prime motivating factor in a scientific revolution. The paradigm shifting scientist is firmly established in the existing tradition; hence the strong contrast of anomaly situation only stands out because of strength of rigidity of existing paradigm. The anomaly situation appears unbelievable, surprising and always something wrong (Kuhn, 1977). This explanation of Kuhn can be used to infer that the establishment of existing schema (synonymous with the concept of a paradigm) is as important as violation of the schema in a learning process or paradigm changing scientific inquiry.

2.7 Summary of Literature Review

We have established a general pattern in a knowledge discovery event and its similarity with the structure of narrative and the process of constructivist learning. Developing the details of a knowledge discovery event or scientific inquiry, we elaborated upon the idea that "what is it the agent discovering, when he/she is discovering something?" To find the answer to that question, we did a survey of historical development of theory of Knowledge and found two major paradigm shifts; one was Aristotle's Formal Logic and other, Symbolic Logic and still further the groundwork laid down by John Dewey and Later Thomas Kuhn for development of a Narrative Logic. While Formal Logic is centered on defining and identifying Entities through their enduring properties, Symbolic Logic is centered on identifying and defining objects through their relationships with other objects in a given system. In theory of Narrative, the basic elements of a story were identified by review of works of various authors. In theory of learning we learnt from Piaget the similarity in a child's acquisition of knowledge and a scientist's way of discovering phenomenon. Vygotsky's notion of social constructivism was accessed to understand that the learning acquired by a person is directly associated with the social environment in which she is nurtured. This idea further develops into understanding the social environment of the world of science based societies. Similarity of this notion was seen with Kuhn's ideas on how scientific communities advance their knowledge. In the next chapter we discuss the research methods used to integrate the three domains of Theory of Knowledge, Theory of Narratives and Theory of Learning.

Chapter 3

Research Methods

3.1 Introduction

The main research methods for reasoning used in this research are that of Deductive Reasoning, Inductive Reasoning, and Historic method. The reason for using Deductive reasoning is that it helps to combine a set of given premises to form a valid inference. Deductive logic has helped us combine statements from the three theories and produce valid inferences that resulted in the formation of Epistemological Narrative Framework (ENF). The data to form premises in a deductive argument was taken from historical research to collect factual information about the evolution of a particular idea or concept through history. The emphasis was not on finding the exact date and the person associated with a discovery because a phenomenon is discovered over a period of time and many scientists are involved in it rather than one person (Kuhn, 1969). What we trace is the development of idea, how it has changed over time, for example the rejection of Phlogiston theory and introduction of Oxygen as the gas responsible for combustion. We have relied upon results of historical research by other writers, for example, for the evolution of chemistry we referred to the four volume books by Viva-facts on history of science series and Asimov's '*A short history of Chemistry'*. We will talk about it in detail in the section on Historical Method. With the help of Deductive Reasoning we were able to develop the Epistemological Narrative Framework. Then, with the help of ENF and data collected from Historical method, examples of narratives were created to explain selected concepts. Deductive logic alone cannot provide validity of claims because it is not arrived at through experience. Therefore, a method which creates valid knowledge by observation of sense experience is required. Such a methodology is provided by Inductive reasoning. Hence, For the purpose of experimental validation of the Narratives developed using ENF, the methodology of Inductive reasoning was applied. Since Inductive logic includes taking a number of cases or samples, then observing a general trend or pattern within the sample and then predicting that if in the future a sample of same class is taken, what will be the probability of getting the same results? So this Inductive logic helped us see the student performance of a sample size of 207 students. From the achievement result, we could conclude with some level of certainty, that if the same experiment is repeated in the future, the student's cognition of subject matter will probably be better with the textbooks designed using the ENF as compared to their existing central board textbooks.

3.2 Deductive Logic

The rules of Deductive reasoning are such that, they combine more than one statement to form a new statement. If the premises are valid and the conclusion true then the new statement holds the weight of validity. Since it was required to find a valid method for synthesizing statements from Theory of Knowledge, Theory of Narratives and Theory of Learning, deductive reasoning seemed most appropriate for this purpose.

3.2.1 Literature survey on Deductive Logic

History of Deductive logic goes back to the time of Greek philosopher Aristotle. He was the first one to propose a formal system of Logic for arriving at valid knowledge. The practical importance of his method has been immense in the development of the scientific method for the western world. Even though Aristotle's syllogistic logic is no longer prevalent in modern times but it has played a pivotal role in the development of western logic as we know it today.

> The scientific study of logic began with Aristotle in the fourth century B.C. His impressive work, combined with other influences, is the foundation of a long tradition of logic that still continues (Perry & Hacker, 1991, p.3).

Quoting Dag Westerstahl in this context:

> The amazing thing about Aristotle's logic is in fact how 'modern' it is. His results can easily be stated, understood and proved in a modern framework (Westerstahl, 1988)

Following is the formal argument for starting our study the subject matter of logic.

P1: We know that valid knowledge originates from True and Justified beliefs (Steup, 2008) (Ross, 2008) (Chrucky, 1997).

P2: Truth and justification of beliefs can be systematically inquired by application of Logic (Copi, 1961) (Hacking, 1972).

C: Therefore, it follows from P1 and P2 that in order to study subject matter of Knowledge; one needs to do an enquiry into application of Logic.

A visual representation of the above argument is given in figure: 3.1

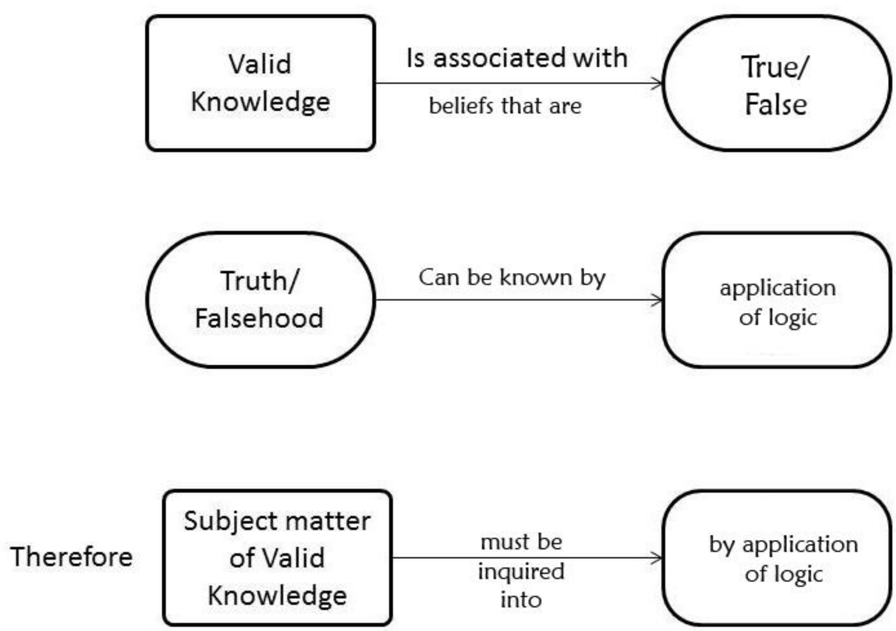

Figure 3.1: Visual representation for argument favoring study of subject matter Logic for understanding knowledge and how it can be attained in a valid manner.

Keeping Aristotle’s logic at the base, we will be in a better position to understand the later development in Theory of Knowledge.

3.2.2 The Basics of Logic[16]

Before getting into detail of logic, let us see the relationship between science and logic. Carnap explains that Science involves making statement about some pattern which is repeated constantly in nature:

> The observations we make in everyday life as well as the more systematic observations of science reveal certain repetitions or regularities in the world. Day always follows night; the seasons repeat themselves in the same order; fire always feels hot; objects fall when we drop them and so on. The laws of science are nothing more than statements expressing these regularities as precisely as possible (Carnap, 1995, p.3).

The above description of science by Carnap contain a sentence “the laws of science are nothing more than **statements** expressing these regularities as precisely as possible.” This sentence contains the word, **statement**. In science, a statement carries a law. A law is a law only if it holds true or some degree of it. Logic is a practice which tests; to what degree a statement is true or false. The way, we have understood logic is this: a set of statements are arranged in such a manner such that the statements referred to as **premises** are connected with each other in a way that self-evidently leads to a certain **conclusion**. Testing the Validity of such an arrangement of statements (also known as an argument) is the subject matter of Logic. Logic is defined as the science of reasoning (Copi, 1961). However Copi argues that study of human reasoning process is a concern of the psychologist. The reasoning process may involve various mental states of a particular mind. But the logician is only concerned with the statements made in support of reasoning. By checking if the conclusion drawn “does” follow from the premises stated (Copi, 1961).

What is a premise and what is a conclusion? First, let us understand the distinction between sentences that are **statements** and those that are not.

A statement is that which is either true or false

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16 Section 3.2.2 to 3.2.4 is referred from “Logic for undergraduates” (Kreyche R. J., 1961) and “A concise introduction to logic” (Hacking, 1972).

For example: *All plants have roots*

This is a statement because, it can be judged to be true or false or partially true or false.

Contrasting this statement with another sentence:

What are you doing?

This sentence is not a statement because we cannot ask whether it is true or false. This sentence is a question. Similarly there are other sentences in English language that are not statements, like

Please fetch me some water. Or, *Get out of this room.*

These sentences are requests and command respectively. They cannot be judged to be true or false. Let us now understand the structure of a statement.

3.2.3 Structure of a statement

A statement is made up of a **subject** and a **predicate**. A subject is a person, place or a thing and its predicate is something attributed to the subject. So, a statement is about some attribute or property of something or someone. If what has been predicated to a subject is true, then it is true, else false.

An **argument** is made up of two kinds of statements; a premise and a conclusion.

Consider the argument

Premise 1: All planets are spherical

Premise 2: Pluto is a planet

Conclusion: Therefore Pluto is spherical

Premises are the evidence for the validity of a conclusion. Conclusion follows from the premises. In other words we can say that conclusion can be inferred from the premises. Premises help in drawing valid inferences. What is inferred from the premises is termed as the conclusion.

So, if the premises are true and the conclusion is true, then the argument is Valid. We do not say that an argument is true or false, it is said to be Valid or Invalid (Hacking, 1972).

Logic is a tool to judge valid from invalid argument and know why it is so (Kreyche R. J., 1961)

3.2.4 Formal structure of logic, the categorical syllogism

Logical statements (in the world view of classical philosophy) have a certain predefined form or we may say structure. They are of four types.

1) Universal Affirmative (A)

Example: All S is P

2) Universal Negative (E)

Example: No S is P

3) Particular Affirmative (I)

Example: Some S is P

4) Particular Negative (O)

Example: Some S is not P

Statements must correspond with one of the above forms. It is possible to construct complex statements from these basic forms. The forms mentioned above are for Categorical Statements. There are other type of statements as well, known as conditionals (hypothetical syllogism) and modal propositions.

3.2.5 Hypothetical syllogism

In this section we introduce other types of syllogism apart from categorical. These are Conditional and disjunctive syllogism.

A conditional syllogism is of the Form

If A is true, then S is True.

Example: If the train is on time, we will not get late.

Form of the disjunctive syllogism is as follows

Either A is true or B is true

Example: Either this substance is a metal or a non-metal.

3.2.6 Structure of a Valid Argument

A valid argument has a formal structure. As mentioned earlier, an argument consists of Premises and conclusion. And the conclusion follows from premises. There are total three terms. One is subject, one Predicate and the Middle term. The middle term is what connects the subject and the predicate of the conclusion. For example consider the syllogism

P1: All skillful people are useful for society.

P2: Nitin is not skillful.

C: Therefore, Nitin is not useful for society

We take the conclusion first

Nitin is not useful for society

Now we need to find the Middle term.

Middle term is the term which connects the subject and the predicate. So in this case we have "skillful people" as the Middle term. There are many type of fallacies that one needs to take care while analyzing a syllogism. For example, the middle term must be a Universal in at least one premise. We will not go into the complete detail of each and every type of syllogism. Our main purpose of elaborating upon this subject was to emphasize the point that a logical argument necessarily follows one of the structures defined in the formal structures of logic.

3.2.7 Deduction by Symbolic Logic

Symbolic logic was developed to introduce a precise language by which the validity of statements could be judged. It is required in the structure of symbolic logic that statement be replaced by symbols. Each symbol denotes a function. A simple statement can be like "It is raining". It can be denoted by symbol R. Statement like "it is raining" and the streets are wet is a complex statement made of two simple statements and an operator "and".

For example

It is raining = R

The streets are wet = W

And = .

It is raining and the streets are wet can be symbolized as = R.W

There are three types of general rules for deduction, Modus Ponens, Modus Tollens and Disjunctive syllogism (Gale, 1979).

Modus Ponens:

Premise 1: $P \rightarrow Q$ ($\rightarrow$ stands for if-then relation)

Premise 2: P

Conclusion: $\therefore$ Q

For example:

P1: If it rains, then harvest will be good

P2: It is raining

C: Therefore harvest will be good

Modus Tollen:

Premise 1: $P \rightarrow Q$

Premise 2: ~ Q (~ is not)

Conclusion: $\therefore$ ~P

Example:

P 1: If he reads the book, he will know the answer

P 2: He did not know the answer

C: Therefore, he did not read the book

Disjunctive syllogism:

Premise 1: PvQ (v is symbolized for OR)

Premise 2: ~ P

Conclusion: ∴ Q

For Example:

P1: A substance is either an alkali Earth Metal or a Non-Metal

P2: The sample before us is not an Alkali Earth Metal

C: Therefore the sample is a Non-Metal

Symbolic logic essentially expresses relation between concepts. As one concept leads to other, there is a kind of continuity maintained in reasoning.

3.2.8 Practical syllogism

Another type of Syllogism developed by Aristotle was called Practical syllogism. The difference between practical logic and formal Logic discussed before is that the conclusion of practical logic is an action, not a statement. For Example

I should make something good

A house is something good

I make a house (Thornton, 1982)

Or

I should be healthy

If I take this medicine, I shall be healthy

Therefore, I take this medicine (Thornton, 1982). Each act is related to a previous act in this narrative. The new act is a result of some act previously done.

For example

A man was sleeping peacefully.

He felt hungry.

Since hunger disturbed his sleep, He needed to search for something to eliminate his hunger.

He knew from previous experience that fruits eliminate hunger.

He searched for fruits.

Upon eating food, his hunger was eliminated.

This example illustrates how Practical and Formal Logic can be combined to form a narrative.

3.2.9 Deductive Logic and the idea of Continuity and connectivity of concepts

The key idea in logic building is connecting a series of facts to form a new fact, a theory, a law or General principle. They form a continuous chain.

For example in the argument

P1: All Planets are spherical

P2: Pluto is a Planet

C: Therefore Pluto is Spherical

Here the terms Planet, property of being spherical and Pluto are connected with each other in the following way:

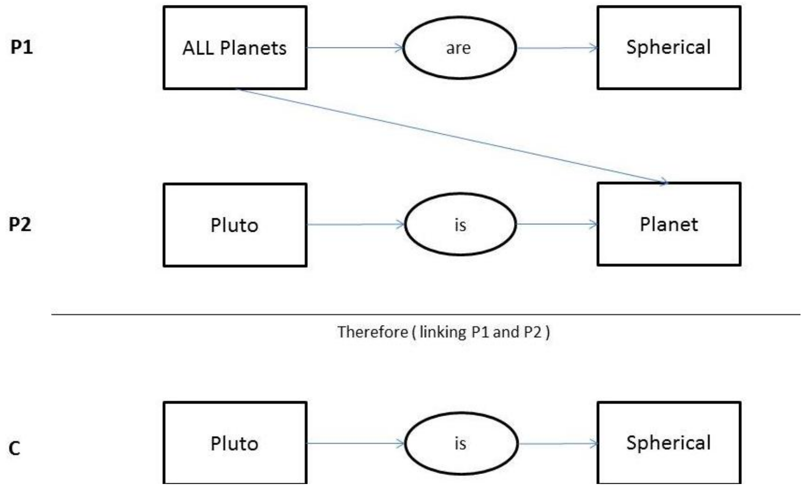


Figure 3.2: Structure of a deductive argument (Categorical Syllogism)

In simpler terms

P1: Planet = Spherical

P2: Pluto = Planet

So, we can substitute Planet in P1 with Pluto in P2 to get

C: Pluto = Spherical

Other type of continuity exists in a chained argument like (figure 3.2):

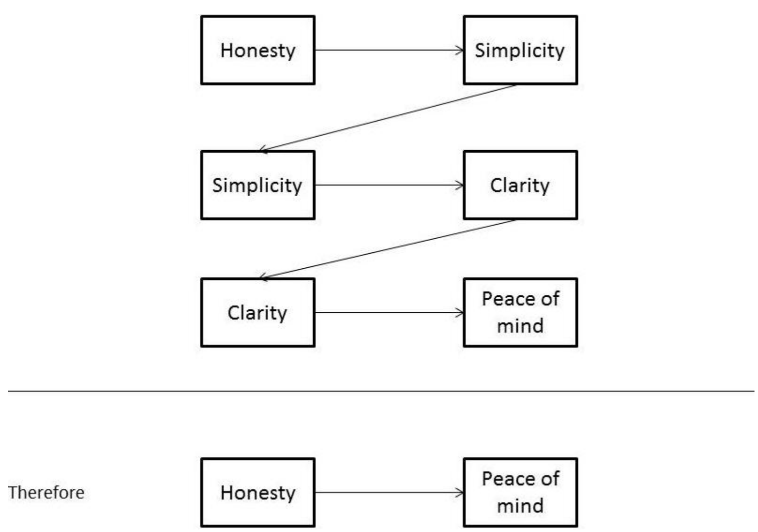


Figure 3.3: Structure of a chain Argument

3.3 Using ENF approach to represent an argument in the form of a narrative dialogue

This section demonstrates how a deductive and inductive argument can be converted to a dialogue. The dialogue converted from a logical argument can be termed as Epistemological dialogue.

3.3.1 Dialogue structure for deductive argument

Let us start with a simple deductive argument of the form All S is P, A is S therefore A is P:

P1: All cats are carnivorous

P2: Puma is a cat

C: Therefore Puma is carnivorous

It is observed that a question is presupposed in an argument. In the above argument, the presupposed question is “What are the attributes of a Puma?” And the conclusion of the argument is the answer to the question “Puma is carnivorous.” The argument extends to:

Q: What is one of the attributes of Puma?

A: Puma is Carnivorous

Q: What is the justification of your belief that Puma is Carnivorous?

A: I believe this because

> **P1:** All cats are carnivorous
>
> **P2:** Puma is a cat
>
> **C:** Therefore, Puma is carnivorous

Q: Indeed. The answer is justified.

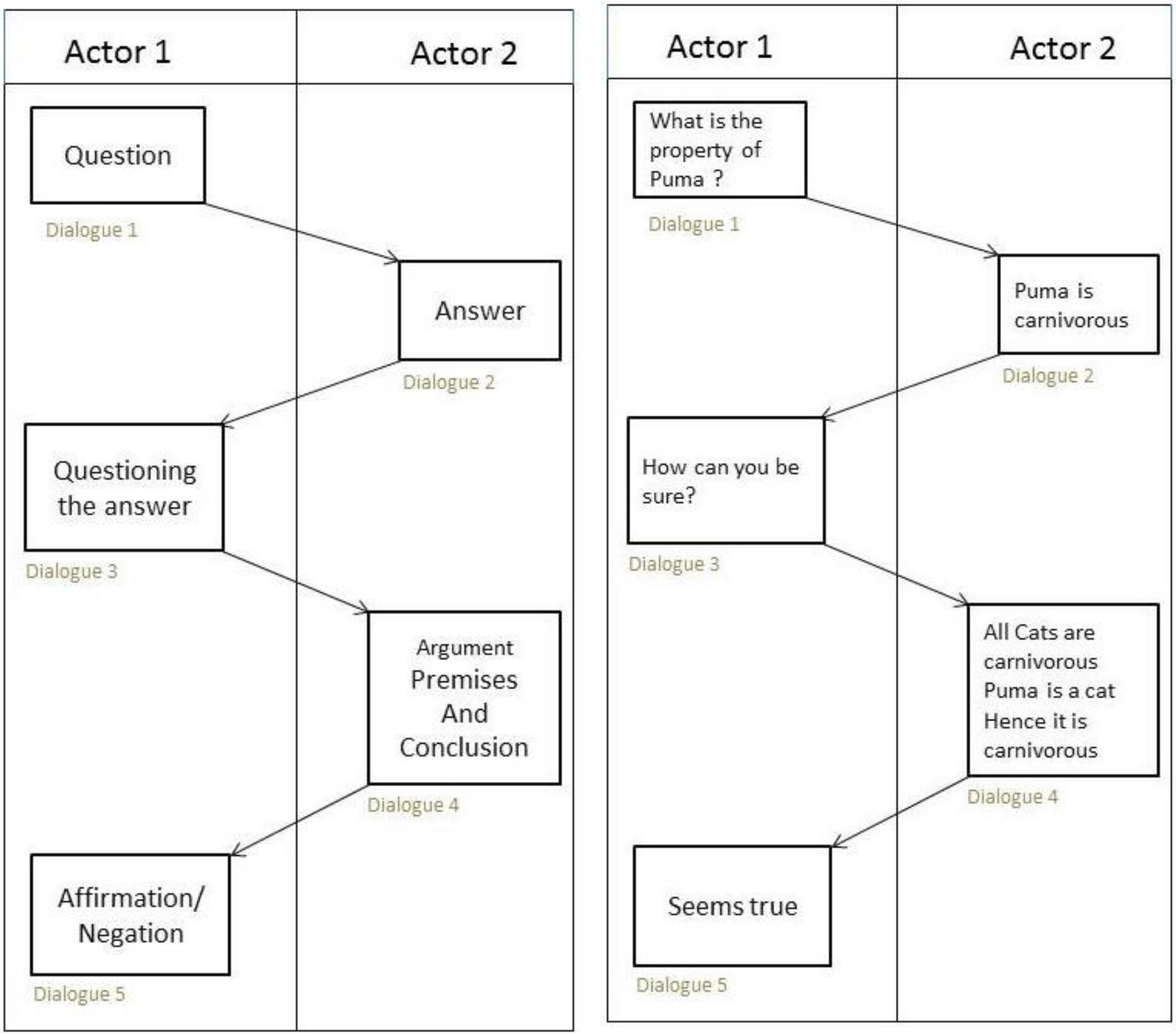


Figure 3.4: Dialogue structure based on Deductive Reasoning (Left), Example (Right)

Figure 3.5: Illustration of Deductive argument in a narrative dialogue

3.3.2 Dialogue structure for Inductive Argument

In this section we see how an argument of inductive form can be represented as a dialogue. For this purpose let us consider the following argument:

P1: Copper, Iron, Zinc, Tin and Gold are malleable

P2: Copper, Iron, Zinc, Tin and Gold are metals

C: Therefore all metals are malleable

We observe that the question “What is the property of Metals?” is presupposed in this argument.

Q: What is the property of Metals?

A: Metals are malleable.

Q: How do you know that?

P1: Copper, Iron, Zinc, Tin and Gold are malleable

P2: Copper, Iron, Zinc, Tin and Gold are all Metals

C: Hence, Metals are malleable

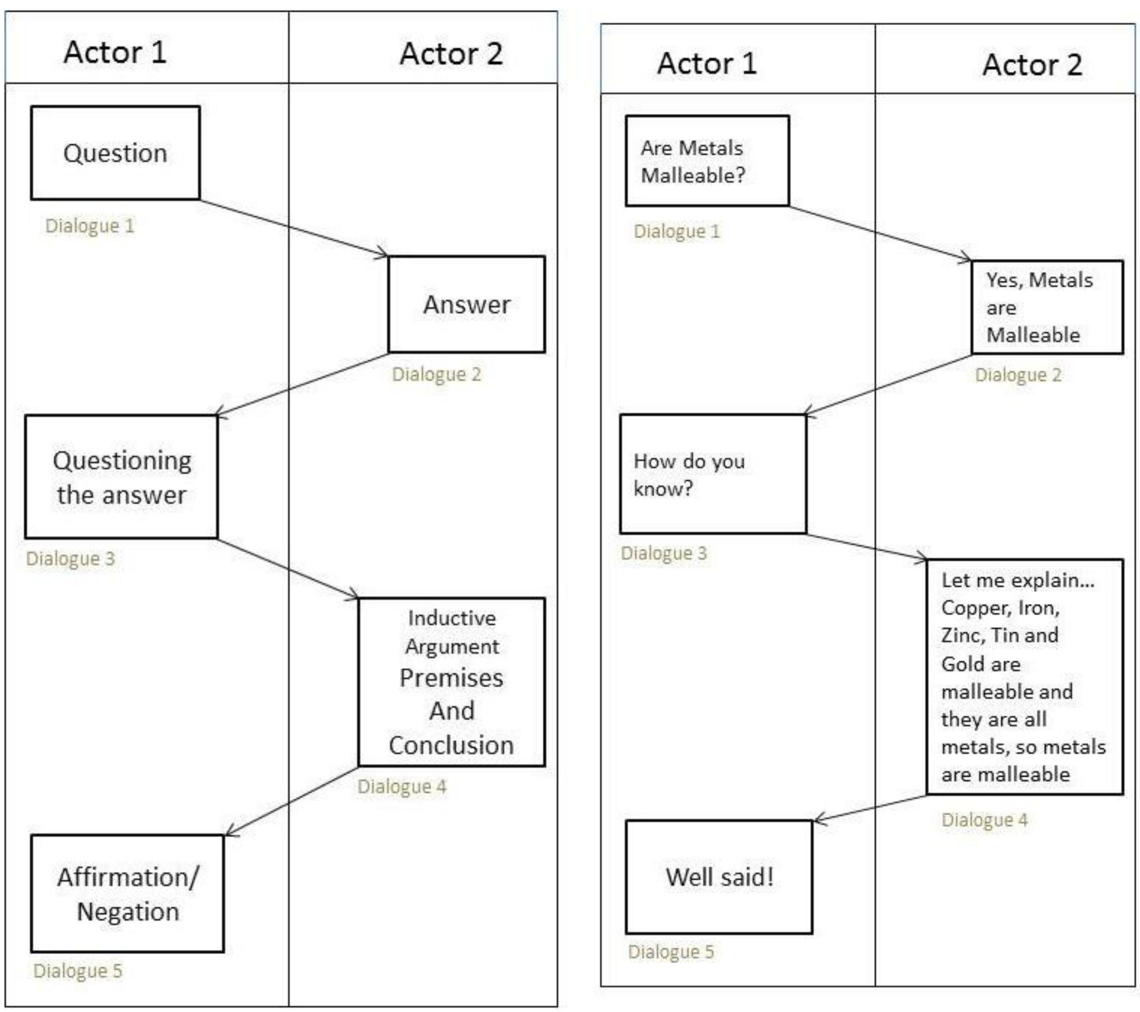


Figure 3.6: Dialogue structure based on Inductive reasoning (Left), Example (Right)

However, an inductive argument does not end at that. It is subject to further questioning. Continuing the previous argument:

Q: How do you know that Copper, Iron, Zinc, Tin and gold are malleable?

A: For that we will need to perform the test of malleability with all these metals. Let's try with Copper

Actor 2 passes individual samples of each metal through a machine that turns item into thin sheet

Copper when passed through the machine becomes a sheet. Iron when passed through the sheet becomes a sheet. Likewise Tin and Gold also become sheets when passed through it. So it is confirmed by observation that metals are malleable.

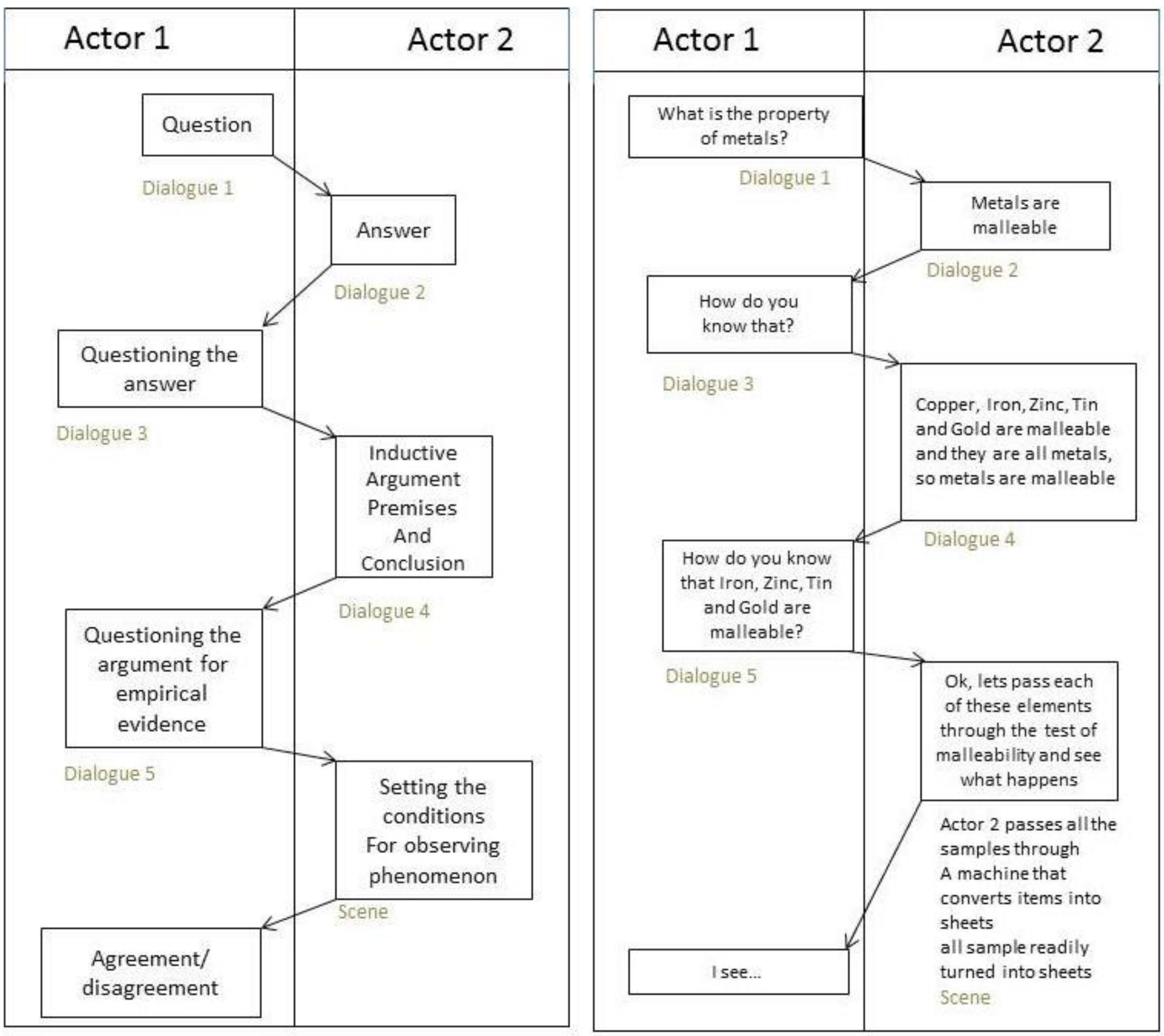


Figure 3.7: Dialogue structure based on Inductive reasoning and experimentation (Left), Example (Right)

An inductive argument does not stop at that. It can further continue with more questions. **Q:** The other day, sample of metal was tested, but it did not turn into sheet. The metal was mercury. Can we still say all metals are Malleable?

A: In that case we can only say that there is a high probability that if a sample of substance is a metal then it will also be malleable. The answer of an inductive inference is expressed in terms of probability.

The basic structure of the dialogue is Question>Argument>Answer. However, the next question which emerges from the above discussion is, what is before Question and what is after Answer? Is there a narrative before and after these? The answer is yes. Question, Argument and Answer form only the middle of the narrative. It is represented as part of a narrative structure in Figure 3.7.

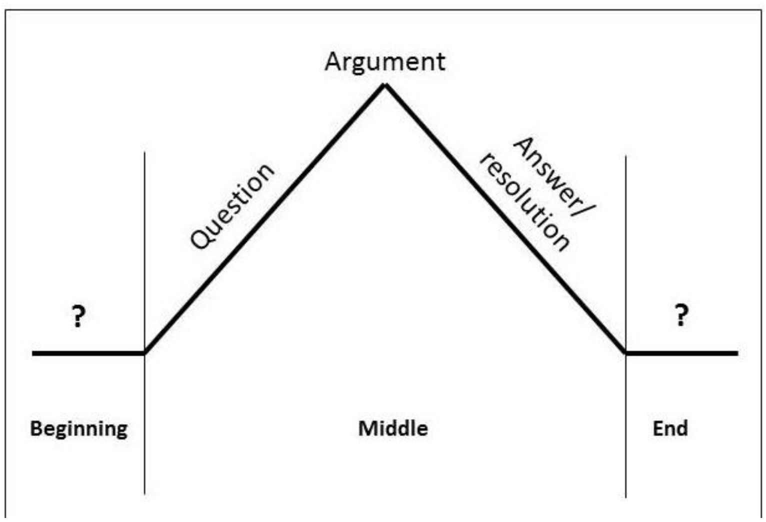


Figure 3.8 Position of an Argument in a narrative plot structure

If the argument structure only forms the middle of the narrative, then what does the beginning and the end contain? What events lead to asking of questions and what ensues after the answer? These questions we will attempt to answer in the next chapter on the development of the Epistemological Narrative Framework.

3.4 Argument structure for building Epistemological Narrative framework

The following deductive argument is applied to deduce the Epistemological Narrative Framework from two basic premises.

Premise 1: General form of a narrative is presented by five basic events; an exposition, rising action, conflict, falling action and denouement.

Premise 2: John Dewey has presented basic events in a scientific inquiry as Existing situation, Doubt (questioning), suggestion, reasoning and resolution.

Conclusion: From P1 and P2 we can consider a scientific inquiry to be a narrative with five basic events, Existing situation, Doubt, Reasoning, Suggestion, and Resolution[17].

In the next chapter we will elaborate more on the structure of the narrative formed by these five basic events and add more events to it with support from other statements from literature to deduce the Epistemological Narrative Framework.

3.5 Historical Method

After developing the ENF using Deductive reasoning, it is required to apply it for creating narratives for science learning. The data required for making the narrative comes from historical record associated with a discovery event. In order to get authentic data, the historic method is used. Historical Method is defined as "The process of establishing general facts and principles through attention to chronology and to the evolution or historical course of what is being studied. (method histoircal, 2012) It is a research method that was used to study the development of a particular domain or field of study (The Historical Aproach to Research, 1999). There are further two aspects associated with History, past actuality and record of past actuality. Past actuality is what really happened and record of past actuality is recapturing of past in words or images and associating some meaning with it (Marc, 2005). The recordings can be of three types: Narrative, Didactic and Genetic. Narrative is the true story that is told. It is the oldest form of recording

[17] Exposition is taken to be same as Existing situation; Rising action is analogous with Doubt; Conflict is same as Reasoning or; Suggestion is similar to falling action and that is what leads to resolution of conflict which is denouement.

history. It is about simply telling of history in chronological order. Didactic is telling of history to teach a lesson. By looking into the past, actions for future are decided. Genetic puts emphasis on understanding the causal relations between events which reveal growth, development and evolution associated with a phenomenon (Marc, 2005). In Historical research, the resource from which data is collected is important. There can be three types of sources. 1) Primary Source: Those in which people write or speak of themselves or contemporaries. 2) Secondary Source: Those writings of a later day about earlier events. 3) Tertiary source: A compilation of secondary sources (Marc, 2005). We have used mostly tertiary sources in our study. These sources are compilations of history of science in general. Then there are sources about specific fields like history of Chemistry, History of physics, Theory of science, History of electrochemistry, History of electric battery, History of electricity etc. The record of past actuality which is considered while screening the history was Genetic which means, the growth, development and evolution of the a domain was traced. We have used the historic research done by other authors to get information about evolution of a particular field. Since ENF approach is centered on the idea of continuous development of a field, we have used data from historic research to enrich our knowledge of that domain. And that data helped us in constructing the narratives. The following keywords were used to find historic research in its related domain: History of Science, Theory of Science, History of Philosophy, History or evolution of clothing, History of Battery, History of Electrochemistry, History of Chemistry and History of Electricity.

The history of each of these fields was studied from various sources like books and internet. The framework developed is based upon looking at the historic narratives of evolution of these fields through the structure of scientific revolution proposed by Thomas Kuhn which we have described in the section on Literature survey. The sample stories given in the next section are from History of clothing for the story of Fiber to Fabric, History of Electrochemistry for the story of Voltaic Cell and History of modern chemistry from the story of Lavoisier's discovery of Oxygen and History of Electricity for developing story of electromagnetism.

We will demonstrate how the notion of continuity is maintained with the example of history of clothing. The source of this information is 6th standard NCERT textbook of Central Board of Secondary Education. The information is correlated with different web resources by typing the

Keyword “History of Clothing” in the search bar. The historic events give a chronology in which the events happen one after the other. The events are linked to each other in such a way that one causes the other. A discovery is an outcome of observation of a certain set of events. But mere observation of an event does not lead to discovery. When an event contradicts with what has happened or stated previously, then discovery process begins. The act of previous recognition is what builds the chain connecting the past from the present. Historic approach helps in building such a chain of connection. Figure 3.8 shows how the chain of events is linked in the history of clothing.

Early man developed the first string by twisting together handfuls of plant fibers. Preparing thin bundles of plant material and stretching them out while twisting them together produced a fine string or thread

Animal skin > Grass, leaves > Threads from plants, Weaving>wool>Woolen clothes

First primitive man wore Animal skin as drape

Then Animal skin was replaced by Grass and leaves

Then weaving technique was discovered

Grass and leaves were made into thread

Grass thread was used for weaving to form drapes

But grass was weak, it tore easily

Then Cotton was discovered

CottonYarn was weaved to form Cotton drapes

Cotton drapes replaced grass and animal skin as new kind of clothing

Figure 3.9: History of clothing showing how woolen clothes evolved from drapes of Animal skin

Primitive human>Animal skin>Weaving>Grass>Wool>Woolen Clothing

The fact that study of history helps us connect the evolution of a concept or idea in time is clearly implied in the following statement:

> Johannes Kepler, the great astronomer-theorist of the 17th century, had stood on the shoulders of Tycho Brahe. Isaac Newton, the great synthesizer, stood on the shoulders of Galileo (Spangenburg & Moser, 2006).

What this means is that every researcher builds upon an idea which was developed by his/her predecessor. The idea is taken forward by identifying and overcoming its limitations.

3.6 Induction

Deductive or Formal logic is about reasoning by deducing inferences from known premises (which does not involve experience), while Inductive logic is about reasoning through observation of many instances of a single event. In other words, Deduction is about making particular inferences from general premises and Induction is about making general inference from particular premises (Harrod, 1956).

Deductive reasoning has some limitations that are overcome in Inductive reasoning. In a deductive argument, inference is arrived from other known statements called premises. The conclusion is only true if the premises are true. But what if the premise itself is false? How does one know the truth value of the premise? Such questions are answered through Inductive reasoning. Let us recall the example of statement “all plants have roots”. This statement cannot be deductively proven to be true or false because one will have to rely upon other statements. However, there is another way by which one can test the truth or falsity or validity of this statement. By observing many cases of plants in the actual world, one can very certainly find plants that do have roots attached to them. Even if someone says that maybe one or two plants have roots, but when again and again one finds plants that have roots, one will begin to feel the presence of a law like rule, that if something is a plant than definitely it will also have roots. The conviction after observing many cases will be so strong that if in a case, one sees a plant buried in ground and only half of its stem is visible. Even though, no root will be seen in that case, but the observer will readily predict the presence of the plant’s root beneath the earth’s surface. And after digging the earth, it is found that the plant does have root, the belief in the law that all plants have roots will be strengthened and one will say with confidence that yes, the statement that all plants have roots is indeed true. Contrastingly, if someone makes the statement that "All plants fly", one can clearly find the falseness in this statement. But the falseness is again based upon reasoning. For example maybe, on a stormy day, a person observes set of plants flying in the air. Without making any connection of flying with wind, he may infer that the plants are flying. But he may also immediately see that some plants like trees are still firmly rooted in ground. He may modify his statement that "some plants fly". But maybe, a keen observer may find that the impetus of flying was not coming from inside the plant, but from the wind which carried other lighter things with it, then one may further modify one's statement as "No plants fly" or simply plants don't fly it is the wind which carries them. In all these cases, one can judge if a statement corresponds with actual facts. If it does, it is true, if it does not, it is not true.

Induction involves collecting samples for the purpose of observing a phenomenon. Samples are subjected to various kinds of tests and finally after many tests, the sample is identified with some level of probability, to have a certain relation with some other variable to be observed. Various statistical methods are used for this purpose. Inductive logic works on the belief that if "n" number of instances of a particular event is observed to have certain X property than the probability of finding that property in an unknown instance is high. For example 100 cows are observed to be white, than there is a good chance of finding 101th cow with color white. The chances will keep increasing as more and more number of cows with white color is discovered.

First an initial belief or hypothesis produced either by Deduction or previous observations is tested through the statistical method. The statistical method we used for our purpose of testing the effectiveness of ENF approach on students' recall was "the independent sample t-test."

3.6.1 Independent sample t-test

An Independent samples t-test helps in comparing the means of two groups of samples on a particular variable (Archambault, 2000). The first step in any inductive approach is to select a sample that is representative of the population. There are different kinds of sampling methods. The method of Cluster sampling was used to select the participants for experiment. Cluster sampling involves selection of a group from a population that is naturally together (Ary, Jacobs, & Razavieh, 1972). The school was selected based upon convenient sampling which means that the school that gave permission for conducting of experiment was selected.

The sample is to be divided into two groups and the two groups are subjected to different type of interventions. One group which gets the standard intervention is called the control group. The other group which gets the new intervention (teaching method to be tested) is called the experimental group. In our case the control group was given lesson from NCERT textbook and the experimental group was given lesson designed as a narrative using ENF approach. It is called a two sided or two tailed test because the difference can mean can occur in both direction, i.e. it may be the case that students score more in NCERT compared to Story intervention.

> A *two-sided* (or two-tailed) P-value is appropriate when the difference between the two means can occur in both directions: it may be either negative or positive; the mean of one sample may either be smaller or larger than that of the other sample.
>
> A *one-sided* test should only be performed when, before the start of the study, it has already been established that a difference can only occur in one direction. E.g. when the mean of sample *A* must be more than the mean of sample *B* for reasons other than those connected with the sample(s) (MedCalc, 2011).

Evolution of ENF

The development of ENF went through many evolutionary stages. A design process of iteration and testing of models was adopted to arrive at the current framework. A model was tentatively first developed, then some stories were created based upon that model. The stories were tested in different educational setups and based upon the feedback, the model or framework was changed and modified and the current version of the model was chosen or built after many iterations and changes. SO e can say that ENF has evolved from the process of design rather tat the opposite.

3.6.2 Design of experiment

Aim of the experiment was to test the effect of lessons designed using ENF on participant's short term memory. Best believes that the content of short –term memory is considered as the boundary of our consciousness (Best, 1986). It is memory that retains information for short interval of time. Experiments that test short term memory generally expose the subject to visual or auditory input and they are asked to recall it after a short time interval. The time interval can be of a couple of seconds. Best refers to Peterson and Peterson (Peterson & Peterson, 1959) who showed in a classical study that subjects were able to recall a three-consonant trigram after time interval of 30 seconds with no difficulty (Best, 1986).

3.6.3 Variables

A single variable experiment design was adopted for our experiment where effect of one independent variable was tested on the dependent variable. Following is the description of the variables.

Teaching Method (Textbook Based TB or Story Based) = Independent Variable

Achievement Score = Dependent Variable

In order to make sure that student did not have prior knowledge of subject matter, a screening test was conducted. The subjects whose screening test score was more than zero was not taken into consideration. After the delivery of teaching method to both groups, an essay type achievement test was given to the students. The students were marked by the researcher by comparing their responses by model essays. The mean of the scores of both the groups was then compared using the independent sample t-test. Software used for performing the comparison was SPSS. The significance of the difference between the scores of achievement test was calculated in SPSS.

3.6.4 P value of significance

Significance of difference in means is calculated by p value. This value gives the measure of the chances of the difference happening due to coincidence. If the chances are less that the difference is a mere coincidence then the difference is significant if the chances are high, than the difference is not significant. Anything below 0.05 is considered to be a significant difference. If the p value is 0.1 that means there are chances that the difference being a coincidence is one in 10. If the p value is 0.01 that means that chances that the difference is due to coincidence is one in 100. In educational research, the most commonly used level of significance is 0.05 and 0.01. Anything below 0.01 is highly significant (Ary, Jacobs, & Razavieh, 1972)

3.6.5 Confidence Interval

The significance is calculated for a particular confidence interval value. The most commonly used is 95%, which helps in interpreting the result of significance. For example if the mean difference is significant at p value of 0.02, then the comparison can be repeated at 98% or 99% confidence. If it is still significant that means that the results can be stated with high degree of confidence. In another case let us say that at 98% confidence, the mean difference is a value larger than 0.05 which is not significant, that does not mean the difference is absolutely insignificant, the significance can be re-calculated at lower level of confidence. So the result can still be significant but at low level of confidence.

3.7 Conclusion

The research methods used in this research can be classified under Deduction, Historical Method and Induction. Deduction was used to draw inferences from Theory of Knowledge, Theory of Learning and Theory of Narratives to connect different strands of thought and developing the ENF approach. The method of converting an argument into a narrative dialogue form was also demonstrated. Historic method was used to collect raw data for building the story. This data included studying the historic development of evolution of a certain idea by investigating into different historic sources. Story examples developed using the ENF approach were tested using, method of Induction in which Control group experiments were conducted and their results analyzed to test the effect of lesson designed using ENF approach on student achievement score. In the next section we will use Deductive arguments to show how the ENF approach was developed. Method of Induction for experiment design will be used in chapter 5 on Experiments.

Chapter 4

Epistemological Narrative Framework

4.1 Introduction

If attention is drawn to the events associated with a scientific inquiry, it remains to be seen what type of Narrative a discovery event is. For this purpose it is essential to find the important constituents of a scientific inquiry event and the way these constituents are connected to each other. The basic elements of scientific inquiry event are found in literature on Theory of Knowledge, Theory of Learning and Theory of Narratives.

4.2 Constituents of a Scientific Inquiry event:

In this section we first outline the names of element of a scientific inquiry event and then provide justification for inclusion of each element with reference from literature. The main elements of a Scientific Inquiry event based upon justification from literature in domain of theory of knowledge, learning and narratives are 1) Belief, 2) Disciplinary Matrix, 3) Observation 4)

Doubt, 5) Question, 6)Suggestion, 7) Reasoning, 8) Experimentation, 9)Theorization, 10) Sharing with community, 11) Replication, 12) Competition, 13) New belief.

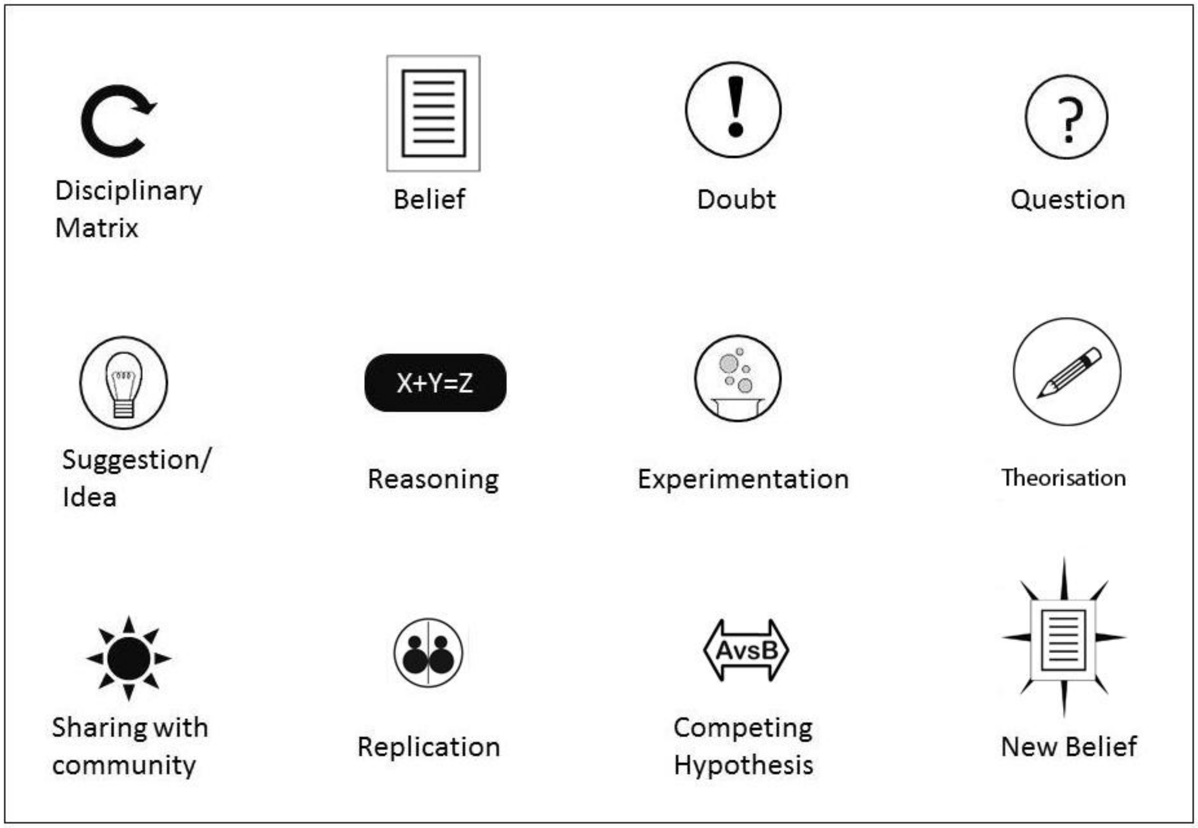
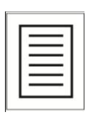


Figure 4.1: Main constituents of a scientific inquiry event.

1. Belief 

The word belief is associated with knowledge. To hold a belief is the first step towards gaining knowledge. According to classical understanding of philosophy, when a belief is justified and held to be true, it qualifies as knowledge. Supporting this is the following statement by Sosa which explains Plato's position on defining knowledge which is that a person S believes that *p* if and only if *p* is true and *S* is justified in believing that *p* is true (Sosa, 1991).

However, Edmund Gettier presented counter examples to prove that it is not necessary that if a belief is true and justified, confirms the presence of knowledge. Even if the above statement is only partially true, the point to take note of is that there is an entity called "belief" and it is related fundamentally to knowledge acquisition process. The meaning of belief is also explained by Bertrand Russell:

> The relation involved in Judging or believing must be taken to be a relation between several terms (Russell, 1973, p.123).

What is meant by Russell is that to hold a belief is to see several terms or concepts as being linked with each other. When one believes that rain will bring good harvest, then one is linking good harvest with advent of rain.

Russells explains this with an example from Othello:

> Thus the actual occurrence, at the moment when Othello is entertaining his belief (that Desdemona loves Cassio), is that the relation called believing is knitting together into one complex whole the four terms Othello, Desdemona, Loving and Cassio. What is called belief or judging is nothing but this relation of believing or judging, which relates a mind to several things (Russell, 1973, p.197).

John Dewey relates the very act of thinking with holding of a belief in the following statement:

> Thinking in its best sense is that which considers the basis and consequences of *beliefs* (Dewey, 1910, p.5).

He goes on to explain the nature of reflective thought as:

> Active, persistent, and careful consideration of any *belief* or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends, constitutes reflective thought (Dewey, 1910, p.118).

Holding a belief then leads to another concept called "truth". The very existence of a belief brings to light the possibility of it being true or false. Russels explain:

> We may believe what is false as well as what is true. We know that on very many subjects different people hold different and incompatible opinions: hence some beliefs must be erroneous. How are we to know in a given case that our belief is not erroneous (Russell, 1973, p.88)?

The vulnerability of a belief to being false is what opens the door for search for a true belief that is justified. Suppose that it is believed by someone that all snakes are poisonous. If such a person is one day attacked by a snake, he will believe that death would be certain. But what if the person comes out completely unharmed from the bite? Would he not be compelled to question the belief about all snakes being poisonous? A further inquiry will convince the person that some snakes are not poisonous. And if the person takes upon himself to find out what exact varieties of snakes are poisonous, he may come with a value in percentage of poisonous snake against the non-poisonous ones. He has modified the old belief and replaced it with a new one. The next aspect of a belief is that they exist in a set. One belief leads to another. If one is false, the other is bound to be false. If it is false that a ship will not reach the end of earth if it continues to travel along a straight line, then the belief that earth is a flat plane of limited length has to be false. Other things associated with planetary motion too must be affected if such a belief was false. This network of beliefs leads us to the concept of a disciplinary matrix or more popularly, a paradigm.

2. Disciplinary Matrix (Paradigm)

The notion of a belief is associated with the concept of a Paradigm, introduced by Thomas Kuhn. A paradigm is a set of interconnected beliefs associated with a phenomenon. A modification of one belief in a Paradigm automatically effect all the other beliefs linked with it. The exact nature of how beliefs are interconnected is shared by a scientific community. The concept of a paradigm has many interpretations. Kuhn's explanation of a Paradigm is as follows:

> Perhaps all natural scientists form a community. At an only slightly lower level, the main scientific professional groups provide examples of communities: physicists, chemists, astronomers, zoologists and the like. What shared elements account for the relative unproblematic character of professional communication and for the relative unanimity of professional judgment? To this question, the structure of scientific revolutions provides an answer, "a paradigm" or a set of paradigms (Kuhn, 1977, p.296).

Kuhn was aware that the word paradigm may lead to confusing multiple interpretations directed in different directions, hence he introduced a new term instead of paradigm called the "Disciplinary Matrix". Kuhn elaborates:

> Less confusion will result if I replace it (the term paradigm) with the phrase "disciplinary matrix". Disciplinary because it is the common possession of the practitioners of a professional discipline and "matrix" because it is composed of ordered elements of various sorts (Kuhn 1977, p.297).

A disciplinary matrix constitutes various elements like the standard problems that students learn to solve, the models, symbolic generalizations and exemplars in a particular domain.

> Acquiring an arsenal of exemplars, just as much as learning symbolic generalizations, is integral to the process by which a student gains access to the cognitive achievements of his disciplinary group. In the course of their training a vast number of such exercises are set for them, and students entering the same specialty regularly do very nearly the same once, for example the inclined plane, the conical pendulum, Kepler ellipses and so on. The scientist student, confronted with a problem, seeks to see it as like one or more of the exemplary problems he has encountered before (Kuhn, 1962, p.187).

A disciplinary matrix outlines expectations within problems and methods of solving them. Since many similar problems within a discipline are solved, the task of a newcomer is only to match new problems with those already solved in the discipline. When the paradigm changes, it changes with it the approach to solving the same problem but in ways never attempted before. Solving a problem rests upon implicit beliefs and assumptions that have worked in solving similar problems in similar situations before. However, sometimes in history of scientific progress, situations arise in which the scientific community is compelled to doubt existing assumptions, beliefs or whole paradigms when they are confronted with what is known as, a Contradiction or an Anomaly.

4. Observation

Observation has been listed down as the beginning point of inquiry or study by Isaac Watts, the author of 'Improvement of the Mind.' When attention is brought to some phenomenon it leads to observation. Only when one observes something can one begin to see something worth taking note of. One can observe the movement of waves, the changing of seasons, the effect of heat on substances, the movement of heavenly bodies etc. The things observed themselves lie under specific categories of disciplines and the theories that form the foundation of these disciplines. For example a person working within the domain of astronomy will have objects of observation as planets, stars and moons and he/she will observe them through the existing theories that explain them. A person working in the domain of mechanics will have motion as his/her object of observation and associated theories. People working in the domain of Architecture will have theories of geometry of enclosed dwelling structures as their object of observation. In the words of Watts:

> Though observation does not include in it any reasoning of the mind upon things we observe or inferences drawn from them, yet the motions of the mind are so exceedingly swift that it is hardly possible for a thinking man to gain experience or observation,

> without making some secret or short reflections upon them and therefore I shall not so narrowly so confine myself on the first mere reflections of objects on mind by observation, but include also some hints which relates to some obvious reflections or reasoning that arise from them (Watts, 1833, p. 51).

Watts is emphasizing here that no one who observes something merely sees an event happening, there is always an element of quick reflection on the event that happened. Again through the help of literature on theory of knowledge, one can speculate that the first inference that an observer might make on observing something is to find that even similar or different from what one has experienced before. If it is similar to something, then the inquiry terminates there, but if it is different from what one already knows, that might lead to the next step which is arising of some doubt about the observed event in the mind of the observer.

3. Doubt 

Doubt may result because of an anomaly which is an event that violates an expectation about a phenomenon. It can also be described as a felt difficulty, an error or surprise. For example twitching of a dead frog's leg when touched with a metal knife is bound to evoke surprise and disbelief. Certain phenomenon when experienced for the first time may appear surprising. For example, imagine a prehistoric man experiencing a spark for the first time on rubbing two stones together. Kuhn explains:

> Discovery commences with the awareness of an anomaly, i.e. with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science. It then continues with a more or less extended exploration of the area of anomaly. And it closes only when the paradigm theory has been adjusted so that the anomalous has been adjusted and that the anomalous has become the expected (Kuhn, 1962, p.52).

The concept of anomaly pointed by Thomas Kuhn refers to rare incidences in history of science which brought about very large scale changes. However, a simpler form of anomaly is explained by John Dewey which he describes as the starting point of a scientific inquiry. He calls it either a doubt or a felt difficulty which marks off a situation as a problematic.

> In cases of striking novelty or unusual perplexity, the difficulty, however, is likely to present itself at first as a shock, as emotional disturbance, as a more or less vague feeling

> of the unexpected, of something queer, strange, funny or disconcerting (Dewey, 1910, p.74).

The beginning of inquiry through observation of some difficulty, anomaly, error or disturbance has some relation with the fundamental learning process in an organism. Something similar is expressed about learning process in constructivist theory of learning by Mathews who explains Piaget's position:

> In both, theory of evolution and the constructivist theory of knowing. Equilibrium in evolution indicate the state of an organism or species in which the potential for survival in a given environment is genetically assured. In the sphere of cognition, though indirectly linked to survival, equilibrium refers to a state in which an epistemic agent's cognitive structures have yielded and continue to yield expected results, without bringing to surface conceptual conflicts or contradictions (Matthews, 1998, p.16).

When events happen, as expected, it does not draw an attention of an epistemic agent. It is only when something unexpected happens; that the agent is compelled to question the cause of the disturbance and a new state of understanding, cognition, learning, adaptation or evolution happens only when the anomalous situation is satisfactorily made part of the repository of expected events. Recognition of an anomaly is seen as a problem. A problem is a hindrance in otherwise expected state of affairs. Something does not happen as expected. There is a gap between the desired and the actual outcome. There is a need to resolve this gap. Overcoming the problem resolves the blocked state of affairs. Sometimes problem resolution may result in bringing the system back to its original state or taking the understanding to a new level. A problem is a disturbance. It begins by doubting something. Doubt, if it has arisen from encountering a real difficulty will lead to a 'question' that specifically points out the nature of problem.

4. Questioning

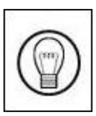
Recognition of an anomaly is expressed in the form of a question "How can this be? What is causing this to happen? What is it? Where is the cause located? Is there something wrong? Have we made a mistake? Why is it not happening the way it is supposed to happen?" John Dewey explains clearly the significance of questioning in a scientific enquiry:

> Inquiry and Questioning, up to a certain point, are synonymous terms. We inquire when we question and we inquire when we seek for whatever will provide an answer to question asked. It is of the very nature of the indeterminate situation which evokes inquiry to be questionable (Dewey, 1938, pp.105).

McKenzie resonates with this view on questioning in the following statement:

> The act of questioning begins the process of reflection and insightful thinking in the mind of the questioner (McKenzie, 2002).

A question is the acknowledgement of the fact that something is unknown or unexplained. It directs attention to those elements on which the inquiry is called for. Why the car suddenly stopped working? Why has Jacob fallen ill? What is causing my shirt to give off a pungent smell after being worn consecutively for 3 days? The question specifically asks for the term with which the observed situation or phenomenon is linked with? In response to the question, comes the answer in the form of an idea or suggestion in the form of an intuitive insight.

5. Suggestion 

A suggestion exists to dissolve a question, to resolve a problem. The answer exists only as a suggestion, a possible solution, a nascent idea. It directs the inquiry from infinite possibilities to choosing a few options based upon some intuition or hunch. It can be completely right, partially right or absolutely wrong. John Dewey sees an answer as a suggestion:

> Suggestion is the very heart of inference; it involves going from what is present to something absent. Hence, it is more or less speculative, adventurous. Since inference goes beyond what is actually present, it involves a leap, a jump, the propriety of which cannot be warranted in advance, no matter what precautions be taken. The suggested conclusion so far as it is not accepted but only tentatively entertained constitutes an idea. Synonyms for this are supposition, conjecture, guess, hypothesis and theory (Dewey, 1910, p.75).

But then, one can ask, where do answers come from? To answer something, one needs to know something about it from prior experience. John Dewey believes:

> What then are the sources of the suggestion? Clearly past experience and prior knowledge. If the person has had some acquaintance with similar situations, if he has dealt with material of same sort before, suggestions more or less apt and helpful are likely to arise. (Dewey, 1910, pp. 12)

Finding an answer is similar to arriving at some knowledge. Schlick defines knowledge with the process of recognizing something previously known.

> To know is to re-cognize or rediscover. And to rediscover is to equate what is known with that which is unknown (Schlick, 1974).

Plato has something similar to say about learning in the following statement:

> Plato's explanation of what occurs when we seem to learn something is that we are not actually learning, but we are actually remembering or recollecting something we already know (Stroll, 1961).

Aristotle related knowing with recognition:

> Recognition, as the name indicates, is a change from ignorance to knowledge (Aristotle, 1989)"

Yolton points at something similar about animals who possess some form of intelligence

> By nature animals are born with the faculty of sensation, and from sensation memory is produced in some of them, though not in others. And therefore the former are more intelligent and apt at learning than those which cannot remember (Yolton, 1965).

Artificail intelligence and e-learning expert, Roger Schank believes in similar line of thought when he says:

> The mind depends upon data in order to give it something to reflect upon. Where is this data to come from? In many ways the most important data we have comes from within. We learn from reconsidering experiences we have already had in light of new information. We form insights by comparing what we are currently examining with what we have already examined (Schank R. , 1990).

When an unknown is encountered, the observer tries to match it with something previously known. This idea of matching is the essence of learning to find similarity and differences in problem currently at hand and those already solved of which knowledge is certain. Kuhn's explanation makes this point clear:

> It is a truism that anything is similar to, and also different from, anything else. To the man who speaks of similarity or of analogy, we therefore at once pose the question similar with respect to what (Kuhn, 1977, pp. 307)?

Kuhn continues:

> In the same way, the science student, confronted with a problem, seeks to see it as like one or more of the exemplary problems he has encountered before. Where rules exist to guide him, he of course, deploys them. But his basic criterion is a perception of similarity that is both logically and psychologically prior to any of the numerous criteria by which that same identification of similarity might have been made (Kuhn, 1977, pp. 308).

This process is compared by Kuhn with a child's learning process[18]:

> Much more nearly it resembles the child's puzzle in which one is asked to find the animal shapes or faces hidden in the drawing of shrubbery or clouds. The child seeks forms that are like those of animals or faces he knows (Kuhn, 1977, pp. 307).

When something has been found to resemble something else or previously known series of events, it is inferred as a suggestion. For example if sharply pointed tool is seen, to the question, what is this thing? It can be suggested or inferred to be some kind of piercing tool based upon prior knowledge of all sharp things used for penetration of surfaces. The initial suggested idea, guess, hypothesis or theory is not yet ready to be strongly believed to be true, unless there are strong grounds for believing it to be so. The ground for believing in a hypothesis is prepared by methods of reasoning.

6. Reasoning 

It is not necessary that the provisional solution or an answer to the question arrived at would resolve the issue at hand. More often, an answer might have resulted because of a personal opinion out of some prejudice. How can one make sure that the solution, idea or the hypothesis proposed, will sufficiently answer all aspects of a question? Is the answer arrived at, links all possible aspects of the problem sufficiently? Dewey explains the role of reasoning in a scientific inquiry:

> Acceptance of the suggestion in its first form is prevented by looking into it more thoroughly. Conjectures that seem plausible at first sight are often found unfit or even absurd when their full consequences are traced out. The development of an idea through reasoning helps at least supply the intermediate or intervening terms that link together into a consistent whole apparently discrepant extremes. (Dewey, 1910, pp. 76)

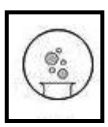
[18] Deanna Kuhn and Eric Amsel have proposed a counter view that distinguishes children's reasoning process form that of scientist and also of Adults (Deana Kuhn, 1988).

Reasoning belongs to theoretical justification by employing rational means. The methodic tool used for performing rational justification is Deduction. What is deduced from a fact or an even is based on some implicit belief or we can say, a general principle. Carnap explains that there are regularities and patterns in the the events that happen in the world around us. Day follows night, Electric current produces magnetic effect, fire burns etc. All these regularities are caused by some general principles working underneath them. These general principle are what Carnap calls as Laws.

> To summarize, science begins with direct observations of single facts. Nothing else is observable. Certainly a regularity is not directly observable. It is only when many observations are compared with one another that regularities are discovered. These regularities are expressed by statements called "Laws" (Carnap, 1995, p. 6).

These laws according to Carnap are used either for explaining existing facts or for predicting unknown ones.

However theoretical reasoning in itself would not mean terminating the investigation. The last and the most significant step is justification by experimentation in which a general principle or Law is tested to be applicable in a particular set of cases.

7. Experimentation 

The ideas which are theoretically formed as distinct hypothesis need to be tested on certain practical grounds. Particular cases are selected and investigated to check match or deviation from general principles.

> In the course of this serial process, the ideas that represent possible solutions are tested or "proved." Meantime, the order of fact, which present themselves in consequence of the experimental observations the ideas call out and direct, are trial facts. They are provisional. They are facts if they are observed by sound organs and techniques. They are tested or proved with respect to their evidential function just as much as ideas are tested with reference to their power to exercise the function of resolution (Dewey, 1955 pp. 114).

Elsewhere Dewey states regarding experimentation that:

> Conditions are deliberately arranged in accord with the requirements of an idea or hypothesis to see if the results theoretically indicated by the idea actually occur (Dewey 1910, pp. 76).

Many time it is difficult to separate the two steps of reasoning and experimentation, they rather seem to go hand-in-hand. Dewey expressed that a complete act of thought involves both Inductive and Deductive methods of argumentation. Induction involves forming an intuitive hunch of a general principal while trying to connect particular sets of instances. On the other hand deduction is an act of matching particular cases under the light of available general principles (Dewey, 1910). Once the outcomes of a series of experiments match with the theoretical findings, the hypothesis is said to be proven valid. Such knowledge would then be represented in 'symbolic' notations and be shared with the scientific community.

8. Theorization

After the process of testing a hypothesis is satisfactorily run over and over again, the agent/scientist finally arrives at a statement with some certainty regarding some aspect of a phenomenon under observation. This statement relates two or more entities in a unified whole. This is similar to a belief, but the one which has been tested justified on rational grounds. It is the theory statement which becomes available to the scientific community once the individual scientist has finished work on it.

> In the sciences, theories are created after observation and testing. They are designed to rationally and clearly explain a phenomenon. For example, Isaac Newton came up with a theory about gravity in the 17th century, and the theory proved to be both testable and correct. Scientific theories are not quite the same thing as facts, but they are often very similar; scientists usually test their theories extensively before airing them, looking for obvious problems which could cause the theory to be challenged (S.E.Smith, 2011).

Once a theory is formulated it is sent to a scientific society which consists of fellow research scientists in a given field. This allows the Theory to pass through further tests and criticism by many minds, so that the limits of the theory can be identified.

9. Sharing with the community

Scientific knowledge is able to travel across generations without getting lost because of the presence of a scientific community. The community has cohesiveness due to common goals that members aim to achieve. Moreover the presence of scientific community ensures that the knowledge is always at hand to novice as well as experts. Kuhn explains the importance of community in scientific advancement in the following statement:

> A scientific community consists, in this view, of practitioners of a scientific specialty. Bound together by common elements in their education and apprenticeship, they see themselves and are seen by others as the men responsible for the pursuit of a set of shared goals, including the training of their successors. Such communities are characterized by the relative fullness of communication within the group and by the relative unanimity of the group's judgment in professional matters. To a remarkable extent the members of a given community will have absorbed the same literature and drawn similar lessons from it (Kuhn, 1977, pp. 296).

One thing that the community provides for the expansion of knowledge is possibility of replicating the work of a researcher by any other member of the community.

10. Replication

It appears that replication of work of a master by an amateur or his contemporary has played an important role in the development of knowledge in western civilization. By replication one gets acquainted not just in theory but also in practice with different premises and results of a previous theory. During acts of replication, possibility of finding something new may arise.

> In pure or basic science-that somewhere at ephemeral category of research undertaken by men whose most immediate goal is to increase understanding rather than control of nature-the characteristic problems are almost always repetitions, with minor modification, of problems that have been undertaken and partially resolved before (Kuhn, 1977, p.92).

Often, it is during replication, that an anomaly or an error becomes visible in the existing theory. Occurring of any such instance provides ground for the development of an alternate hypothesis. This repeats the previous cycles of doubting, questioning, answering, reasoning, experimenting and symbolizing by other researchers. The alternate proposition then stands in competition with the existing hypothesis.

11. Competition/Comparison 

Within the scientific community the possibility of replication of an existing work creates many alternate hypothesis proposed by different members of community and selection of the most appropriate hypothesis becomes a challenging task for the community. On what basis are competing theories selected? According to Kuhn:

> I consider the ways scientists are brought to abandon one time-honored theory or paradigm in favor of another. Such decision problems, I wrote cannot be resolved by proof. To discuss their mechanism is, therefore, to talk about techniques of persuasion, or about argument and counterargument in a situation in which there can be no proof. Under these circumstances, I continued, lifelong resistance to a new theory is not a violation of scientific standards. Though the historian can always find men-Priestly for instance-who were unreasonable to resist for as long as they did, he will not find a point when reason becomes illogical or unscientific (Kuhn, 1977, pp. 320).

It is not to say that no logical criterion for theory choice exists. The criterion is discussed by Kuhn in the following statements:

> Two sorts of difficulties are regularly encountered by the men who must use these criteria in choosing, say, between Ptolemy’s astronomical theory and Copernicus’s, between the oxygen and Phlogiston theories of combustion or between Newtonian mechanics and quantum theory. Individually the criteria are imprecise: individuals may legitimately differ about their application to concrete cases. In addition, when deployed together, they (criteria of choosing among theories) repeatedly prove to conflict with one another; accuracy may, for example, dictate the choice of one theory, scope the choice of its competitor (pp. 322).

The final verdict on selection of a competing theory can be made by testing them with new experiments. And finally when a new theory is selected among many, it establishes new set of beliefs and new paradigms that change the disciplinary matrix of existing field of knowledge.

Brief description of each symbol is summarized in the glossary.

Linking of points in Theory of Knowledge according to Narrative structures

We recall that the basic narrative structure, presented by Freytag, had 5 main components: Exposition, Rising Action, Complication, Falling action and denouement. A general narrative structure is also said to be composed of three Acts; Beginning, Middle and End (Freytag's Pyramid, 2011). Freytag’s pyramid is shown in figure 4.2.

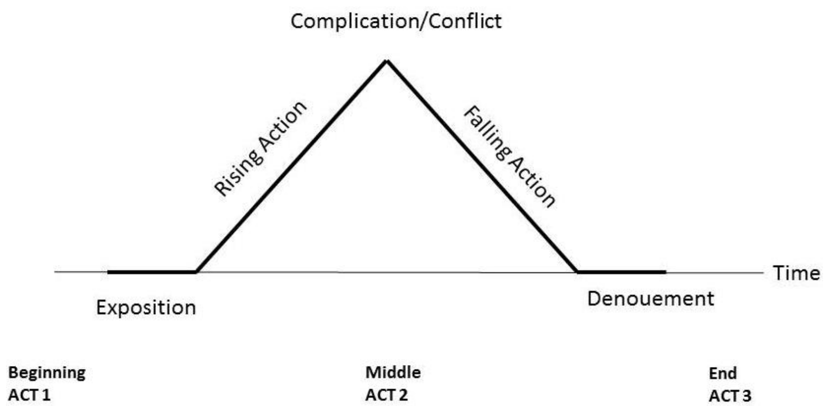


Figure 4.2: Freytag's plot structure of drama

This narrative structure can be seen in a range of scenarios. For example, the script of a restaurant can be represented in the following manner as described in figure 4.3.

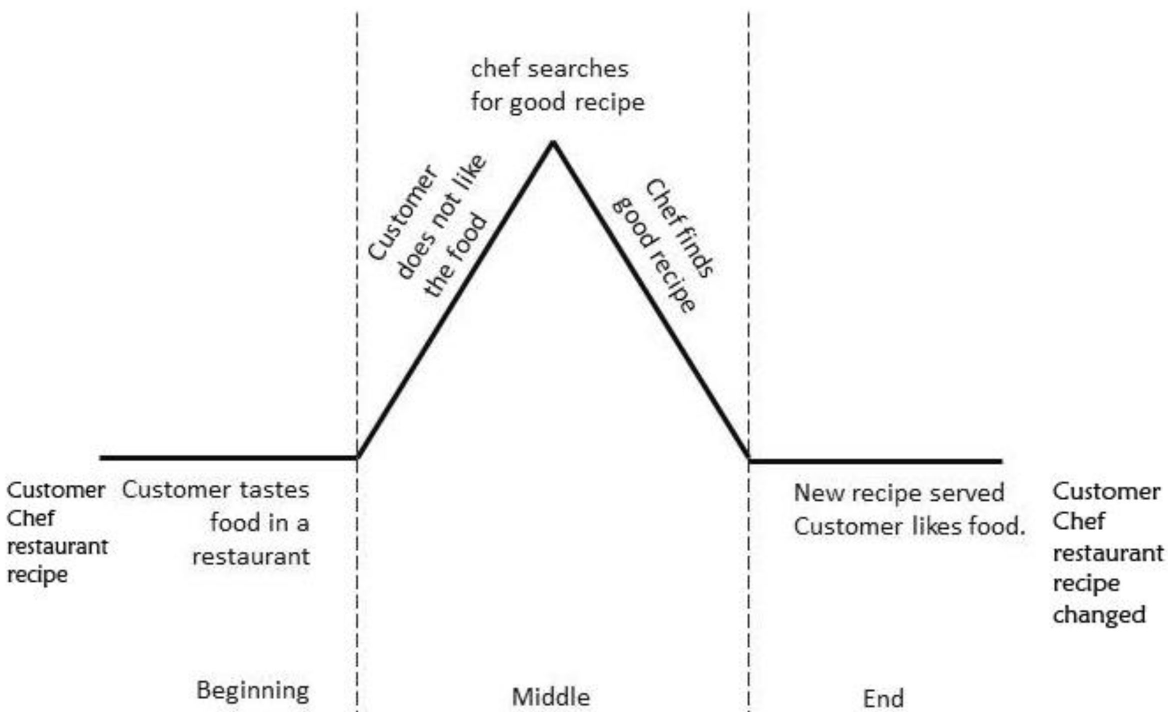


Figure 4.3: Restaurant script

The narrative structure elaborates how the final Goal of a task is achieved in spite of the obstacles. The goal is the End of the story or Denouement, obstacles in achieving the goal, search for solution and final solution is the middle of the story and beginning of story is simply introduction to the world and characters associated with the story. Similarly, if someone is going on a journey and his/her car break down. This event can also been seen as a narrative with Freytag's structure as shown in figure 4.4.

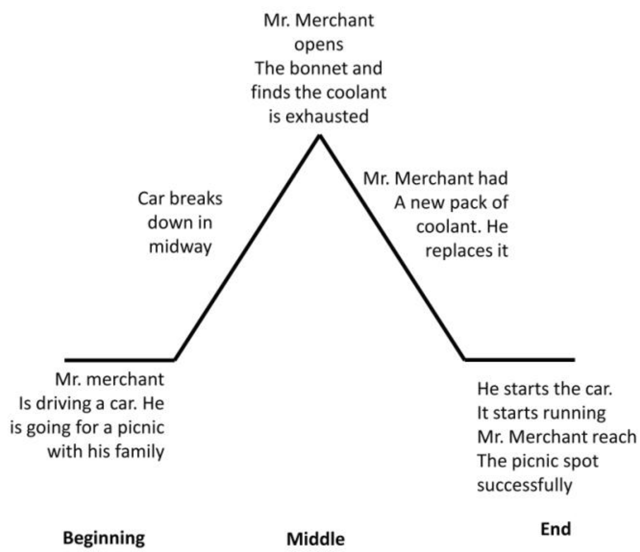


Figure 4.4: A car breakdown script

The middle of a narrative can extend further to an unlimited possibility as many obstacles the author chooses to put in the story. Figure 4.6 shows a script with extended middle.

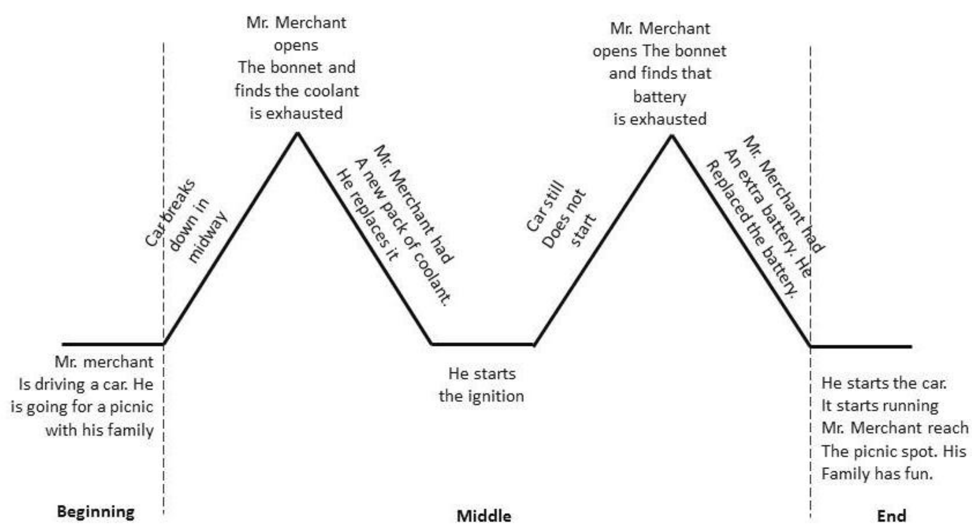


Figure 4.5: Script of a Family going for picnic. The middle has more than one problem solution.

Similarly, a discovery event or a scientific inquiry event can be interpreted as a narrative in which the elements of a scientific inquiry are related to each other in a sequential manner. The main elements of the discovery plot are initial situation, recognition of a problem, search for solution, solution and the final resolution of problem (Dewey, 1955).

An elaborate structure of a scientific inquiry was given by John Dewey in figure 4.7 which had the additional elements of reasoning and experimentation. This figure is author's representation of Dewey's description. The graphic element is similar to triangle of drama structure. The line becomes ascending at the point of doubt. The ascending line represents a change of initial situation. And the descending line represents another change of situation but towards resolution. The first change starting with doubt increases tension, the second change starting with reasoning and search reduces tension. Since these elements are similar to rising and falling action of the structure of a drama, the same figure is used and Dewey's events of a scientific inquiry are superimposed on to it.

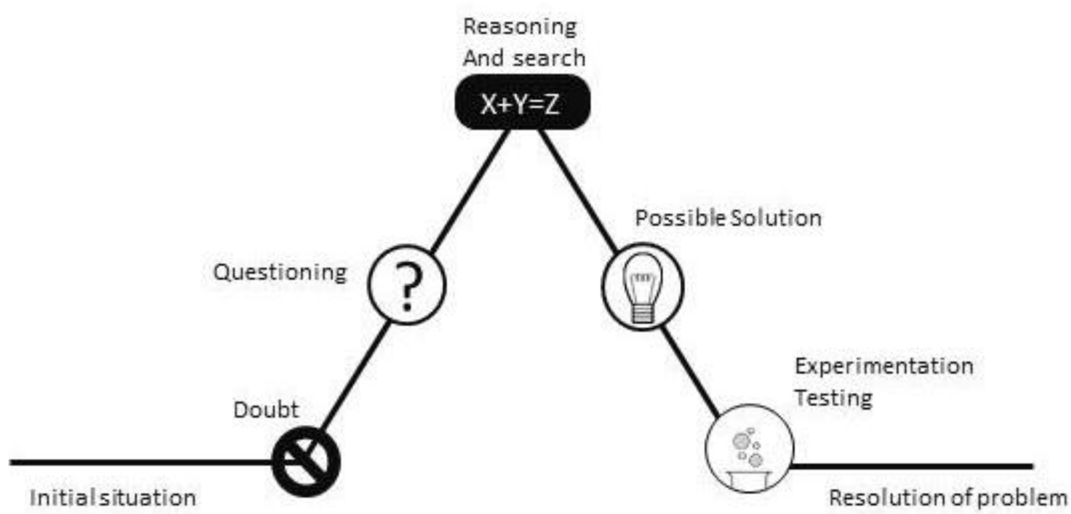


Figure 4.6: Diagrammatic interpretation of Dewey's problem solving inquiry script

So far we have seen the sequential order of a scientific inquiry of a single individual. However, from Kuhn and later also by Arthur Stinner, we see that scientific inquiry is the scientific culture includes work of many individuals. Hence a better picture of structure of scientific inquiry narrative is captured by the diagram in Figure 4.8. Here, the research journey involves not the inquiry process of one, but of more than one competing hypothesis of different protagonist or it could by many hypothesis of one protagonist itself. The designation of letter A or B before a symbol represents the journey of each particular individual. Hence the symbol (A vs B) gets meaning where proposition of A competes against proposition of B. Figure 4.8 represents the complete discovery process incorporating some of the ideas in theory of knowledge and theory of Learning, in the narrative format.

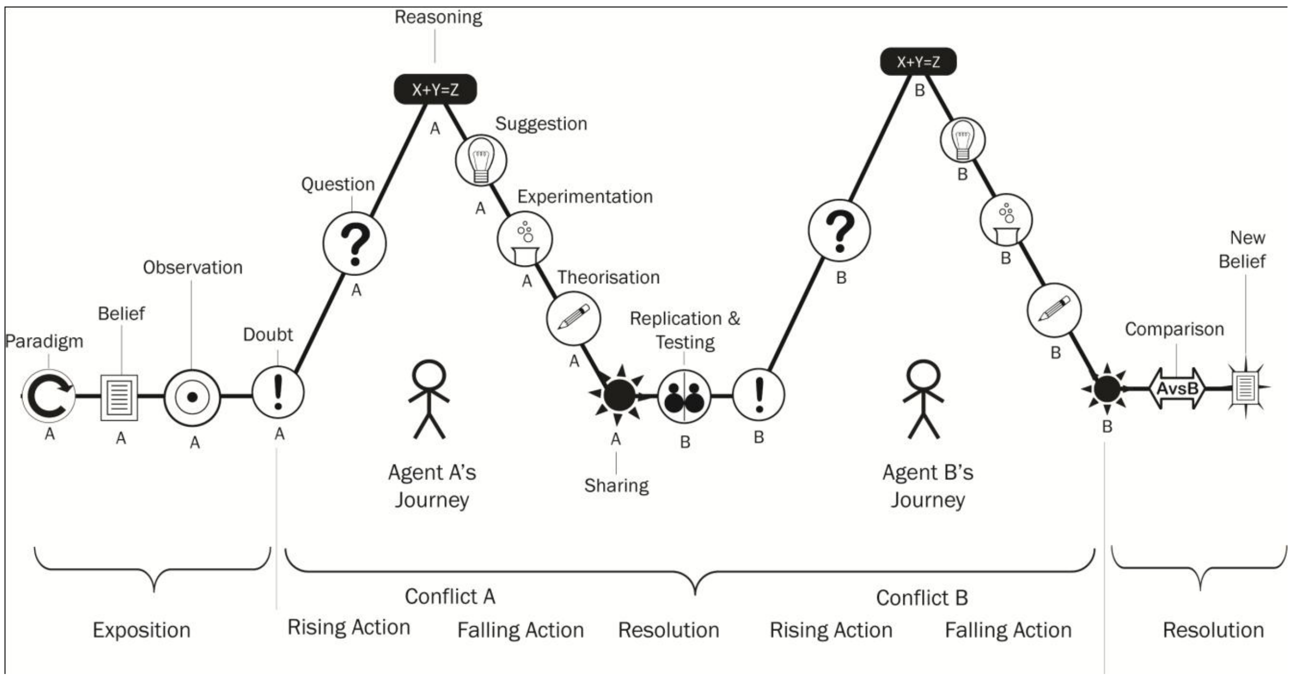


Figure 4.7: Script describing process of scientific inquiry within a science cultural community

It is not claimed that all scientific inquiries follow exactly the same steps. For example a single event of a person solving the mystery of a lost object can be done with proper reasoning and justification. But that does not constitute a scientific inquiry in the context of the culture of science as described by the scientific community. The scientific inquiry must extend beyond an individual. Other people must be able to verify and extend that knowledge. Unless the sense of sharing and community is not present in an inquiry, it cannot be called 'scientific' in the context of the cultural tradition of science.

These are various constituents that are most likely to be present in a scientific inquiry situation in unique combinations and the manner in which each event occurs is unique in every discovery related episode. For example, the event titled 'sharing with community' may happen in many different ways in history of a particular discovery is searched. The proposition of one scientist may be shared as a research document with the community or a person from the community may be the scientist's friend and that's how he/she may get to know the hypothesis. There may be other unique ways by which a scientist's hypothesis or proposition may get known to some fellow member of community. Einstein's acquaintance with current research happened not in a structured classroom, but when he worked in a patent office. That is where he got his exposure to latest patents in various scientific disciplines and hence got the opportunity to develop existing ideas further (Kumar M. , 2011).

4.3 Other Elements of Epistemological Narrative Framework (ENF)

So far we have only dealt with arranging the plot of a scientific inquiry Narrative in a certain way. However there are other elements of a Narrative which are its essential constituents. These elements were discussed in Literature review chapter (pp. 50). They are discussed in detail in this section.

4.3.1 Character

We have already established the first element, namely the story structure or plot in the previous section. Now we move on to discussing the next element, Character. The agents by whose action a story events unfold in cause and effect relation are called Characters. Just as objects are defined by their properties so Characters are defined by their qualities. Since our plot is already outlined in the previous section, the variety of characters possible in the framework of an epistemological Narrative is limited.

The first defining feature of a character is someone practicing one of the Arts[19]. He / She is occupied or training to be occupied in some profession. Since a character is primarily defined by its motivation, the motivation of a character in the story is defined by the requirements of the occupation in which he/she operates. For example, the personality of a scientist is defined by a

[19] Here art is referred in the Aristotelian sense to some professional occupation like carpentry, Engineering, Architecture, Medicine, Teaching etc.

set of commitments he/she holds for their occupation. Thomas Kuhn provides hint of one such set of commitments that a scientist holds for their profession:

> Finally, at a still higher level, there is another set of commitments without which no man is a scientist. The scientist must, for example, be concerned to understand the world and to extend the precision and scope with which it has been ordered. That commitment in turn must, lead him to scrutinize, either for himself or through colleagues, some aspect of nature in great empirical detail. And if that scrutiny displays pockets of apparent disorder, then these must challenge him to a new refinement of his observational techniques or to a further articulation of his theories (Kuhn T.S., 1962, p.42)

Secondly, the character has a background which means that he lives in a particular time and place. Mention of his/her family members is optional but not necessary. But mention of time and place is necessary because that forms the initial situation in the plot. There can be various roles that characters can play in the given Plot.

Problem Solver – Person responsible for bringing the story to conclusion by contributing to the extension of knowledge in a particular occupational domain.

Old Belief Holder – Person, who was earlier popular because he was responsible for advancement of knowledge in that domain previously. He/she is the predecessor of the New Paradigm.

Problem Solver Helper Assistant: This character is merely present to externalize the Protagonist's thought process. This person can literally be a lab assistant or the protagonist's wife, friend or family member. They externalize the protagonist's thought process by starting a dialogue.

Community: An essential event of ENF is sharing with community. Knowledge is shared among the community members through papers published in journals or presentations of articles. Since there are many competing presentations it is by dialogue and debate among the community members along with the representative council heads that a theory is finally chosen that satisfactorily resolves a shared problem. Hence various members of community form an important class of characters.

Supporting characters: Other characters in story may not have any specific characteristics. They are parents or siblings or friend of the lead character. They may play the role of Problem solver helper assistant or a member of a community, but in generic role, their impact on unfolding a story is only secondary.

Emotional States of the Character: This is an important aspect of identity of the character, but in the ENF, it has not been taken into account. The main identity of the character is defined by his/her occupation. Essential trait or the essence of the lead scientist character is that he/she believes in validating a belief through experience. They do not believe in a claim merely on its face value, nor on authority, neither on Tenacity, but on the scientific method. Pursuit of empirical truth is the highest value that the Scientist character holds.

4.3.2 Setting

Next element of a Narrative is setting. It is described by the time and place where events of the story happen. Because ENF covers a limited type of events based upon which a story is set, the possible places are of a certain type where the action takes place. The main setting is the workplace of the agent. It can either be a workshop, a laboratory, a factory or an office. The place also includes natural setting as sometimes the agents need to travel back and forth between natural and cultural setting. The second important setting is the presence of a knowledge sharing community platform. It can be an amphitheater, a governing council or society or just a gathering of a crowd. The third important element under setting is the time in which story is set. Time defines the type of clothing the characters will wear and it also defines the visual appearance of environment because through it we know the era in which the story is set, whether Prehistory, Greco-Roman period, Medieval age, Renaissance or Industrial civilization.

4.3.3 Dialogue

A dialogue is an important aspect because in many situations; the dialogue reveals the background context which the characters are dealing with. The dialogue here is specifically developed to carry the purpose of elaborating the ‘reasoning process’ of the scientist. In logic, reasoning is commenced by an argument. An argument has a specific form. We have attempted to experiment representing an argument in the form of a dialogue. This work can be titled as, how to write an argument of formal logic in the form of a dialogue. In previous sections, we have seen that formal logic is categorized into categorical syllogism and conditional. In symbolic logic, a conditional is given in three forms, Modus Polen, Modus Tolen and disjunctive syllogism. We take the simplest form i.e., the categorical syllogism and demonstrate how a categorical syllogism can be represented in the form of a dialogue.

Let us take a simple categorical argument:

All glass is transparent. This prism is made of glass therefore this prism is transparent.

This can be reduced to the form All S is P, Y is S, therefore Y is P.

We asserted in previous chapter that in every argument, there is a presupposed ‘question’.

In the above argument, the presupposed question is:

“What is one property of this Prism?”

Question is the beginning of a dialogue. Response to the question in the form of answer or conclusion is the second part of dialogue. The third part is a specific question that asks for the justification of the answer and the fourth part is the justification of the answer. Fifth part is acceptance or rejection of justification. Let us present a simple narrative to explain this.

Characters: Questioner, Answerer

Questioner: I wonder “What is the property of this prism?”

Answerer: It is transparent

Questioner: How can you be so sure?

Answerer: This Prism is made of glass and all Glass are transparent. Therefore this Prism is transparent.

Questioner: I got it. Thanks.

The above dialogue is based upon deductive reasoning. There can be a dialogue based upon Inductive reasoning. An Inductive argument cannot be done simply by a dialogue because induction relies upon real observations. The dialogue in an inductive argument can only be present when the actors are acting or doing something or pointing at something that can be perceived through senses in the real world.

There is no fixed way or thumb rule of defining how dialogue should flow. These are only suggestions of some essential elements of a dialogue i.e., Question, Answer and Justification. These elements can be expressed in any manner based upon the personal style of the content Narrative designer.

4.3.4 Narration

The ENF gives a sequence of events associated with a discovery story plot. However, the narration of the story need not necessarily follow the same order. The narration of a story may begin at any point, either middle first or end first. It can also begin at any other event in the story as long as all the important events are eventually knitted together which has the complete ENF structure.

4.4 Examples of stories designed using ENF.

In this section the ENF method of developing a discovery narrative in history is demonstrated

4.4.1 Example 1: Story of Clothing

The first story designed using the EN framework was that associated with evolution of clothing. The design process was as follows:

1) First the decision of making a story on Fabric and how it is made was taken. This decision was taken because in order to make a story lesson that can be compared with the existing textbook lesson, then such kind of content was needed which discusses the evolution of a concept. Chapter Fiber to Fabric in class 6th NCERT textbook provided such content. Its story title was called “Story of Stich”.

2) Then the history of clothing was searched through various sources from the internet.

3) The history search revealed a chronological development in the evolution of clothing fabrics. Early man used animal skin as drape. It was succeeded by use of various types of grass. Then, weaving technique was discovered probably from basket makers. Later discovery of cotton and wool, along with weaving techniques, resulted in the creation of cloth or Fabric. This stage is diagrammatically represented in Figure 4.9.

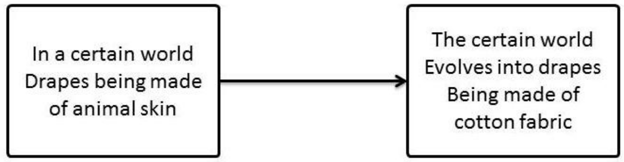


Figure 4.8: Depiction of change in story of clothing

4) Once the basic beginning and end of story are decided, one can proceed to outlining the middle and other aspects of the story like characters and events. The set of characters needed to be decided are:

   a) **Problem Solver:** This person is part of the old routine but witnesses an event that raises certain doubts in his mind. He takes on the quest of finding answers to the questions and finally discovers new knowledge that brings a new routine into being. In simple terms, this person is the final Hero of the story. In this case this person is Stich.

   b) **Old Belief Holder:** This person is well established in the previous routine. He forms the primary force standing in competition to new Routine. In this story, this agent's role is played by Mr. Sharp. To keep the first story simple, the element of opposition is not added.

   c) **Problem Solver Helper Assistant.** This person is someone, who provides a dialogue to the routine changing agent which helps the agent solve a problem. In the story of Stich, this role is played by his elder brother.

   d) **Community:** Since the story necessarily has a display or demonstration component, the Public forms the essential character in the story. In the story of Stich, public plays the role of making fun of Stich in his first demonstration and hailing him in his second demonstration.

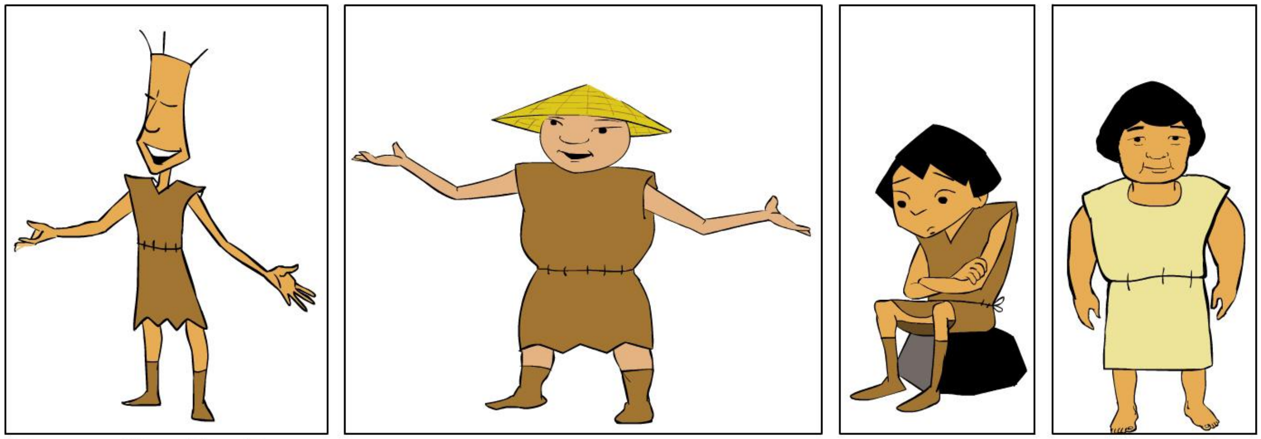


Figure 4.9: The main protagonists in the story of Clothing

e) **Additional routine/Agent**: Additional routine is that which the new routine agent uses to synthesize with existing routine to create a new routine. In the story of Stich, the boy synthesis the drape making process with the process of basket weaving. The agent and setting representing basket weaving is Basket maker and his basket making workshop. By getting acquainted with the routine of basket weaving, Stich is able to create a new routine. Figure 4.11 gives list of protagonists in the story.

The three stages (beginning, middle and end) outline the flow of events. Other details are added only after the basic backbone of the story plot structure is built. For first stage detailing, one needs to position the main protagonist in the old world/routine. For example if the old world is about making drapes from animal skin then what is the position of the lead protagonist Stich in this scenario. Mostly he will be working as an assistant to a professional or some professional him/herself in the old world. The surprise situation in this story is Stich’s observation that a surface can be formed by weaving because it contradicts the existing belief that surfaces can be made only from other surfaces like animal skin. (a disliking for killing animals could be another reason for change). Search for an alternative lead Stich to the world of basket making. He combined the weaving process for making surface for drapes with grass. But again there was a limitation in grass drapes as they tore easily. So an alternative material was required. Search for material lead Stich to discover Cotton plant. Because fibers could be pulled out of Cotton ball, Stich found it suitable for making fabric from weaving the fibers made from Cotton ball. Finally Stich invents a needle to stich different pieces of cloth together to create Creationland's first cotton garment. The steps involved in the plot are given in Figure 4.13. This is second level of detailing of the plot. The third level of detailing involves subjective decision making regarding how specific events are constructed. For example the introductory scene begins by general explanation of a place called Creationland. It is established that Stich and his father are drape makers. This is a subjective choice because the story can even begin with Stich being an assistant of Mr. Sharp who is a drape maker. It does not matter what exact role the main protagonist has as long as his important role of being the one who would eventually bring the change is fixed. Similarly it is not essential how the main protagonist encounters the world of basket making, he can either work as an assistant with a basket maker (quitting his old job) or he can accidently see a public demonstration made by a basket maker. It does not matter how exactly it happens as long as the protagonist gets inspiration from a weaving process which he can also get by observing a bird's nest. An illustrated example of this story is given in Appendix 3.

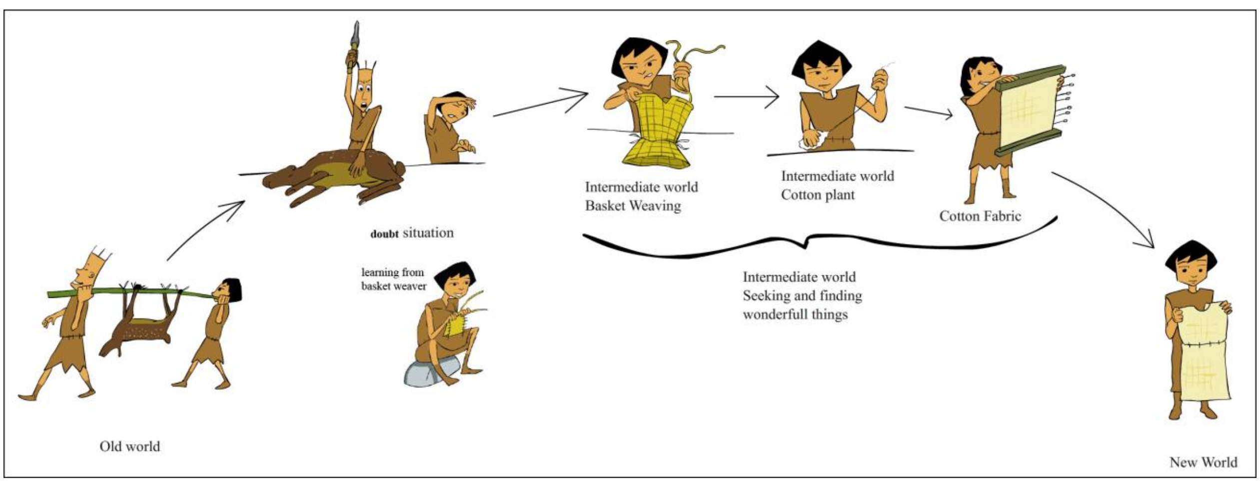
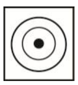
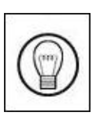
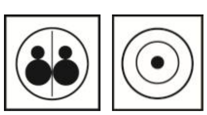


Figure 4.10: Story of clothing scenes of beginning, middle and end

Event vise detail of Story of clothing according to ENF is given in the following table 4.1:

Story of Clothing

	Stich was a Drape maker in a place called Creationland. Every day he went to forest in search of dead animals. He made drapes From dead animal skin. It was dangerous to go in the forest for other scavengers were also in search of dead animals. He always wondered if somehow he could make drapes without risking his life.
 	One day while returning from the forest, he saw a gathering of people. A man called 'Weaveman' was showing something to people. They had never seen such a thing before. It was a basket made from cane.
	Stich had many questions in his mind about the basket Weaveman was showing. What was it made of? How he got the idea? He asked these questions to Weaveman to quench his curiosity.
	Weaveman told Stich that once he was going to a forest when he noticed the strangest nest he had ever seen. He decided to wait and observe how the bird made it. He saw the bird bringing dried sticks and arranging it in criss-cross manner. Stich thanked Weaveman and went back home. That night, he thought that if a surface could be made by arranging sticks, then the surface can be made for making drapes as well.
	That night, Stich suddenly jumped out of his bed. He got an idea in dream. He saw himself wearing drape made of cane basket.
 	Without wasting any more time, he chiseled a cane tree to form thin strips out of it. Then, he weaved them together and formed a crude drape like thing. His belief got confirmed that yes drapes could be made by making a surface made from thin bamboo or cane strips arranged in a criss-cross manner.

	When the drape was ready, he was so excited to show it to people of Creationland. A Few people tried it, but they were disappointed.
	They found Animal drape better than this cane drape because Animal drape was one smooth surface, soft and comfortable to wear. But drape made from cane basket was hard and uncomfortable. Hence they rejected it.
	Stich was disappointed and went back to doing his routine work of collecting animal skin from forest.
search 	There was a farmer in Creationland. His name was Plantree. He had discovered a new kind of plant that no one in Creationland had ever seen before. He wondered what this plant was?
	Plantree knew that there was no plant like this he had seen before, so he decided to observe its properties and give it a name. This plant had strange flower which was like a very soft ball. Thin thread like things could be pulled out of it and rolled on fingers to form fiber. He called this cotton plant
	Plantree could not hold his excitement of finding a new plant and he told his friend Stich about it.
	Stich went to the forest and found the cotton plant with same properties which Plantree mentioned. He could pull out thin strand of fibers from Cotton ball. And he also observed that though the fibers were soft and weak, when they were pressed together in finger, they formed a soft but strong thread.

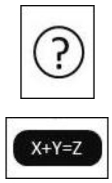
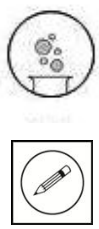
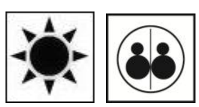
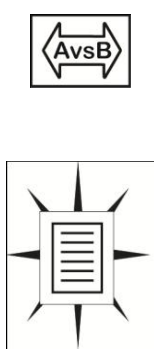
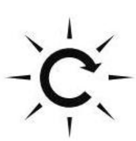
	Stich wondered if he could use this material for making strips for weaving a surface instead of cane. He thought this because of the softness and strength of cotton better than cane.
	And so he tried making thin fibers from cotton flower and rolled them to form yarn. The yarn he weaved in criss-cross manner to form the drape surface expecting it to be strong and soft. And when he tested it by stretching and pulling, it did turn out to be soft like animal skin and strong as cane as he had expected. He called it “the cotton fabric”. He also theorized that a softer material like Cotton was better for making drapes because if was strong and soft at the same time.
	He could not wait to share it with people of Creationland. He went up and showed everyone the new cotton cloth. A few people tried.
	They found this cotton cloth as comfortable as animal skin and it was also strong because of the weave. And he could make it in any shape he wanted. Stich became famous in Creationland for giving them new kind of clothing. People now believed that Animal skin was not the only way of making drapes, they could make it by weaving cotton fibers as well which is a safer and cheaper way of making cloths because Cotton could be grown as much as they wanted and they did not have to risk their lives in forest.
	Some people thought that if fabric could be made from cotton plant, there could be other plants as well. They found Jute could be used to make drape and sheep hair as well. This started a new era of exploration in clothing in Creationland.

Table 4.1: Table showing details of discrete events and their description in the Story of Clothing

The structure of story of stich is as follows:

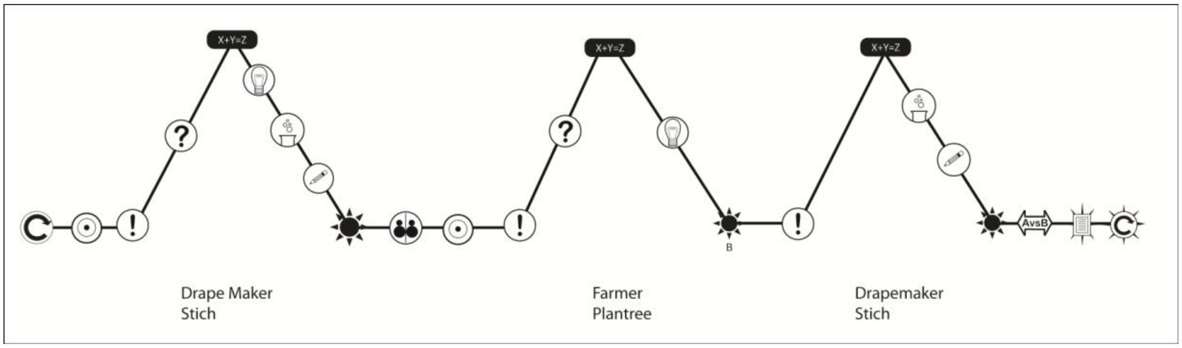


Figure 4.11: Symbolic representation of Story of Clothing: How Stich invented Fabric.

4.4.2 Example 2: Volta and the Voltaic Cell

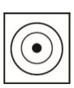
Following the similar process, we develop the story behind invention of the Voltaic cell. **Act I:** In a place called Electroland, people suffering from muscle spasm were treated with the help of a device called the Leyden Jar. A doctor by the name of Galvani was famous for using Leyden Jar for treating such patients. One day while experimenting to test the effect of electric charge on Frogs, a strange thing happened. As soon as he touched the frog's leg with a metal knife, it started twitching. But this was hardly a cause for surprise because Galvani thought it must be because of the Leyden jar connected to the frog. The real surprise came when Galvani disconnected the frog from the Leyden jar. As soon as he touched the frog's leg, it started twitching wildly.

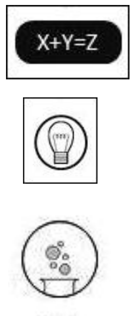
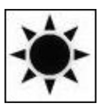
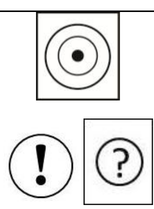
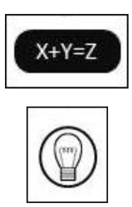
Act II: Galvani after some contemplation came to the conclusion that there was some form of electricity possessed by the frog. He immediately made an announcement in Electroland of having discovered a new form of electricity called animal electricity. There was another scientist in the crowd, Volta. He decided to replicate the experiment in his lab. He found out that the frog's leg only twitched when it was touched by knife made of metal (zinc) different from the metal with which the frog was clipped (copper) on a board and it did not twitch when the metals of knife and the clips were same. He immediately made an announcement that the leg twitched because of metals used in knife and the clips and not because of animal electricity. But Galvani showed that leg twitched even when touched by finger. Volta returned home and this time tried to see if there was any effect when the frog itself was removed. He found that when he connected the metal and plate with wire, it showed a deflection in Electroscope. This confirmed that the current was in the metal knife and not in the frog. Volta made an apparatus to demonstrate this phenomenon.

Act III

Volta made an announcement again in the central city square. He showed the apparatus and called it the Voltaic cell. The presence of electric current was tested by deflection in electroscope. This apparatus, Volta showed to prove that there is another form of electricity called 'Contact Electricity' which is generated when two metals come in contact with each other and that Galvani's claim of animal electricity was false. The crowed hailed Volta for showing them the truth about Electricity. Soon everyone started making their own Voltaic cells. An improved form of Voltaic cell was used to run the electric bulb and thus the life of people of Electroland changed forever. An illustrated example of this story is given in Appendix 3.

The Voltaic Cell

	In eighteenth century Italy, lived a physician whose name was Galvani. He routinely used the Leyden Jar to treat patients who suffered from muscle spasms. Leyden Jar was a static electric charge storage device. Galvani was also studying the effect of electric charge on animal tissue for which he experimented with frogs.
 	In one such experiment when Galvani was testing the effect of electric charge on frog, a strange thing happened. As soon as he touched the frog with a metal knife, its leg started twitching.
	Galvani wondered what caused the dead frog's leg to twitch?

	Since Static electricity is associated with magnetic properties as well, Galvani inferred that the frog's leg moved because it was connected to Leyden jar. Galvani removed the Leyden jar to see what happened. The leg still twitched. Galvani Recalled that electric eel gave electric shock when touched. Galvani inferred that maybe charge was produced inside the animal body.
	From this experiment Galvani proposed that there was another form of electricity that was distinct from static electricity. He called it the 'Animal Electricity' which is generated inside the body of animals.
	He went to the scientific council of Italy and shared his discovery with them. His theory was readily accepted.
	However, there was another scientist in Italy called Volta who decided to Replicate Galvani's experiment.
	Volta noticed that leg of frog did not twitch in all conditions. It twitched only when leg was touched by a metal different from the metal dish in which the frog was kept. He wondered why this was happening?
	Since twitching of Frog's leg was dependent upon combination of metal used in plate and knife, Volta inferred that the twitching of frog's leg must be due to difference of metals rather than animal electricity.
	Volta shared his hypothesis with the Community. But…

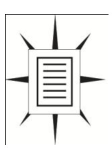
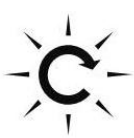
	Galvani showed that the frog's leg twitch with his finger as well when no metal was touched at all. Galvani's theory was still strongly believed
 	Volta was still not convinced. He thought if the leg twitching was due to metals used, then the current should be present even when frog was absent. He did another experiment by removing the frog altogether from the experiment. He made an apparatus resembling the copper dish, Saline solution and Zinc knife setup. The apparatus was a zinc and copper strip dipped in saline solution. When he connected the zinc and copper electrodes, it showed deflection of aluminum foil in the electroscope, confirming the presence of current.
	Volta proposed that the twitching of frog's leg was due to a different type of electricity called 'Contact electricity' which gets generated when certain metals come in contact with certain chemicals. He confirmed his theory by making a real apparatus called the Voltaic cell.
 	When Volta shared the idea of contact electricity, there was resistance from accepting it but when he demonstrated with the help of the Voltaic cell, it became clear that the idea of Animal electricity was wrong.
	This established that a different form of electricity could be produced with some metals and saline solution without providing any friction as in static electricity.
	People started making Voltaic cell as it was very easy to make and the first source of continuous electric supply, came into being. Later many other scientists did experiments to improve the efficiency of the cell in the process many different varieties of batteries got invented.

Table 4.2: Constituents of ENF in discovery event related to story of Voltaic cell

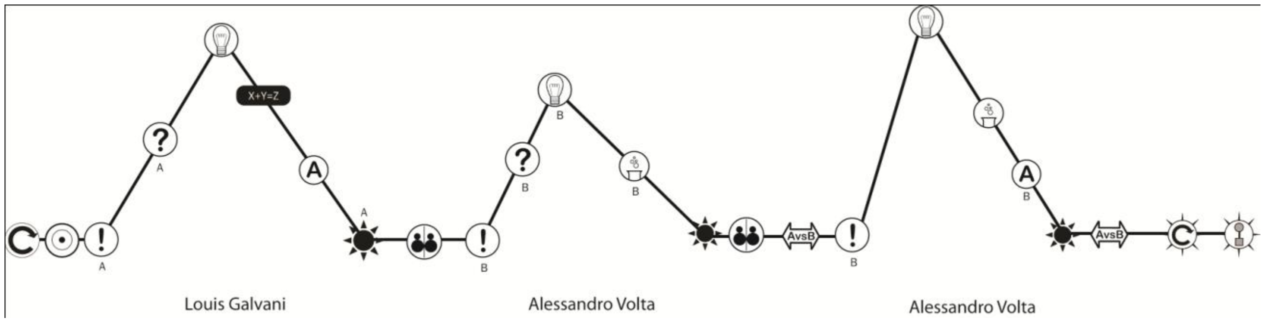


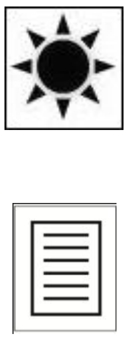
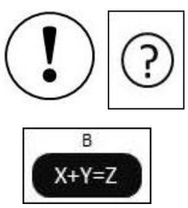
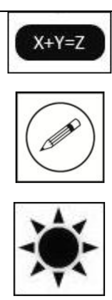
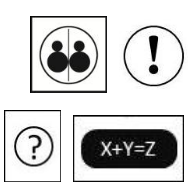
Figure 4.12: Symbolic representation of Story of Voltaic cell

4.4.3 Example3: Discovery of Oxygen (Asimov, 1972)

We will see the same framework working behind the discovery of Oxygen and replacement of the Phlogiston paradigm by Lavoisier. A brief synopsis of the Story is as follows. In 18th century Europe there was a chemist by the name of Stahl who proposed a theory of combustion. According to this theory, all things, animate or inanimate, contained in them a fiery substance called Phlogiston. This phlogiston was the prime cause of combustion. When something burns, it is because of release of this substance in air. The remaining substance was earth minus the Phlogiston. Some substance burnt rigorously while others slowly because of the proportion of Phlogiston present in them. Rusting was also caused due to release of Phlogiston at a very slow rate. Chemists at large believed in the Phlogiston theory accept some, like Herman who could not understand how rusting could be a form of combustion because they knew that the substance gained weight after rusting. If Phlogiston was released, then the thing should lose weight. Chemists, rather alchemists of that time responded to this by saying that there were two types of Phlogiston, one with positive weight while other with negative weight. When a substance lost negative Phlogiston, it should weigh more rather than less. Many people got satisfied with this explanation, while others continued to investigate into the mysteries of combustion. A scientist called Joseph Black made a very important discovery while trying to collect vapors from various experiments. The vapor that he got after heating lime seemed to have strange properties which were different from properties of air. This vapor did not support combustion. A candle would not burn in it. He named this vapor as “Fixed Air”. And it lead to doubt in the belief that air was a single homogeneous substance. By 1770, some other gases were also discovered namely Hydrogen and Nitrogen. Inspired by the results of Black, another scientist, Joseph Priestley also tried collecting vapors by heating various substances. But he also went ahead and tried collecting vapors over mercury instead of water because he had found out that some gases like Carbon dioxide dissolved in water hence, they could not be collected over it. So he decided to collect gases over mercury. In one of his experiments, he heated mercury to form its calx. It was oxide of mercury (but priestly did not know since oxygen was not discovered by then.) Then he concentrated rays of sun over this Mercuric oxide. This reaction reduced mercuric oxide back to mercury, but a gas was also released in the process, which Priestly had carefully collected. He found out that the gas collected possessed unfamiliar qualities. Any combustible substance burnt more brilliantly in this gas. Priestly thought that this particular “air” has lost its usual quantity of Phlogiston that is why it was accepting phlogiston from the burning substance more eagerly. Priestley showed the results of his experiments to a French scientist Lavoisier. Lavoisier was very particular about precise measurements and applied it in all the experiments he did with chemicals reactions. He heated tin and lead in limited supply of air to form their calx (rust). When he weighed the calx, it was heavier than the metal before heating. But the surprise came when he weighed the substances (metal and air) together along with the vessel before and after the reaction. HE found that the weight remained the same before and after the reaction. How could this be because the calx weighed more after heating. This could only happen if something from the air was getting added to the calx, reducing the weight of air. Lavoisier’s intuition was confirmed when he tried opening the lid of the apparatus after experiment. As soon as he opened the lid, air suddenly gushed into it confirming that the reaction had created a vacuum inside the apparatus which means that the air lost something from it into to the heated substance. This lost something was later termed by Lavoisier as Oxygen, one of the constituents of air. These set of experiments not only established that Air was not a single substance but a mixture of various gases, but also that in a reaction, the mass of reactants and products remains unchanged. This famous law later became the foundation of modern chemistry and was known as the Law of Conservation of mass. Lavoisier went on to develop scientific nomenclature for naming various elements. Illustrated example of this story is given in appendix 3.

Lavoisier, Priestley and the discovery of oxygen:

A story of how modern chemistry came into being

	A scientist in Europe Declared that he had understood the phenomenon of combustion. He said that out of the four elements; Earth, Air, Water and Fire, the Element Earth was made up of another fiery substance called Phlogiston. This substance is responsible for combustion. All matter is composed of some proportion of Phlogiston and the more Phlogiston a substance has, the more rigorously it burns, releasing Phlogiston in the form of smoke into the air. The remaining ash is nothing but the element Earth without Phlogiston. He also added that rusting itself was a form of Combustion only a very slow one. It had become a popular belief in the community that Phlogiston was the cause of combustion of substances and their rusting.
	Many years later, a scientist called Joseph Black tried to understand nature of spirits (vapors) collected after chemical reactions and its relationship with combustion. He started collecting vapors that released from burning substances. When he collected vapor from burning Calcium Carbonate, he found that this vapor was not Air, it was something else. What was it? Some experiments needed to be done to find markers to identify this gas.
	This gas had different properties than air because a candle extinguished immediately in it. Joseph called it fixed air and shared these results with the community. This discovery took the scientist community by surprise because they believed that Air was only one, homogenous substance, but it seems that it was doubtful.
	Inspired by Black’s experiment, two scientists independently did two other experiments. Scheele in Sweden and Priestly did some experiments with the calx of mercury. They first heated mercury to form its calx with is brick red in color(we now know it as mercuric oxide).Then, he reduced it by concentrating sun’s rays on it through a magnifying glass. This gave

	back the mercury along with a gas. Priestly carefully collected this gas and found it unfamiliar properties. Candle and other combustibles burnt brilliantly in it. Priestly reasoned that this gas must have lost its usual content of Phlogiston, hence it accepted phlogiston from combustible substance more eagerly. Hence Priestly called this gas Dephlogisticated air.
	Priestly shared his experience of mercuric oxide with his friend Lavoisier.
	Lavoisier tried to do similar experiments with calx of tin and lead (their oxides) by heating then in limited supply of air.
	He found a surprising thing. When he weighed the calx alone, its weight increased after the heating. But when he weighed the whole setupm with vessel and all substances in it, there was no change of weight before and after the reaction. How could this be? Did something from the air got added to the calx?
	If something gains weight in a tight container after a reaction, it must have come from something within the container. Lavoisier reasoned that something from the air in the jar must have got added to mercury.
	His doubt was confirmed when he released the lid from top. He had to apply a little force to open the lid because it seems a vacuum had got developed inside the apparatus.
	Lavoisier challenged the Phlogiston theory before the community. He established the new belief that rusting happens because of addition of a specific gas from the air. This gas he called Oxygen and it was the same as depholgisticated air of Priestley.

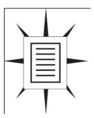
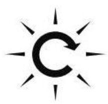
  	For many years the community was reluctant to believe in Oxygen theory of combustion. But gradually when many scientists confirmed Lavoisier's findings, a new paradigm got established. Rusting was now believed to be a combination reaction, not a reduction reaction and the most important of all, Lavoisier establish the Law of conservation of mass according to which the mass of reactants and products in a chemical reaction remains constant. After this, the new routine of balancing chemical equations got established and the discipline we know as chemistry came into being. Lavoisier also brought a system of nomenclature by which he changed names of many elements and gave names to new ones.

Table 4.3: Constituents of ENF in discovery event related to story of modern chemistry

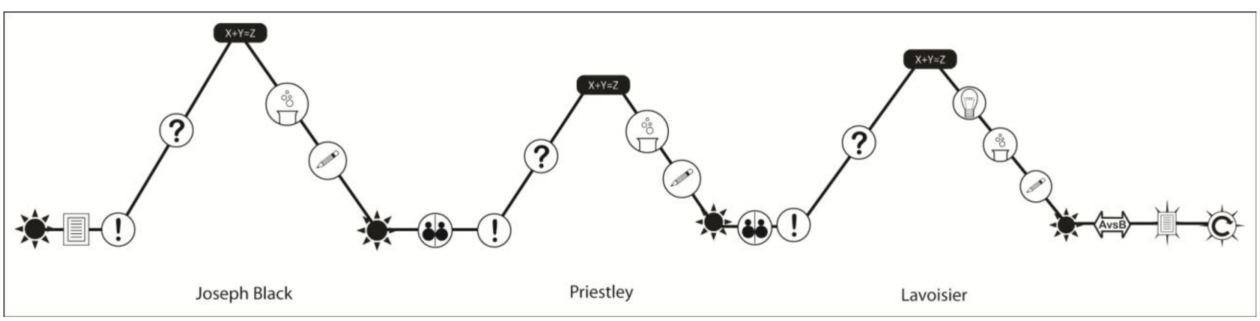


Figure 4.13: Symbolic representation of Story of discovery of oxygen and beginning of Modern Chemistry.

These stories were designed at different stages of development of ENF and they may comply with the Framework in a varied manner. The process of using the framework is iterative. There may be gaps in accurately using it, but the more it is used the more the person may improve the process of using it to build epistemological narratives.

4.4.4 Story of How Electromagnetism came into being

This particular story example is presented specifically to show the nature of continuity in science. One story is not an end or termination of inquiry. It grows to more inquiry and hence extension of the story. We saw the story of Voltaic cell. The story does not end there. The story of development of electromagnetism is connected with the development of the Voltaic cell because it provided a steady flow of current to experiment with the properties of electric current, which before the Voltaic cell, the Leyden jar did not provide.

The Story of Voltaic cell continues…

The Voltaic cell immediately became famous in different parts of Europe as it was very easy to make. Many researchers made use of it to understand the mysteries of electric current. In the early 19th century, there was a scientist in Denmark who experimented sincerely with the steady current which the Voltaic cell provided. His name was Oersted. He found out that the current from Voltaic cell was different from the one produced from Leyden jar on two accounts. One was that, the Leyden jar discharged its current when the electrodes were connected with a conductor, in one instance while the voltaic cell provided steady flow of current for a longer period of time. Secondly, static electricity had attraction property. The charge producing Amber or glass rod also attracted pieces of paper or metallic foil placed near it. But the current produced by this voltaic cell did not attract pieces of paper or metal foils.

But Oersted wanted to be sure if there was really no property of attraction associated with it. So he tried different kind of materials. Nothing got attracted towards the electric current carrying wire, except one thing, a magnetic compass. Oersted was surprised that the current produced in electric wire kept over a distance affected the compass; it means there must be an attraction property associated with current electricity. He also saw that the Orientation of the magnetic compass needle was always perpendicular to the flow of current. Oersted published his observations regarding magnetic effect of electric current and everyone in Europe was fascinated to know that electric current from a Voltaic cell also had magnetic properties.

There was another scientist called Ampere who lived in France. He replicated Oersted's experiments in many ways and did new explorations. He thought that if a current carrying wire had some magnetic effect, what would happen if two wires carrying current were kept near each other? To his astonishment, Oersted found out that when the current was in same direction, the wires repelled each other and when it was in opposite direction, they attracted each other. Both the current carrying wires had turned magnetic! Oersted recalled William Gilbert's experiments in 17^{th} century on converting iron into a magnet. He thought if a piece of iron could be magnetized by beating it in presence of magnetic field then will it also be possible to magnetize an iron piece in the presence of magnetic field of electric current? To confirm his doubt and belief, he wound up a coil of wire around a piece of iron bar and switched on the current from a battery source. His belief got confirmed, the iron bar got magnetized, and it started attracting iron nails!

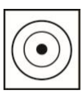
This discovery caught the interest of a British scientist called Faraday, who started his career at the age of 13 as a book binder but due to his immense interest in scientific experiments, got membership in the Royal society. Replicating both Oersted and Ampere's experiments, Faraday thought, if Current could produce a Magnet, then can a Magnet produce current? He believed this because for any reversible existing process, the reverse of that process may also be true. To confirm his belief, he wrapped a thick coil of wire and started moving a bar magnet in various ways. No deflection in galvanometer was noticed. But when he moved the bar magnet in and out of the coil, there was some deflection in the galvanometer. Certainly some electric current was being produced in the coiled up wires! Faraday got convinced that Magnetic effect of current was a reversible process. This was the first idea in development of the Electric generator or dynamo, in which a moving magnet generates electric current in wires coiled around it.

The electricity we get in households is produced with this principle.

Faraday did more explorations. He fixed a magnet on a tray and hung a nail on top without touching it. When he passed current through the nail, it started rotating around the magnet. This was happening because of repulsion and attraction happening between the field of the magnet and the magnetic field produced by the current in the nail. This was the principle which later lead to development of the electric motor. All electric motors we see today, in Fans, in Electric juicers, in cars everywhere, run on this principle.

Faraday's discoveries and inventions the Dynamo and the Electric Motor have been most influential in shaping our world as we know it today.

The stepwise description of the story showing constituent elements of the ENF are given in table 4.4

	Story of Electromagnetism
 	The voltaic cell fascinated another scientist called Oersted. He replicated the voltaic cell to observe the behavior of current produced by it.
	First observation was that it was similar to static electricity produced by Leyden jar in terms of its sensation,
	But there seemed to be two things that distinguished it from static electricity from Leyden Jar. One, it produced a steady flow; secondly, it did not attract other substances.
	Oersted wondered if this current will have no attraction effect on any material
	Oersted thought that there must be an attraction associated with this current as well because property of attraction was associated with phenomenon of static electricity. He wanted to try different materials to confirm that the electric current did not have any attraction property.
	So he decide to test with many materials, mostly metals and found to his amazement that a magnetic compass did get moved from its north pole position when the current was switched on in the wire.
	Orsted concluded form his experiment that The current from voltaic cell did have a magnetic effect associated with it. And shared his theory with scientific

	community.
	Ampere repeated Oersted's experiment and found the same results. Ampere also did some free explorations to see what happens if wires were placed close to each other.
	Ampere observed that the current affected the magnetic needle and it moved perpendicular to the direction of current flow.
	When placed two wires parallel to each other, found out that they attracted and repelled from each other based upon the direct of current.
	Ampere wondered if an iron could be magnetized if placed in large amount of current?
X+Y=Z	Ampere recalled that William Gilbert had shown two centuries ago that an iron could be magnetized by heating and beating if placed in alignment to north and south pole. Similarly, an iron rod could be magnetized in presence of electric current.
	Ampere constructed an apparatus called a solenoid by wounding lot of wires packed tight together around an iron bar. When he allowed the current to pas through the wires, the bar got magnetized
	Ampere came up with theory that current could magnetize iron and shared it with the community
	Faraday, a book binder and assistant of Davy, saw Ampere and Orsted's experiment and replicated them.
B X+Y=Z	He recalled that if in Orsted's experiment, a magnetic needle is moved in presence of electric current in vicinity, then can a static magnetic source move a wire with current? And also if from Ampere's experiment, if electric current could magnetize an iron, then can a magnet produce current? The only justification was that the opposite of one process may also be true

 	Faraday made two apparatus and confirmed that that it did happen as he had suspected. He showed that Current could be produced from a moving magnet which was the principle behind the first electric generator called a dynamo and he also showed that a stationary magnet infused motion in a current carrying wire suspended freely around it.
 	Faraday shared his inventions with the scientific world and these resulted in creation of the most useful inventions of all time in history of science, the Dynamo and the Electric Motor.

Table 4.4: Constituents of ENF in discovery event related to story of electromagnetism

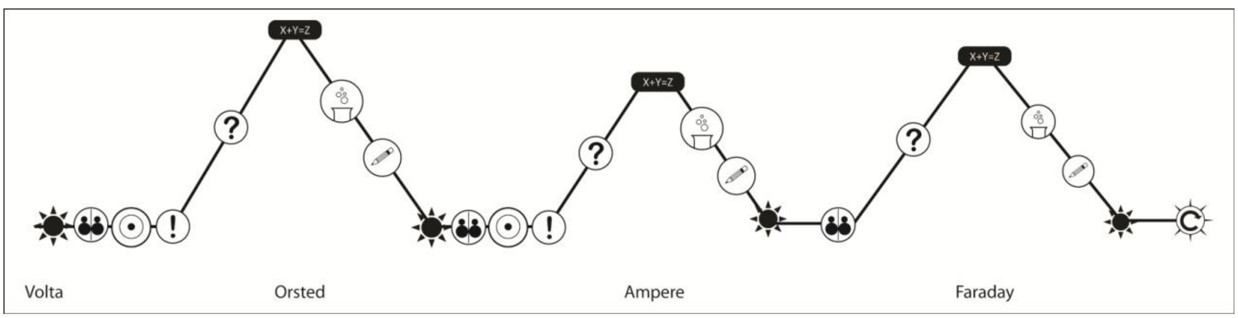


Figure 4.15: Narrative schema of scientific inquiry related to electromagnetism

In the next section, we explain how the model evolved from initial ideas about knowledge acquisition process.

4.5 Evolution of Epistemological Narrative Framework

4.5.1 Version 1 of ENF

The Epistemological Narrative Framework was developed after many iteration. In this section the earlier versions of the model are presented. Pilot experiments were conducted with earlier versions of the model and based upon feedback from experiments, literature was repeated and from new insights from literature on Theory of Knowledge, the model was modified. In this process, the model was tested and evaluated with students and teachers at each stage of development. The results of the explorations were analyzed and compared with the expected results. Since the experiment results did not match expectations, new modifications in the model were introduced and then feedback was taken from students and teachers. This was the continuous process followed to arrive at the final version of the model. The first version of model started from a concept taken from Theory of Knowledge, the concept of making a distinction. Our earlier understanding of what it meant to know something was associated with the knowledge of a distinction. The story building framework was centered on the concept of a Distinction.

Distinction - That which is distinct is that which is separate or apart from those that are around it. Let's have a look at some of the definitions of distinction as defined by oxford dictionary.

- A marked difference or contrast.
- Distinguished as not being the same; not identical; separate.
- Different in nature or quality; dissimilar (sometimes fol. by from): Gold is distinct from iron.
- Clear to the senses or intellect; plain; unmistakable.
- Distinguishing or perceiving clearly.
- Readily distinguishable from all others; discrete.
- Easily perceived by the senses or intellect; clear.
- Clearly defined; unquestionable.

Capturing a distinction is an integral part of any research endeavor. Without the ability or skill of distinguishing, it is impossible to discern the presence of any phenomenon. The world, when undistinguished, will appear homogeneous, made of the same substance. But when mind begins to observe closely, it will observe that the seeming homogeneity is comprised of many distinct entities. The very nature of distinction brings in the element of comparison, because to distinguish something, it has to be compared and separated from something else.

This idea of distinction making has been outlined by Piaget in his constructivist learning theory.

> When we read Piaget carefully, we begin to realize that there is no physical fact that can stand independent of some system of relations that gives it meaning. The color red, surely thought by many to be a raw and uninterrupted sensation, is not understood as red until it is implicitly compared by the observer to colors that are not red. Our eyes may be stimulated by the red band of light, but that wavelength does not become known to us as red until we think (albeit automatically) about it, compare red to not red, or, in more general terms, compare A to not –A. At some other time we can look at the same stimulus A and compare it to something else-for example to a darker object. There are infinite numbers of not-A comparisons that are possible, and it is the observer who makes the choice, not the environment (Forman, Kuschner, 1993).

The first Epistomological Narrative framework was focused on understanding man-made objects by differentiating them from other objects in the same category. For example to understand an incandescent lamp, it needs to be compared with other portable sources of light like Oil lamp or kerosene lamp. The narrative framework was nothing but competition between two makers of the same category of object. One object is distinguished by comparing its limitations with advantages of another. Figure 4.16 shows the representation of distinction between two objects through it evolution. The variable terms in the model used are as follows:

1) Provided entity 1
2) Provided entity 2
3) Provider 1
4) Provider 2
5) Knowledge associated with provided entity 1
6) Knowledge associated with provided entity 2
7) Customer
8) Choice

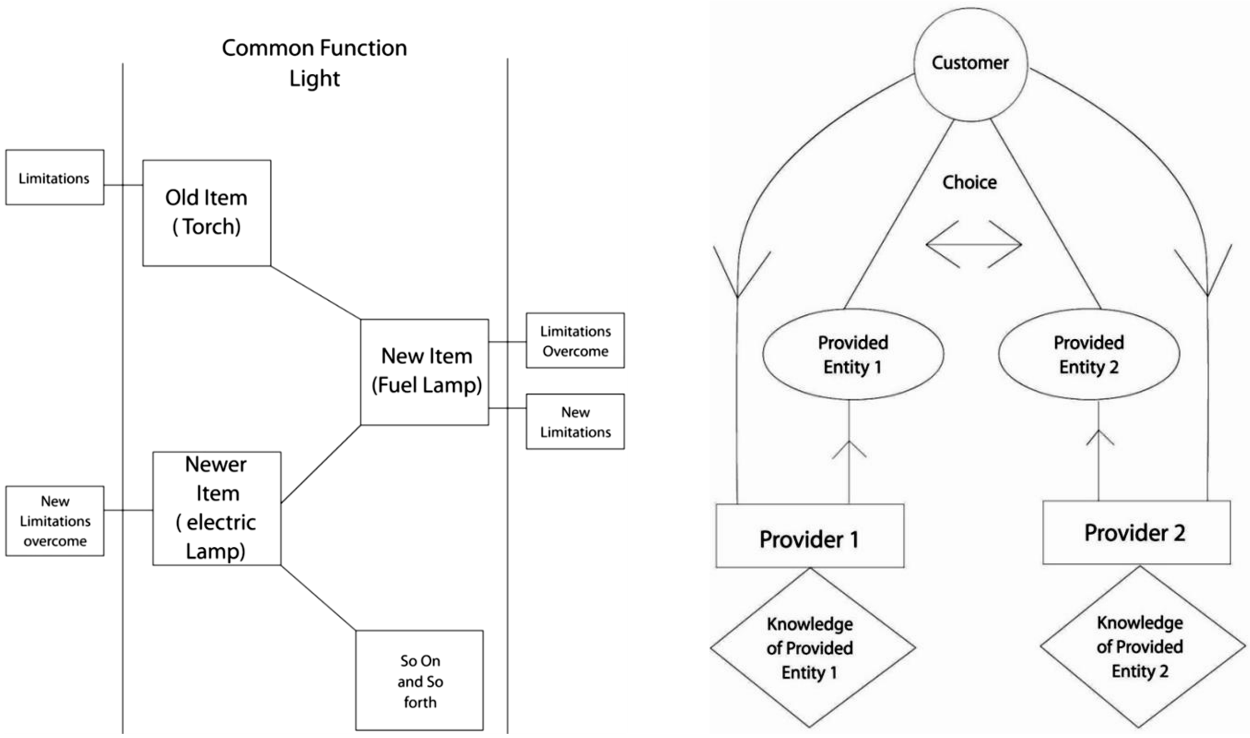


Figure 4.16: Idea of understanding an object evolution of an object by distinguishing it from other objects in the same category.

Provider 1 and 2 are two competitors providing the same object. As the story unfolds, Provider 1 and 2 compete for making a better object. In the process, they acquire knowledge about the object and try to improve it. Whoever is able to satisfy the customer best, wins. The limitation of this model was that it is only applicable for objects that are in competition with each other. It does not cover all the various type of knowledge content. It is only meant to explain comparison related knowledge content. And also this model was too general to be used for any type of teaching requirement. Building a story needed a well-defined plot structure that helped the story developer in step by step building of the story.

4.5.2 Version 2 of ENF

The second approach chosen to overcome the limitations of the first model was inspired by Vladimir prop's analysis of Russian folktale. He provided a way by which stories could be broken down to a few set of simple functions (we can also call it a generic event). The model presented to participants in this case was a sequence of events or functions with characters and objects as variables. The participants had to replace the variables with their own terms. Propp's

31 functions are given in Appendix 2. Inspired from Propps' functions, similar attempt was made to express a scientific inquiry event in the form of functions. There was a basic story plot which was given by functions given in table 4.7

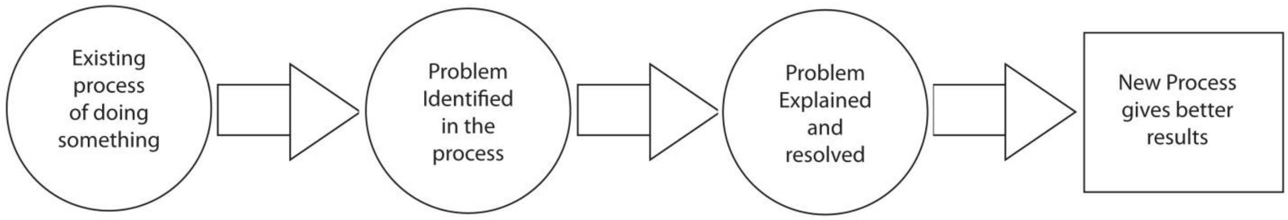


Figure 4.17: Plot structure of version 2 of ENF

Symbol	Definition	Action
I	Hero Intro	The main character is established as the maker of a product item
C	Challenger intro	A challenger is introduced who produces the same product as the hero.
Ci	Modification	Challenger's design is a slight modification of the previous design which makes it more popular.
L	Mediation	The hero tells the loss of face to daughter or friend
D	Hero's departure	Hero departs in search of a better product item
MD	Meeting with Donor. Discovery of New Design	Hero meets the donor who reveals the design of the new product item.
ND	Design Explain	He explains how new design is better than old one.
H	Design Create	Donor tells how new design is created
Tr	Transference	Hero visits the various worlds where raw material is available
P	Promise	Hero makes a promise of giving donor the first item they produce.
R	Return	Hero returns home or to the workshop
De	Demo	A demonstration of the new product is organized
Dw/Df	Demo fail/work	Demo either works or fails. If demo fails, go to D (hero's departure)
Pf	Promise fulfilled	Hero fulfills the promises made to the donor
S	Success/Fulfillment	Crowd loves the new design and hero gains prosperity

Table 4.5: Plot functions in version 1 of ENF

This approach assumed that there is a basic structure associated with a narrative of knowledge creation event and with different categories of knowledge content various narrative plots could be created from it. The four different categories of knowledge content identified were 1) Knowledge of Names and physical attributes, 2) Knowledge of Processes, 3) Knowledge of a Law, 4) Knowledge of Social Effect. These categories were derived from the 6th, 7th and 8th grade

NCERT textbooks. The four different types of models to explain the four different type of content are given in the appendix 4.

4.5.3 Final Version of ENF

During the process of classification, it was realized that classes are actually related to each other rather than being isolated. For example, a process has within itself names of object terms which belong to certain category and their properties are due to some underlying law of nature. Classification in this context seemed to be repeating the relations that actually exist between Process, Category, Law and Comparison. These four classes are continuous and not separate. Hence when teachers were given these models to develop stories from, they had problem building story content. It was then that further literature review was done to get better understanding of what knowledge is. Review of Theory of Knowledge then showed us that there could be a different way of organizing knowledge content rather than classifying it. The new story structure developed emphasized upon the context in which new knowledge gets created and how knowledge in one field leads to development of another field. Based upon philosophical approaches presented by Dewey and Kuhn, the Epistemological Narrative framework was developed. The new framework is based upon building connections with concepts historically related with each other. By connecting the concepts together, we see how various branches of science are related to each other. An attempt has been made to see these interconnections in figure 4.18. This approach is closer to concept mapping approach in which concept are linked with each other even if they fall in different categories. The concept mapping approach is also used in the latest Maharashtra State Board Science Textbooks.

In the next chapter details of control experiment done with secondary school students to test the effectiveness of chapters designed using ENF are given.

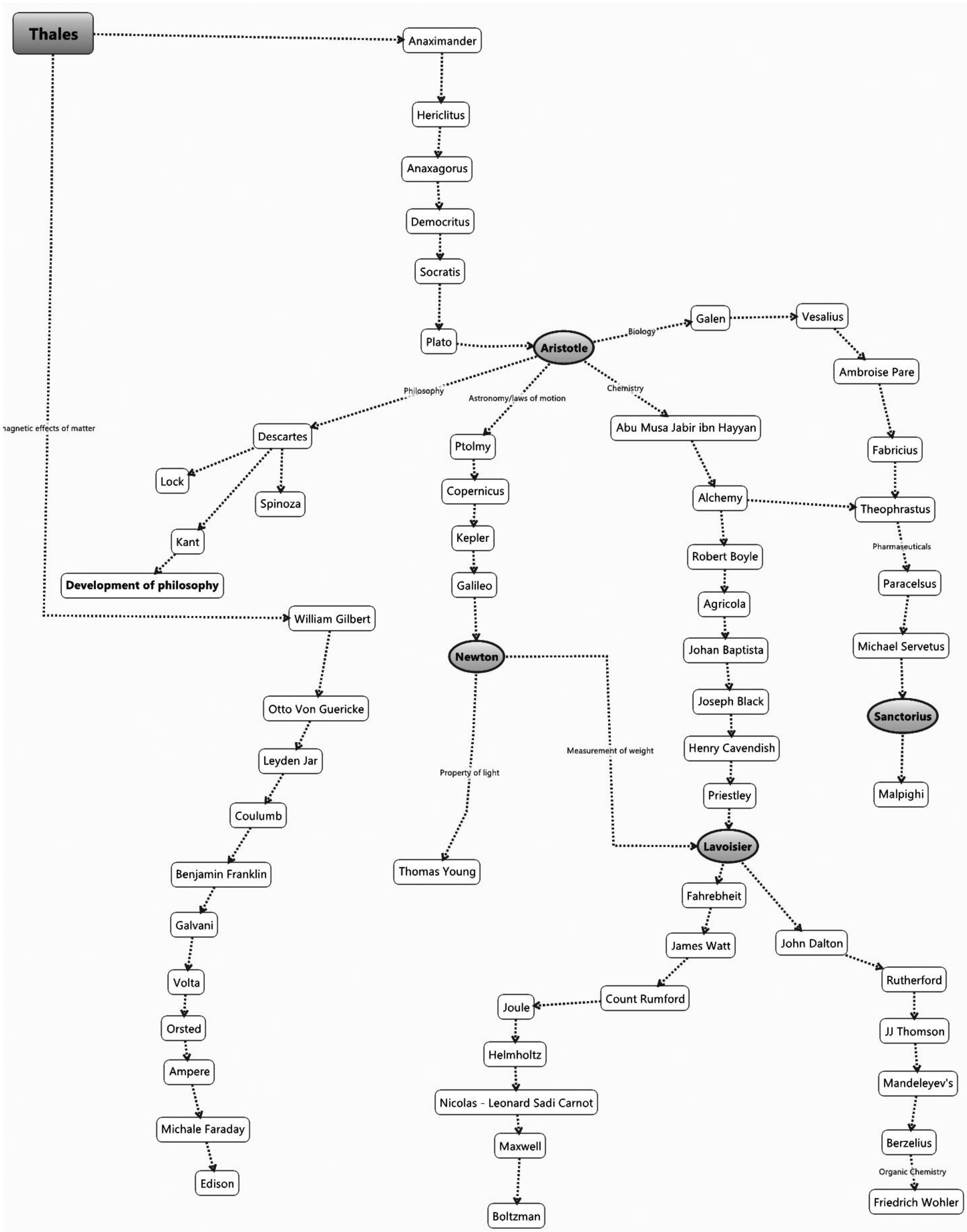


Figure 4.18: History of development of concepts in western science

Chapter 5

Experiments

5.1 Introduction

This chapter has two main sections. First section presents review of existing literature on experiments done for testing effect of story based teaching method on student's learning in the context of science. The second section is devoted to elaboration of similar experiments done by us to test the effectiveness of lessons taught using Epistemological Narrative Framework on certain aspects of science learning.

5.2 Existing literature on experiments conducted for testing story based teaching methods on science learning.

Kokkotas, Rizaki and Malamitsa's conducted experiments in teaching the concept of Electricity and Electromagnetism with sixth grade primary school students to test the impact of a narrative based teaching intervention (Kokkotas, Rizaki, & Malamitsa, 2010). The authors believe that telling a coherent story may be best way of learning, remembering and re-telling of science. They conducted a study in which the objective was to access impact of storytelling on student learning of Electricity and Magnetism. Within this, they wanted to study the impact on three factors a) Importance of evidence and creative thought in the development of scientific theories b) Consider how scientific knowledge and understanding need to be supported by empirical evidence and c) Relate social and historical contexts to scientific ideas by studying how a scientific idea has changed over time. Their experiment result showed significant effect on student's learning on these factors after the narrative based teaching intervention.

In another study Casey, Erkut, Ceder and Young studied the impact of storytelling technique in teaching geometry skills to kindergarten students. Their experiment result showed a significant improvement in the performance of student. They also found that the impact of story intervention was greater on girls compared to boys (Casey, Erkut, Ceder, & Young, 2008). A comparative study was done between the experimental group which was given storytelling context and geometry component intervention and the control group which was only given the geometry component intervention. Their results showed significant improvement in the learning of students of the experimental group.

Cunningham set up an experimental design to test the hypothesis that narrative text structure would be more interesting than expository text structure and would motivate in learning. It was conducted on five secondary school classes with a lesson from history textbook. The results did not show any significant difference in the students' level of performance among the control and experimental group however they showed positive attitude towards the narrative text over the expository text (Cunningham & Gall, 1990).

Pilot exploratory studies:

Before the main experiments, a series of pilot exploratory studies were conducted with students and teachers to get feedback which helped in the modification and iteration of the ENF approach to lesson design. The exploratory studies were conducted with students in collaboration with Homi Bhabha Centre for Science Education (HBCSE) and with teachers in collaboration with Zonal Institute of Education and Training (ZIET). Details of the exploratory study are given in next subsection. The details of pilot exploratory studies is given in Appendix 7.

5.2 Design of Experiments for testing effectiveness of ENF on memory recall

The aim of our study was to test the effect of ENF approach on student's learning of science. A series of experiments were conducted (which included four pilot experiments and two Control Group Experiments) to test the effect of narrative intervention on student performance in the achievement test. The purpose of pilot experiments was to get feedback from students, improve the narrative framework and to narrow down on the goal of the final experiments. The experiments were conducted with both secondary school students and teachers. Details of pilot experiment are given in Appendix 7.

Three experiments were conducted, one with std. V and other two with std. VII students. Std. V students represent lower secondary school segment while std. VII represent higher secondary school. In all the three experiments, the same control group experiment approach was adopted. The experiment was divided into the following subsections: a) Aims and objectives,

b) Participants, C) Measuring instrument, d) Design, e) Material and procedure, f) Result and discussion.

Aims and Objectives: The main aim in all three experiments was to compare the difference in student achievement score on memory recall between two groups, one who were taught using chapters designed with ENF approach and other who were taught with their current textbook. Since the experiment was mainly centered on testing recall of chapter content after lesson delivery, we would like to differentiate between memory recall and rote memorization. In rote memorization, repeated exposure to material to be memorized is given. While memory is a cognitive process, which does not include repeated exposure. The recall in these experiments confirms a cognitive process rather than rote memorization as the students have to answer questions within a few seconds after only one recitation of the lesson. According to Bloom, 'remembering' is at level one of bloom's taxonomy of cognitive domains (Bloom, 1956). Hence, one can say that whatever the students recall after the lesson, it is due to some degree of cognition of content rather than rote memorization.

Participants: Method of cluster sampling was applied to select the participants. Cluster sampling is used when the participants form a group that is naturally together, for example, children in a classroom or professionals in an office or in the same department of an office. One cluster generally comprises a homogenous group. First was from Kendriya Vidyalaya IIT Bombay. The students in this group are children of staff members at IIT Bombay campus. Students in second group were from campus school, IIT Bombay. They are children of staff members at IIT Bombay campus. Students in third experiment were from Powai English Medium School. It was assumed that the student groups in different section of each class had students with equivalent learning capacity. This assumption was necessary to compare the results of control and experimental group. The teachers and school authority confirmed that different sections of each class had students with similar learning ability[20].

Measuring instrument: In all the three experiments, measuring instrument was the achievement test which comprised of a set of questions from the chapter itself. Ebel has prescribed long and short essay type test as a standard measuring instrument for testing learning performance of students (Ebel, 1966). The Subjective essay test questions prepared were from the list of 16 types of questions in textbooks of science outlined by Francis D. Curtis. Type of thought questions chosen out of these were:

1) **Explanation or Definition:** This type of question contains explaining the definition of a term for example: What is a yarn? What is a Fabric?

2) **Outline:** This type of question contains explaining a process for example: Describe the process of making cotton fabric

3) **Criticism:** This type of question asks to explicate the advantages or disadvantages of something. For example the advantages of Cotton fabric over animal skin.

4) **Summary:** This question is about writing the summary of chapter in one’s own words. (Ebel, 1966).

The questions selected were also approved by subject matter expert.

[20] This fact had to be considered because in some schools in India different sections of a class divide students from highest scoring students to least scoring students. For example if a class 5 has three sections 5A, 5B and 5C, then some schools divide the students in classes in such a manner that section A have students whose academic performance is highest and 5 C has those whose performance is least. Such a division was not present in any of the schools in which we performed the experiment. All sections in each class had students with similar academic background. Still, since random sampling was not involved, the possibility of some discrepancy in students learning ability in each section of same class is not ruled out, hence we call it only a quasi – experiment.

Design: A quasi-experimental design was used within which**,** the design type was 'Non-equivalent control group design.' It is a type of pretest-posttest design in which participants are not selected randomly (Research Writing, 1999). The participants are selected in a cluster from a class or workspace etc. Such sampling becomes necessary if the experiment is done in a natural classroom situation (Ary, Jacobs, & Razavieh, 1972). However since the sample is not randomly selected it is called a quasi – experiment design and not true experiment design. The details of control and experimental group composition are given in table 5.1. The control groups were taught using existing NCERT textbook chapter while the Experimental group was taught with chapter designed using the ENF approach. Both control and Experimental group were given a Pretest and Posttest. The Posttest of both groups was compared to find the difference in achievement score.

Pretest-posttest Control Group Design

STEPS	PROCEDURE		AIM
Step 1	Cluster sampling of Control Group	Cluster sampling of Experimental Group	For selection of Participants
Step 2	PRETEST	PRETEST	To measure the degree of the dependent variable before the treatment
Step 3	No treatment	Treatment	To influence the dependent variable
Step 4	POSTTEST	POSTTEST	To measure the degree of change

Table 5.1: Pretest-Posttest Nonequivalent control group design (Research Writing, 1999)

Variables: There is one dependent and one Independent variable in the three experiments. The independent variable was 'Teaching Method' and the dependent variable was 'Achievement Score'. Two different teaching methods were assigned to the Control and Experimental group. Teaching method assigned to control group was a chapter from the NCERT text book. Teaching method assigned to experimental group was the same chapter redesigned using the ENF approach. The posttest score of both the groups were compared after delivery of lesson to find the difference between the two.

Materials and Procedure

Material in all three experiments consisted of pre and posttest questionnaires. Lesson was given as printed handout consisting of 2, A4 size sheets. There was consistency in font type and size in both lessons for control as well as experimental group. Same typeface was used for typesetting text for the handouts that were distributed to both Control and Experimental group (Century schoolbook with 14 pt. size). Students' responses were collected in the question paper itself as there was space provided to write below the questions. The procedure for conducting the test was as follows. First, the volunteers distributed the pretest questionnaire. Students filled up the responses and returned the question sheets. After that, the lesson handouts were distributed to every student. Then, the facilitator (a third person, not involved in development of ENF) delivered the lesson by reading it aloud from the handout. Students were asked to prompt the instructor if they had any doubt. After delivery of the lesson, Posttest questionnaires were distributed to the students and their response was recorded in the questionnaire itself within the space provided. The same procedure was repeated with the experimental group but the lesson handout designed using ENF approach was read out to the students. The achievement score of both control group and experimental group were calculated using the statistical data analysis software called SPSS.

Result and Discussion

Results were calculated after evaluation of the achievement score. Each question in the questionnaire carried a score in the range of 0-5. Each question also had a model response against which the student's response was compared. The total score of each student was added and the mean of all students was calculated. The mean of both control and experimental group were compared for finding the p value of significance using Independent sample t- test. Inferences were drawn based upon the differences in mean of both groups and their value of significance. The value of standard deviation was also taken into consideration for a better understanding of the results.

The details of each experiment are elaborated in the sections that follow.

5.3 Experiment no. 1: KVIIT, IIT Bombay

5.3.1 Aims and objective

A comparative study was done between Control group and Experimental group to test the effectiveness of ENF approach. The parameter chosen for test was effect of teaching method on short term memory. The study was conducted with class V students from Kendriya Vidyalaya School at IIT Bombay Campus. Two sections of the same class were selected. One section was treated as the Control group, the other as the experimental or the Intervention group. The experiment was performed in the natural classroom setup during regular school hours. The experiment was conducted by an Instructor, who was not associated with development of ENF. This was to remove researcher bias while delivering the lesson. The volunteer taught two separate lessons; one using their current textbook lesson and other from lesson designed using ENF, to two separate groups on two consecutive days.

5.3.2 Participants

The participants were 76 lower secondary school students from Kendriya Vidyalaya IIT Bombay. They formed two separate groups of 37 and 39 students. The method of Cluster sampling was used to select the participants for experiment. Cluster sampling involves selection of a group from a population that is naturally together (Ary, Jacobs, & Razavieh, 1972). For our purpose, we chose students from grade V because the lesson to be taught was from standard VI text book. It was expected that grade five students will not have prior knowledge of grade VI lesson. Two different section of same class were chosen that were already grouped by the school. This type of sampling is high on ecological validity as the experiment is done in an actual real life environment.

5.3.3 Instrument

The measuring instrument used was unstructured questionnaires that were given to student prior and post the delivery of lesson. Unstructured questionnaire is one in which respondents are asked to answer the questions in their own words as against a structured questionnaire which directs the response to a limited set of correct options. The questions asked were related to structure and function of items associate with clothing. For example, what is a yarn? How to make a cotton fabric? These are also standard questions asked in the current textbook. The questionnaire was developed in consultation with subject matter experts. The list of questions used in the questionnaire are given in Annexure 2

The pre-test consisted of three simple questions. What is Yarn? What is a fabric? And describe the process of making a cotton fabric. The post-test consisted of five subjective type questions.

The Subjective essay test questions prepared were from the list of 16 types of questions in textbooks of science outlined by Francis D. Curtis as given on page 138. The screening test and Posttest had the same questions except the question on writing the summary of lesson which was given only in the posttest. The scores of achievement test are discussed in the subsection on results.

Achievement score is the response of students to a set of questions that they were to answer post the delivery of lesson.

5.3.4 Design

A single variable design was adopted for this experiment where effect of one independent variable was tested on the dependent variable. Following is the description of the variables.

Teaching Method (Textbook Based TB or Story Based) = Independent Variable

Achievement Score = Dependent Variable

Operational definition of each variable is as follows:

Teaching method is the way a lesson is delivered to a group of students. Textbook based (TB) teaching method means that a chapter from current NCERT textbook is taken as it is and is read out to the students. The Textbook based independent variable constitutes the control group. Story based (SB) teaching method means that the lesson was delivered in the form of a narrative. The story design of chapter was based upon ENF approach which is explained in the previous chapter.

Irrespective of the teaching methodology (TB or SB), a screening test was done to make sure that the students have not studied the chapter before, although the possibility of participants having prior knowledge of the subject was not ruled out.. In case the student scored in the screening test, their post test score was not considered for final evaluation.

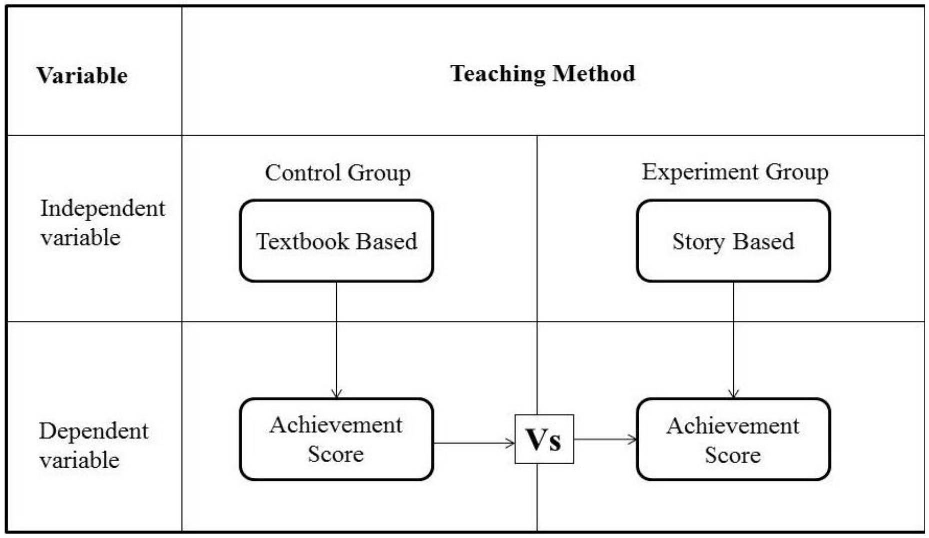


Figure 5.1: Pretest-Posttest Nonequivalent control group design.

The significance of difference in the mean score of both achievement tests groups was calculated using independent sample t-test, which is the index used to find the same (Ary, Jacobs, & Razavieh, 1972). The test is called independent because there is no relationship between the control and experimental groups.

5.3.5 Material and Procedure

Each group was delivered a lesson from a class VI N.C.E.R.T. textbook. Control group was taught from existing lesson on how fabric is made, while Experiment group was given the same chapter but it was redesigned using the story design approach. The layout and font size of both the chapters were kept the same. The lesson was taught to each group from their respective booklets. The same instructor read out the chapter to the groups on two consecutive days. The chapter chosen was fiber to fabric. It describes the process of making fabrics from different type of material like cotton, jute etc. The group which was chosen for experimentation had no prior exposure to the contents of the chapter. This was ensured through the screening test. The achievement test was evaluated by giving scores to students on each correct answer.

5.3.6 Result

The scores of each group were totaled and their average calculated. The Experimental group scored on an average 8.97 (44.8%) out of a total score of 20, while the control group (N.C.E.R.T.) scored 4.17(20.85%). Pre-test total average of Control group was 0.28 out of total score of 15, while that of experiment group was nil, which makes the final average score of control group to be 8.69 (43.4%). Significance of the difference in score of Control and experiment group was calculated by performing two tailed (t-test) independent sample test on the mean of each group. There was a significant difference between the two lesson delivery of NCERT and Story groups in their Posttest performance (p<.0005, two-tailed). The result of the analysis is given in table 1. The significant difference in the means of Posttest scores show that the probability of the difference happening purely through chance is less than 5 in 100000 cases, which is a highly significant difference.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	37	4.175	3.702	.000
STORY (Experimental Group)	39	8.974	5.312	

Table 5.2 The mean difference is highly significant at p<.0005for KVIIT, IIT Bombay

Since there is significant difference between the means of Posttest results of both groups, we may infer that there is a probability that ENF framework has positive effect on student achievement in subjective test.

5.3.7 Essay type test

Subjective test is distinguished from objective test in terms of flexibility in expression of the student response to a question. While in objective test, the answer to a question is fixed and the student has to choose from a set of given choices while is subjective type, the student has to express the answer in his/her own words (Ebel, 1966). Summary test was taken to test how much of the contents of chapter are students able to recall immediately after the teaching session.

5.3.7.1 Procedure

An essay type test was given to the students Post the delivery of lesson. Students were asked to write the summary of chapter they read. Their responses were evaluated based upon comparison with a model summary of chapter which contained a fixed number of sentences that explained the chapter. The student's response was analyzed sentence wise and matched with the sentence on the model summary. The list of sentences in model summary is given in Appendix 5.

5.3.7.2 Results

Results of the data analysis show a highly significant difference in the number of sentences recalled by Control group against the experimental group. The average number of sentences recalled by Control group was 1 out of a total of 12 sentences which is 16.6 % of the total while number of sentences recalled by the Experimental group was 6.2 out of a total of 17 sentences which is 41 % of the total number of sentences.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	37	0.9189	1.163	.000
STORY (Experimental Group)	37	6.243	4.023	

Table 5.3: The mean difference is highly significant at $p<.0005$ for essay type test

The independent sample t-test show the difference in mean score of two groups to be significant at $p<.0005$, with confidence level of 99.99%.

5.3.7.3 Discussion

Subjective type achievement test show significant difference in student Posttest performance with the Experimental group scoring significantly better than Control group on achievement test. The results of this experiment prompted us to raise further questions. Will we get the same results if another set of students from different demographical background are tried and can we develop another chapter using the ENF and find similar results. If yes, then it may be possible to generalize the results to some extant for larger population. To find answers to these questions, further experiments were conducted with another set of grade 7 students of Campus school with different chapter content, that of electricity.

Interpretation of Result

The mean of Story group is significantly higher than the NCERT or control group. However since the std. deviation is also high, the curve seems to slide towards the higher side of mean. This means that a higher mean may be caused by few students scoring exceptionally well. The reason of this could be that students with good writing ability may be in a better position to write the answers while those with poor writing abilities may be at a disadvantage in answering the questions. Even in the story group, students with poor writing abilities may have scored low. To overcome these disadvantages of experiment, few more experiments were conducted with different student groups and different content to cross evaluate if the results were similar or different. If they are same then some generalization could be made.

Another experiment was conducted with grade VII students of campus school in IIT Powai. We will discuss the details of the experiment in the next subsection.

5.4 Experiment no. 2: Campus School, IIT Bombay

A study was conducted on class VII students from Campus School inside IIT Bombay premises. Two sections of the same class very selected. One section was treated as the Control group, the other as the Intervention or experiment group. Control group (N.C.E.R.T) contained 10 students while Experiment group (Story) contained 22 students. The experiment was performed in the natural classroom setup during the regular school hours. The experiment was conducted by a third person, the researcher acted as observer. The difference in content is that it deals with a more complex set of problems. The previous chapter on clothing does not involve any deductive reasoning by the protagonist, the central problem in story is solved by trial and error method, while in the second story of electricity, and protagonists are involved in a dialogue involving a deductive form of argument. This was done to test the expanse on which the ENF can operate, from simple to complex concepts.

5.4.1 Design

The same design was used as the first experiment. The science content to be taught was chapter on electricity taken from class VII N.C.E.R.T. book.

5.4.2 Material and Procedure

The same procedure as previous experiment was repeated the only difference was in the material provided. The students were given lesson on Electricity from class VIII NCERT textbook. Two separate booklets were created, one was chapter from NCERT book as it is, and other booklet was designed using the Narrative framework. The instructor read out the lesson from both booklets to two separated groups on two consecutive days.

Achievement test

An achievement test in the form of a set of long and short essay type questions was given to both the groups before and after the lesson delivery. The achievement test was meant to measure the difference in mean performance of Control vs. Experiment group. To find if the difference was significant, an Independent sample t-test was conducted with the help of SPSS software. List of questions and model answers are given in Appendix 5.

5.4.3 Result

The scores of each group were totaled and their average calculated. The mean score for Experimental group was 7.7 out of a total score of 20, while the control group (N.C.E.R.T.) scored 5.6. Significance of the difference in score of Control and experiment group was calculated by performing two tailed (t-test) independent sample test on the mean of each group. Independent sample test was chosen because the two groups did not have any relation with each other. The significance was calculated for the campus school students, the value was 0.27 which means that the probability of the hypotheses being true is 27 in 100. Since $p>.05$ the difference between mean of the control group and experiment group is not significant. But the number of participants in this group is not sufficient for coming to any conclusion. Another study is proposed to be conducted to get the number of students large enough for getting a statistical conclusion.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	10	5.650	3.858	0.27
STORY (Experimental Group)	11	7.721	3.908	

Table 5.4: The mean difference is not significant at $p>.05$ for campus school

5.4.4 Essay type test

5.4.4.1 Procedure

A subjective essay test was given to students after delivery of the lesson. The students were required to write the summary of chapter in their own words. There was a significant difference in students' recall of summary of chapter. The response was analyzed by comparing each summary to a model summary developed by the researcher. There were a total of 13 sentences in each summary. The number of correct sentences formed by students was noted. The total average number of correct sentences was calculated for both Control Group and Experiment group. Correct sentence do not mean grammatically same but one which implies the same thing as mentioned in one of the 13 sentences given in the model summary. They may be grammatically incorrect, but if they match in meaning with the 13 model sentences, then they are accepted as correct.

5.4.4.2 Result

The average number of correct sentences by control group was 1.27 out of a total of 13 correct sentences which is 9.7% of the total. For the experiment group, total correct sentences were 6.09 out of 13 which is 44.8 % of the total. The significance of difference was calculated using independent sample t-test. The difference in mean of achievement score between control group and experimental group is significance at $p<.0005$ with confidence level of .001.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	11	1.272	2.370	.000
STORY (Experimental Group)	11	6.090	2.300	

Table 5.5: Significant difference in means of Control (NCERT) and experimental (Story) groups at p<.0005 of campus school essay type test.

5.4.4.3 Discussion

In both the experiments we see a significant difference in the mean of achievement score in both subjective essay type and subjective type questions. The difference was not significant in subjective type achievement test with class 7 students, but the number of students in experiment was too less to consider this result.

5.5 Experiment No. 3: Powai English Medium School

5.5.1 Aims and objectives

Objective of experiment was to find the difference in short –term memory recall of students who were taught with chapter designed using the ENF approach against those taught with current NCERT textbook approach. The experiment was conducted with a larger number of samples. A study was conducted on class VII students from Powai English Medium School at Powai, Mumbai. Two sections of the same class very selected. One section was treated as the Control group, the other as the Intervention or experiment group. The control group had 52 students and Experiment group had 50. The experiment was performed in the natural classroom setup during the regular school hours. The experiment was conducted by a third person, the researcher collected data in the form of response to achievement test.

5.5.2 Design

The study was a between group design comparing two types of lesson delivery approach namely Current NCERT Textbook VS Chapter designed using Epistemological Narrative

Framework. The science content to be taught was chapter on electricity taken from class VII N.C.E.R.T. book.

5.5.3 Material and Procedure

The same procedure as experiment 3 was replicated. The difference was in the material provided. The std. VII chapter on electricity was the story of how the Voltaic cell came into being. This story is more challenging than the previous story of how clothing came into being in terms of complexity of arguments. In the cloth story the solution is arrived at by simple trial and error method, however in the story on Voltaic cell the solution is arrived at by argumentation using deductive logic.

5.5.4 Achievement test

An achievement test in the form of a set of long and short essay type questions was given to both the groups before and after the lesson delivery. The achievement test was meant to measure the difference in mean performance of Control vs. Experiment group. To find if the difference was significant, an Independent sample t-test was conducted with the help of SPSS software. The questions developed in achievement test were in collaboration with subject matter expert from Homi Bhabha centre for science education Dr. Sugra Chunawala. The long essay type question simply asked the students to write the summary of chapter on Electricity in their own words in the case of Control group while the Experiment group was asked to write the story of Volta and the Voltaic cell in their own words. The short essay type question were a total three in number the first question asked the structure of Voltaic cell and the question was What is a Voltaic cell made of? The second question was to find what they understood about the function of Voltaic cell and the question asked was, What is the use of a Voltaic cell. The third question was to cross check with the second question whether the response was result of understanding. So it was the reversed form of second question which asked how electricity could be generated. Same questions were given before and after the test to know the difference in response. The pre-test was meant to check their prior knowledge of subject which was supposed to be none as the chapter on electricity is taught to class 8^{th} student and the test was given to class 7^{th}. So the pre- test confirmed that they had almost no prior knowledge of the subject matter. So we can assume that the difference was to be there in post-test that would be because of the lesson delivery alone.

5.5.5 Results

The independent sample t-test was performed three times to know about three different aspects of the experiment outcomes. These three type are:

1) Score difference in mean of all Short essay type questions taken together.
2) Score difference in individual short essay type questions
3) Score difference in Long essay type question

1) The mean score for Short summary type for NCERT was 3.2 while for Experimental (Story group) was 6.3 and the difference is highly significant at $p<0.001$ with confidence level of 95%. The data is shown in table 2.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	52	3.201	2.751	.000
STORY (Experimental Group)	50	6.300	3.157	

Table 5.6: Mean difference is significant at $p< .0005$ for short essay type test with Powai school

2) The mean score for Short summary type question 1for NCERT was 1.6 while for Experimental (Story group) was 2.13 and the difference is not significant at $p>0.05$ with confidence level of 95%. The data is shown in table 3.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	52	1.634	1.462	.089
STORY (Experimental Group)	50	2.130	1.452	

Table 5.7: Mean difference is not significant at p >.05 for short essay type test question 1 with Powai school

3) The mean score for Short summary type question 2for NCERT was 0.89 while for Experimental (Story group) was 2.35 and the difference is highly significant at p<0.001 with confidence level of 95%. The data is shown in table 4.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	52	0.894	1.318	.000
STORY (Experimental Group)	50	2.350	1.422	

Table 5.8: Mean difference is significant at p <.0005 for short essay type test question 2 with Powai school

4) The mean score for Short summary type question 3for NCERT was 0.67 while for Experimental (Story group) was 1.82 and the difference is highly significant at p<0.001 with confidence level of 95%. Data is shown in table 5

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	52	0.673	1.168	.000
STORY (Experimental Group)	50	1.820	1.680	

Table 5.9: Mean difference is significant at p<.0005 for short essay type test question 3 with Powai school

5) The mean score for Long summary type for NCERT was 0.54 while for Experimental (Story group) was 3.88 and the difference is highly significant at p<0.001 with confidence level of 95%. The data is shown in table 1.

Group	N	Mean	Std. Deviation	t-test Sig. (two tailed)
NCERT (Control Group)	52	0.538	0.821	.000
STORY (Experimental Group)	50	3.880	2.791	

Table 5.10: Mean difference is highly significant at p<.000. Long Essay type test for Powai English medium school

Scores of individual participants are given in Appendix 6.

5.5.6 Interpretation and discussion

Since the achievement score on recall is significantly higher in the Experimental group, it can be concluded that the effect on student's recall because of story intervention is significantly higher than the control group. This implies that students were better able to remember the concepts in STORY group as against the NCERT group. This is not only true for Short answer essay type, but also for long answer essay type question. Within short essay type question, the question about the structure of voltaic cell has received almost equal response from both the groups that is because there is no significant difference in this case between the groups. The score of short answer type questions is significantly higher for STORY group because of highly significant mean difference of question two and three.

The mean of Story group is significantly higher than the NCERT or control group. However since the std. deviation is also high, the curve seems to slide towards the higher side of mean. This means that a higher mean may be caused by few students scoring exceptionally well. The reason of this could be that students with good writing ability may be in a better position to write the answers while those with poor writing abilities may be at a disadvantage in answering the questions. Even in the story group, students with poor writing abilities may have scored low. An additional oral test might give a better picture of overall student performance.

5.6 Summary of Experiments

Experimental results show a significant improvement in the achievement score of students who were taught using Narratives based textbook chapter design compared to those taught with chapter in their existing science Textbook. The results are significant for both participant groups i.e. 5^{th} and 7^{th} grade students. However these experiments are not sufficient indicators of the effect of Narrative based teaching on all aspects of science learning. Separate experiments need to be designed for testing ENF approach for different aspects of learning like development of reasoning skills etc.

Exploratory experiments show that student fared relatively better than teachers in designing stories using the previous models. However, the results of pilot experiments were useful in evolution of the Epistemological narrative Framework.

We can conclude from these premises that stories designed using ENF approach has a high probability of increasing the short term memory recall of students. In the conclusion section we will see how ENF can be used to arrange secondary school science content in a sequential order in which all the various concepts are linked with each other forming a continuous chain of event from prehistoric time to the industrial era.

Chapter 6

Conclusion

6.1 Summary of Research

From literature on theory of knowledge we learnt that major advancement of scientific knowledge in western tradition is the result of an ongoing process of transition from one paradigm to another (smaller advancements happen within the paradigm). We also studied that knowledge is constructed through two types of arguments, Deductive or Inductive. The key idea in scientific progress and development of argument is the linking of one thought to another. Such a successive transition can be traced through the study of history of science. The development is recorded from the Greek period to its culmination in the works of Aristotle and from then onwards branching into different domains with philosophers working in specific domains for example Galileo to Newton in astronomy and mechanics, Arabic philosophers in Chemistry, Galen in life sciences and St. Augustine to Descartes in Philosophy. Further, there is a chained link of development from Medieval to the Industrial revolution. Each advancement in knowledge is a successive step building on the former. These successive developments have some common elements. At any point there exists a certain belief about some aspect of the working of nature, then, someone observes an incidence that contradicts the belief. The scientist pursues and performs series of experiments till he arrives at an alternate model of belief. He/she faces opposition by the established community, but if he succeeds through demonstration, in showing that the new explanation is more inclusive and resolves the contradiction, then it results in the transition to establishment of a new belief which gradually solidifies to become new knowledge.

Similar is the process observed from the Theory of Learning. At a given point a person has a schema about some aspect of the world. An incidence happens that violates the schema; this disturbance is resolved by a process of 'accommodation' by the learner. This is constructivist theory of Learning by Piaget. Learning according to Vygotsky's social constructivism is the function of the social environment the learner is surrounded with. It is the culture to which the person belongs, that is responsible for a particular kind of learning the student is able to acquire. This is reminiscent with Kuhn's view of development of scientific culture through the works of scientists who work cohesively as a community.

Both the processes of Learning and Theory of Knowledge resemble well with the structure of a Narrative with a specific type of Beginning, Middle and End. Beginning is the existing schema or paradigm, middle is again of three parts, the anomaly situation, the struggle to find solution through experimentation, the opposition from existing paradigm and final transition to the new paradigm after successful demonstrations. The synthesis of the three domains of Theory of Knowledge, Theory of Learning and Theory of Narratives lead to the development of Epistemological Narrative Framework. ENF can be useful in providing a frame through which historical narratives can be constructed. The elements provided in ENF help in searching the right clues from history of development of a scientific thought. This further result in the design of stories with knowledge content regarding development of a particular scientific idea embedded in it. The sample stories developed using the ENF was tested with control group experiments with secondary school children. The results showed significant improvement in the achievement scores of Experimental group who were taught with chapter designed using ENF approach against those who were taught from the current central board science textbook.

6.2 Inferences

The first inference drawn from this research work is to connecting the learner to the history of development of a particular domain or field. For example instead of finding ways of teaching electricity to a student, one needs to connect the student to the tradition or the legacy of thoughts that lead to the creation of the concept of electricity as we know it today. And the legacy or tradition of that thought includes the thoughts proposed by Thales, Benjamin Franklin, Coulomb, Galvani, Volta, and Faraday and others. Connecting the student to this legacy also means knowing the arguments proposed by the scientist on discovery of a phenomenon.

Regarding the second inference, experimental results confirm that when students are exposed to a subject in which concepts are connected with each other in a narrative way, such that one concept leads to the other, then the recall value of such content is significantly higher.

ENF framework provides set of guidelines for building a link between developments of concepts as they happened in development of scientific thought in western history and learning of scientific concepts.

6.3 Solution to research questions raised in the beginning

The answers to questions raised in the introduction chapter were satisfactorily found during the course of the study in the following way:

- The first question which inquired about the nature of relationship between Narrative structure and knowledge creation process was resolved by finding similarities on aspects of Theory of Knowledge, Theory of Learning and Theory of Narrative.

- The same resolution also proved the answer to question which stated that the nature of relation between Narrative and knowledge creation in science was independent of any specific domain of science and could be generalized to all domains of natural science. Result of this search was formulation of Epistemological Narrative Framework or ENF.

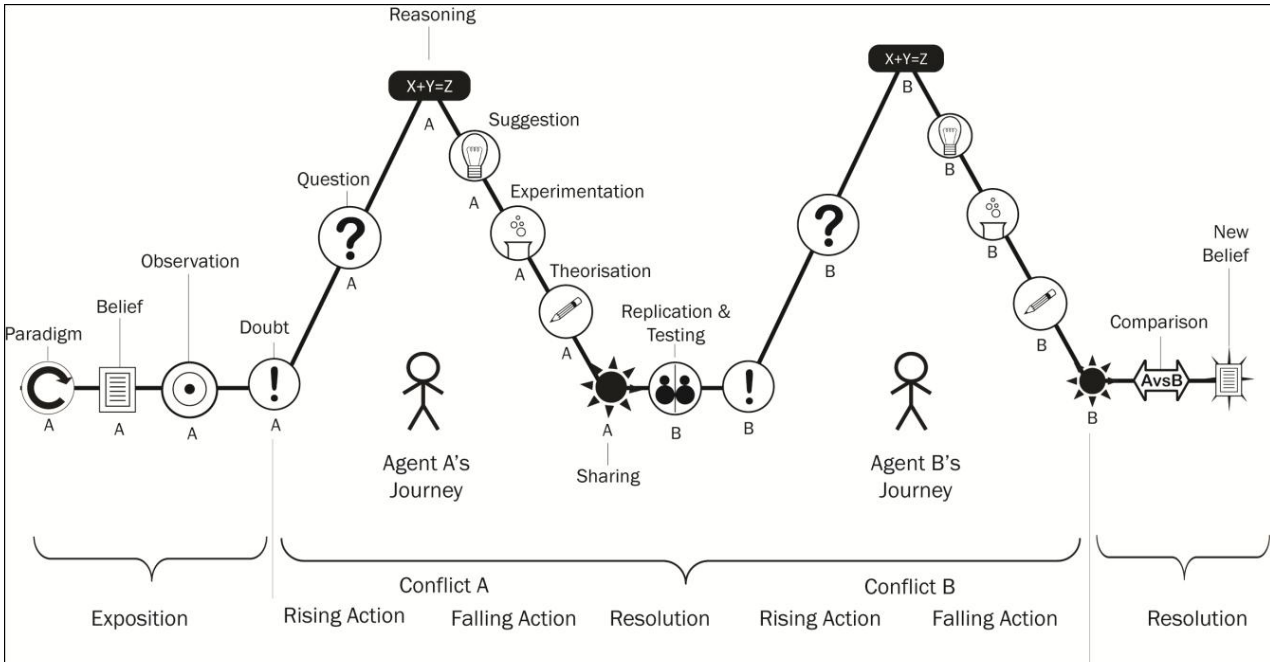


Figure 6.1: Epistemological Narrative Framework as answer to second question

- The third question about how stories can be designed using ENF was validated by construction of sample Narratives for explaining concept in secondary school science textbooks.

- The fourth question was answered by performing empirical experiments which showed significant difference in the short-term memory recall of students who were taught lesson using chapter designed with ENF versus those who were taught with their current textbook approach.

Even though the questions were resolved to some degree of satisfaction, many more questions emerged in the process to which further attention needs to be directed. For example:

- In the Narrative approach, students are not actively involved in building of knowledge. How can the narrative approach be extended to incorporate students' participation in the learning process.

This question can be tentatively answered by proposing that students and teachers can collaboratively build narratives for specific subject matter using the Epistemological Narrative Framework and applying it on information gathered about subject from historical sources.

- It has been emphasized that learning of science is a hands on, practical activity, in the ENF approach, where is the scope for students' learning the subject matter through experimentation.

This question too can be tentatively answered by proposing that the introduction to a subject matter can be given by showing some part of the experiment as it was done by a scientist in history, for example, Galvani's frog's leg twitching experiment. Then the students can be asked to infer from their observation. Only then the story told will have greater relevance for the students because they will be relating it to something real that they too have experienced. The story can also provide a connecting link between series of experiments that can lead to final inference. The next experiment after Frog's leg twitching can be testing leg twitching using different metals and checking in which condition leg twitches. The third experiment can involve removing of frog and using the plate and knife as electrodes to test presence of electric current. The story provides a sequence from simple to complex setups.

Since the scope of this research was limited to finding answers to first 4 main questions outlined in the introduction, it is possible to project some implications and future possibilities that emerge from these answers. One of them could be students' designing or recreating historical experiments. The scope is discussed in detail in the next section.

6.4 Implications for Science Textbook lesson Design

What follows from this research is an alternate approach for organization of lessons in a science textbook itself. What we learnt is the textbook lessons are organized in alignment with the actual development of ideas the way they happened in history, then other things fall into the right place. It provides a chronological chain of connecting one thought with another. This chronology is not a timeline of sequence of events, but a branching of ideas from a common Greek source into various directions. If we can trace the development of idea from Greek period onwards, we can arrange the curriculum content in the same order. What is being transferred is the learning of the culture of science from Greeks onward to the modern age to the student.

In the next subsection we see how the Narrative framework can affect the logical arrangement of chapters in the secondary school science curriculum.

6.4.1 ENF approach to arrangement of lessons in secondary school science textbook

With the given theoretical knowledge base, we examine how design of science textbook chapters can be affected. But first, a better understanding of the constituents of current science textbook is required. A textbook contains a series of chapters covering various aspects of the world of science. At secondary school level it is general science as there is not yet any division into various branches like physics, chemistry and biology which happens at high school level. Each chapter deals with one focused area of study and it contains many concepts under the umbrella of that focused area.

6.4.2 Content of Std. VI General Science Textbook

Following is the list of chapters in class science textbook in exact order:

- Food: Where does it come from?
- Components of Food
- Fiber to Fabric
- Sorting Materials into Groups
- Separation of Substances
- Changes around us
- Getting to know Plants
- Body movements
- Living organisms and their surroundings
- Motion and measurement of distances
- Light, shadows and reflections
- Electricity and circuits
- Fun with Magnets

- Water
- Air around us
- Garbage in, garbage out

The current arrangement of chapters is based upon some form of categorization. For example the first two chapters are associated with Food. Similarly chapter on Electricity and Magnets can be said to be related. However, we can clearly see such a connection does not exist among all the chapters. Many consecutives chapters do not have connection with each other for example components of food to fiber to fabric. The ENF approach solves this problem of continuity by providing a logical base for arrangement of chapters. The current chapters also fit into the ENF approach. According to the ENF approach, chapters move from one form of human habitation to another, for example from being a 'hunter gatherer' to being a 'food producer.' The central binding factor of all chapters is the development of human society seen from the perspective of evolution of science and technology. The chapters are stories set in a particular time and place. The time and place set the initial conditions of the protagonist. For example story set in prehistoric era show characters forming a nomadic group as hunters and then how discovery of growing plants by nourishing seeds lead them to have a more settled life by producing their own food. A detailed description of how chapters can be arranged according to the ENF approach is given as follows:

The overall curriculum from class 4^{th} to 8^{th} of lower and higher secondary school can be divided into two broad categories namely 'Techniques of making' and 'Science and its application'. The logic for this division is that they represent two distinct eras in development of science and technology in Western world i.e. Pre Renaissance which is before Renaissance period and Post Renaissance which is Renaissance to Industrial period. The content under 'Techniques of making' is ordered for classes 4^{th} to 5^{th} while content under 'Science and its applications' is ordered for classes $6^{th,}$ 7^{th} and 8^{th}. Content which involves concept after the Industrial revolution can be arranged from 9^{th} class and onwards which may also include some advanced discoveries in later part of Industrial revolution as well. This schema is explained diagrammatically in figures 6.2, 6.3, 6.4 and 6.5. The domains selected are open to argument and do not represent a rigid selection. Subjects can be added or omitted upon further discussions.

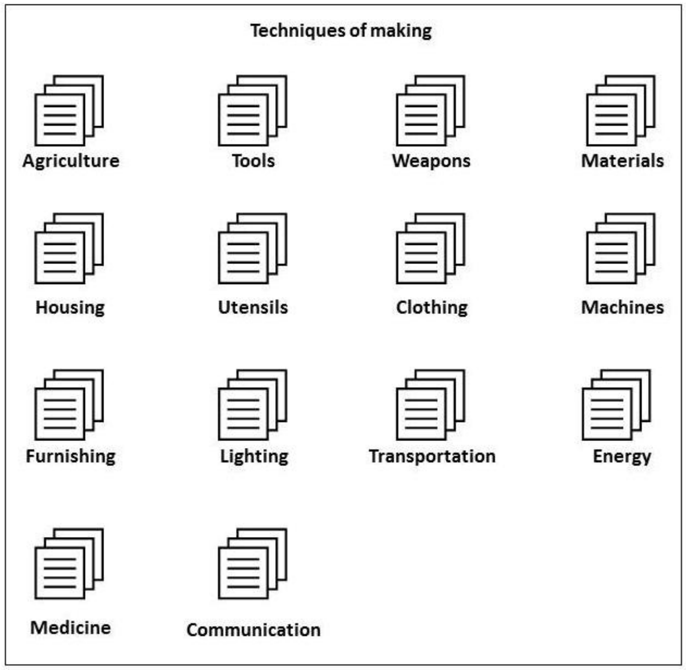


Figure 6.2: The main subjects dealt with in pre-classical period.

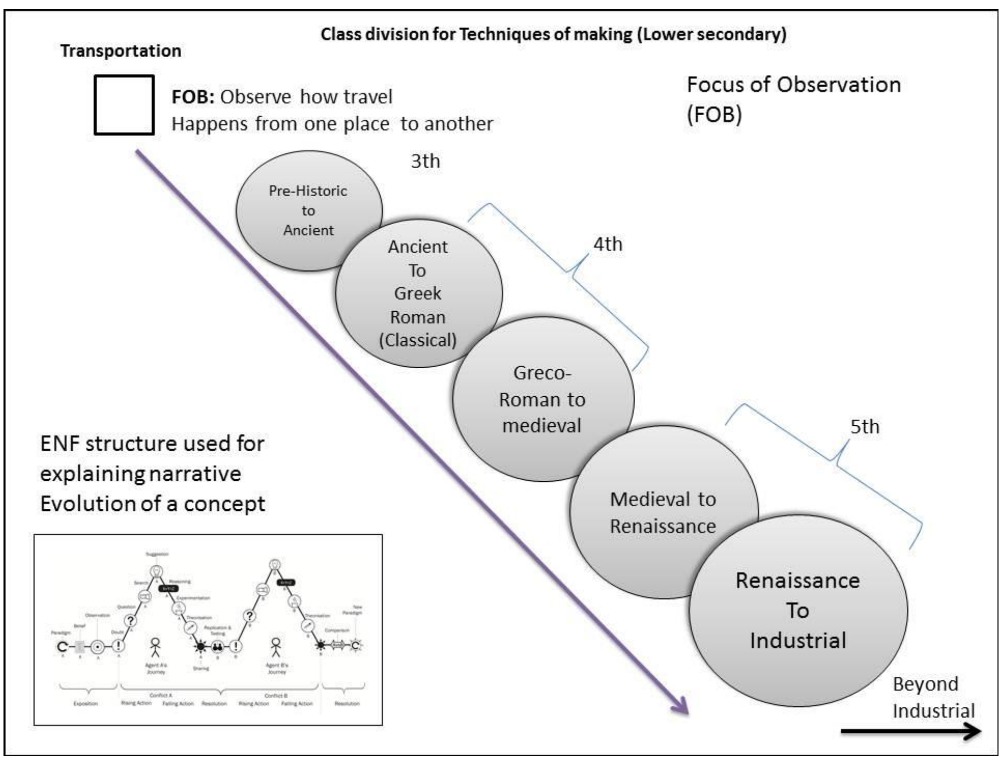


Figure 6.3: The subject content under techniques of making can be distributed between 4th and 5th class. The narratives of this content can be developed using the ENF.

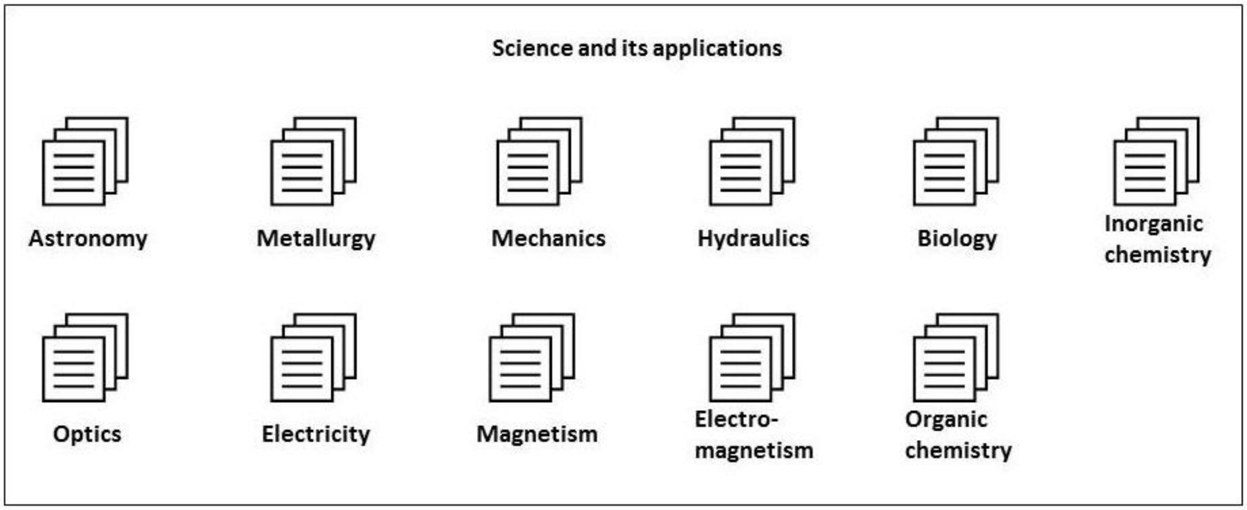


Figure 6.4: The main subjects dealt with under title Science and its applications

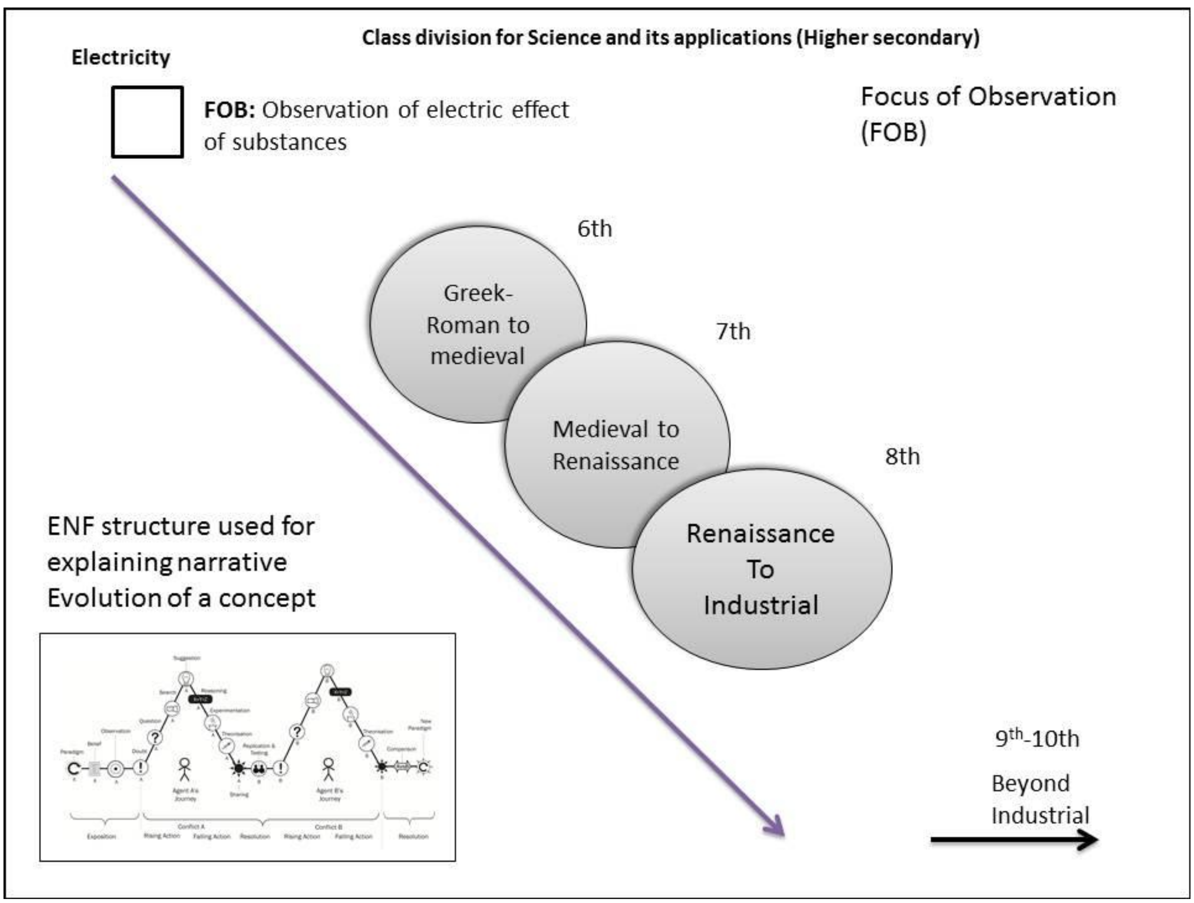


Figure 6.5: The subject content under 'Science and its application' can be distributed between 6th to 8th classes. The narratives of this content can be developed using the ENF.

Each field has associated with it the concept of 'Focus of Observation' also called FOB. It is the entity that is observed in a given domain. The entities observed in a given domain are limited. For example in astronomy the observed objects are heavenly bodies and their relationship, the instruments of observations are variety of telescopes. Similarly in Agriculture, the Focus of Observation is on plants and how their growth happens under what conditions. Defining the FOB of a domain helps in finding what observation on those things have been made by people in history and how their inference of these things have changed over time showing knowledge to be an ever evolving process. This brings us to see implications of ENF into many diverse areas.

6.4.3 Implications for visual design of science textbook

The narrative approach by its very organization allows for more possibilities in visual representation of knowledge content. Since Narrative can be accompanied by illustrations that give ide of the event happening. Images can represent the era in which the discovery is set for example metallurgy related discovery is set in Egyptian civilization, so the characters and environment setting can depict that era which will consist of the type of costumes, physical appearance of people and the architectural setting like pyramids etc. The narrative can also use a sequence of imagery rather than only on illustration. The illustrations can draw specific attention to the kind of experiments done by a scientist. In this way, the students' imagination can be transmitted to different worlds separated by long intervals of time. The chapters no longer remain frozen outcomes of discoveries made by gifted scientist, but it is journey of change in which many mistakes were committed and lessons learned which lead to the betterment of a particular world or society.

6.4.4 Implication for classroom Activity and experiment design

It may be possible to outline a framework for the kind of activities and experiments that students may perform along with the chapter. For example the chapter on electricity, the students can replicate the frog experiment conducted by Galvani and Volta. The experiment that overthrew the phlogiston theory can be replicated as well, experiments of Benjamin franklin with electricity. Experiments of Galileo and Newton for devising laws of motion can also be replicated. By replicating the experiments, students' curiosity can be drawn towards a variety of phenomenon. This may lead to new observations and questioning by students. They can compare their reasoning process with those of the scientist. A repository of main experiments along with the chapter can be made available to students to explore various phenomenon in nature.

6.4.5 Implication for student-teacher discourse and relationship

The aspect of discourse and communication among student and teacher may be affected with this approach. There is one aspect in all the discovery related stories, that mistakes and errors are its stepping stone. They are to be welcomed, not ignored or loathed. The history of science is full of incidences of errors in perception of scientist regarding some phenomenon. It is by being open to and accepting the error does the scientific community tries to look beyond an existing belief and are ready to replace it, however dear it may be. So when as student asks a seemingly stupid question or may answer in a non-typical way, the teacher may see it more towards a necessary step in learning than try to correct him by forceful conditioning.

6.4.6 Implication for Teacher Training: Bringing shift from content based learning to process based learning

Learning methods can be distinguished into “learning of content” and “learning of process”. Learning of content means acquiring knowledge about particular concepts as chosen by the educational authority. Under this, concepts are categorized into various domains like Physics, Chemistry, Biology and mathematics etc. The volumes of concepts are required to be remembered or standard problems in a domain are solved to develop skills in that domain. The concepts to be learnt are pre-fixed by a central educational governing body. This contrasts well with learning of process. Learning of process requires one to master an underlying process that is running behind a large number of concepts. One only needs to learn a process and many different concepts can be learnt by the learner themselves without the help of the instructor by applying the process learnt.

The training of instructor and teacher can involve learning to create their own content as per the requirement of their class. If the instructor is trained to develop their own science stories using the ENF, they can explain the concept in story form to children. They can even involve the children in historical data collection and presentation of story through theater or some artistic medium like storybook. Although in process based learning, the quantity of concepts learnt may be less, but the quality of learning may be more enriched compared to content based learning.

6.5 Limitations of the study

The domain of learning is vast and contains many aspects. This research work is limited to only certain aspects of learning and hence the results presented in the study are valid for only these few aspect of learning and not all. In the subsection we discuss the limited aspects of learning in which the conclusion of this research is valid. But first, let us outline the various aspects of learning. The various aspects of learning are Content, representation of content, Teaching method, Classroom setting, tasks/activities/assignments and evaluation. All these aspects are responsible for learning to happen. Working on one aspect alone may not guarantee learning unless all the aspects are dealt with simultaneously. The research work presented here is limited to content and representation of content. This research only claims to improve the representation method in lesson delivery. Other aspect of learning are equally important and do play a role as extraneous variables in the learning of a child.

Secondly, the type of content which the ENF covers is limited to content which has change or evolutionary nature. For example change in belief about head being a fluid to it being a form of motion. However, this is not the only aspect which is covered in science. The other static aspects include understanding the structure of something and classification. For example structure of atom or structure of a plant. In the ENF approach, only the structure is not talked about, what is talked about is let us say for example, how the notion of atomic structure has change from classical, to renaissance to Industrial revolution in science.

Thirdly, the concepts covered in the ENF approach may be limited to be to secondary school curriculum which has relatively simpler, qualitative concepts. As we move from secondary to high school, the concepts become more quantitative and requires knowledge of sound mathematical principles for their understanding. Since the ENF does not include subject of Mathematics in it sphere, all science concepts that are essentially mathematical may not be suitable for explanation with ENF.

6.5.1 Argument against teaching outdated traditional Greek concepts at lower secondary

An argument that stands against the use of ENF for curriculum design at higher secondary school level (i.e. class 6th to 9th) is that why one needs to teach outdated concepts about nature that were believed by Greek philosophers? Some of these outdated concepts include the four element and four oppositional properties in alchemy and the Aristotle's impetus theory in physics. It is well known that these concepts were proven wrong after the Renaissance and were replaced by new concepts in Lavoisier's modern chemistry and Newton's Laws of Motion respectively. It is true that the classical world of science was full of misconceptions, however it is only in the classical period that the attention of human mind to specific aspects of nature and that there are secret laws governing them were laid down. If Aristotle had not focused his mind upon nature of Levitation and gravitation and shared it with the world, would Galileo or Newton have concentrated the energy of their mind on thinking about these things? Since Aristotle had already laid the foundation, it helped the later generations in focusing their minds on specific subject matter. But this argument in itself holds a fundamental belief about the nature of scientific knowledge. Deanna Kuhn, Eric Amsel and Michael O'loughlin explain that science is nothing but a movement of mind from holding misconceptions about a phenomenon to its gradual correction, clarification, and understanding.

> The development of scientific understanding consists of a succession of incorrect theories within individual conceptual domains, theories that replace one another and only gradually come to approximate the correct one. It is this developmental process to which the science educator must be attuned. Such changes may not only include changes in relationship between terms but the very meaning of core terms themselves rendering successive theories not comparable with one another (Deanna Kuhn, 1988, p. 13).

We believe that teaching science by tracing the process of how scientist have created knowledge can help in inculcating the culture of science in not just a single class but the larger school environment. This thought resonates well with the recent development in science teaching pioneered by Arthur Stinner, Stephen Klassen and Yannis Hadzigeorgieue as we mentioned in the literature review.

6.5.2 Limitations of Experimental validation

We would refrain from generalizing the result of experiments to larger population because the effect of socio-cultural background of students on student response data was not taken into consideration. Students whose parents are teachers or those who are proficient in expressing themselves in English language had greater possibility of scoring well in achievement test. Many students had exceptionally good score which may have caused the mean to be in favor of the control group (story method of teaching). This was inferred from observing wide standard deviation in some of the achievement score data. Definitely students of KV IIT whose parents are college professors in IIT had higher mean score than campus School students whose parents are non-teaching staff. Assuming that a culture of teaching at home will help their children be more readily prepared for learning assignments, we can say that social background of children would have affected the result.

6.6 Future work

The Narrative framework presented so far is limited to science education at secondary school level. However, it is possible to come up with a structure for stories in social sciences. But we speculate that the structure will need to be more dynamic in the case of social science. The main idea would be the same as we have followed here i.e., tracing the development of ideas through history. But we focus on ideas associated with governance, economy and geography. By examining the nature of societies from pre historic to how they changed to evolve aristocratic empires to establishment of democracy, it can be possible to construct narratives that explain all such changes in human history.

Keeping in mind the advantages and limitations of using a Narrative approach for designing secondary school science content, we can now see how learning of science can become an act of learning the ways of the scientific tradition.

6.7 Learning of science as a function of being part of the Scientific Legacy

The attempt of learning by any individual is more than just one person trying to acquire knowledge in a certain domain. It is an extension of the human legacy of struggle for survival and passion for growth that began with the first attempt of the prehistoric human to chisel out a sharp edge out of a blunt stone in order to hunt food for self-preservation. Each field of knowledge has descended down since millennia and every child who learns a skill or trade joins into the journey, becomes one more traveller along with others who have travelled in the past but could go on only to a certain point. The new learner then takes on the flame left by the past generation and carries it further till as far as possible, till it is handed over to the next one. This legacy of human development and growth exists in its narratives and through narratives alone can such a legacy be passed on from generation to generation with past knowledge, increased, expanded and reaching new heights and traversing new, unknown domains. A learner, who has spent his childhood listening to such stories of explorations into the unknown by our ancestors, will know that, born on this earth, one is a descendent of the human legacy of exploration. Their job is to expand the kingdom, overcome its difficulties and help make it better for the present and for the future generations.

Glossary of terms in ENF

Belief: A notion in a person's mind which relates two or more terms associated with a phenomenon with each other.

Disciplinary Matrix (Paradigm): a set of shared beliefs within a scientific community that makes communication of ideas within a group possible.

Observation: Attention of the mind upon objects and/or events.

Doubt: An event that contradicts existing belief within a paradigm (disciplinary matrix).

Questioning: Doubt leads to formation of a Question. The question reflects the desire to know something specific about an object or event being observed.

Suggestion/Hypothesis: A probable answer for the question, by relating the unknown question with something which is previously known.

Reasoning: The act of theoretically connecting various available facts to build a justification for the inferred suggestion or hypothesis.

Experimentation: Testing of the hypothesis on practical grounds on particular cases.

Theorization: In science a theory is statement of assertion regarding relationship between two or more terms.

Sharing with community: Making the community members aware of the discovery for their criticism and suggestions

Replication: Repetition of the experimental conditions proposed by a researcher by other members of the scientific community to test if the results are according to claims by the original researcher.

Competition: Choosing a particular hypothesis among various competing ideas by the scientific community.

Appendix 2

Story Structures

Appendix 2.1: Joseph Campbell's Elements of "Hero's Journey" (Campbell, 1973)

1) Departure
    a. The call to adventure
    b. Refusal of the call
    c. Supernatural aid
    d. The crossing of the first threshold
    e. The belly of the whale
2) Initiation
    a. The road of trials
    b. The meeting with the Goddess
    c. Woman as temptress
    d. Atonement with the father
    e. Apotheosis
    f. The Ultimate Boon
3) Return
    a. Refusal of the Return
    b. The Magic Flight
    c. Rescue from without
    d. The crossing of the return Threshold
    e. Master of the two worlds
    f. Freedom to live

1) Departure

1a. The call to adventure: The example of myth given here is that of Gautama, the Buddha. It was prophesized in his childhood, that he will leave the leisurely comfort of his kingdom and live a life of a hermit. Hence Gautama's Father protected him since childhood within the confines of his kingdom, hiding from him the external world that existed outside his kingdom. But as it happened, when Buddha grew up, he once asked his charioteer to take him outside the confines of his kingdom. And as he stepped out, all that he saw was misery of people. And then he was struck by some deep questions regarding the cause of all suffering. And from then on began his quest to search for an answer to seize all suffering. Thus, he left his kingdom to embrace such a call to adventure. In the words of Campbell:

> The first stage of the mythological journey signifies that destiny has summoned the hero and transferred his spiritual center of gravity from within the pale of his society to a zone unknown. This faithful region of both treasure and danger may be variously represented as a distant land, a forest, a kingdom underground, beneath the waves, or above the sky, a secret land, lofty mountaintop, but it is always a place of strangely fluid and polymorphous beings, superhuman deeds and impossible delight (Campbell, 1973).

1b) Refusal of the call: The call to adventure is not reciprocated or accepted by the hero because he may be distracted by other profitable pursuits. This leads to the hero's destruction.

1c) Supernatural aid: Those who accept the call are provided with a protective figure who provides protection against the negative forces.

1d) Crossing of the first threshold: Here, the hero encounters the guardian who resides at the threshold from where the known world ends and the unknown begins. This is the beginning of land away from the protection of the society. To remain in the previous world is safe as one is protected there. To cross the threshold is to invite a life of risk and uncertainty.

1e) The belly of the whale: As soon as the hero enters the region beyond the threshold, he appears to be swallowed by the unknown represented as the whale. The hero must slay the whale and emerge out of it to continue his journey.

2) Initiation

2a) The road of trials: This is where the hero enters into series of tests and is provided with different type of powers and boons upon the completion of quest. Here the hero meets many helps and supernatural aids.

2b) The meeting with the Goddess: When all the obstacles are overcome, the hero meets the queen goddess of the world at the edge of earth, at central point of cosmos or within the darkness of the deepest chamber of heart.

2c) Woman as the temptress: This aspect of the myth is left as it is too complex and difficult to understand. It is here that the hero meets the conflicting forces of purity of spirit and the ways of the world. When it is dawned upon us or forced to our attention, that everything we think or do is necessarily tainted with the odor of the flesh, then, not uncommonly, there is experienced a moment of revulsion: life, the acts of life, the organs of life, woman in particular as the great symbol of life, become intolerable to the pure, the pure, pure soul.

2d) Atonement with the father: It is in this phase that the wrath of God is let loose upon the hero. It appears to be a stage of extreme crisis.

2e) Apotheosis: This is when the hero begins to see beyond the pain and pleasure. His heart is free of all fear. This is also the phase where the hero seems to touch the zenith of enlightenment.

2f) The Ultimate boon: This is when the deserving hero is given powers of miraculous kinds. When the struggle through tests is vanished to give way to dexterity, he no longer makes any mistakes. Campbell gives the example of Buddha's victory beneath the Bodhi tree of such an act.

3) Return:

3a) Refusal of the return: After the completion of the quest, the hero must return home to share his knowledge, his wisdom in due course of his quest with his community so they too may benefit from it. But too often the hero refuses this call to return doubting if his message will be received in the right spirit.

3b) The Magic flight: If the hero decides by the blessings of a God or Goddess to return. He assisted by all the supernatural beings in his endeavor to bring the benefits of his victory to the whole community.

3c) Rescue from without: The hero has to be brought back to the world by the world itself because hero is too deeply entrenched into the bliss of the other world.

3d) The Crossing of the return threshold: Before reentering the world that the hero left once, he is halted by questions of why to return back to the world. It is here he needs to see the old and the new world as one and the same.

4d) Master of the two worlds: It is here that the hero acquires the power to traverse both worlds with ease. Both worlds are now known to him and he becomes a link between the two.

5d) Freedom to live: And then the hero lives in his community as an agent, a channel through whom the divine powers are bestowed to the community, through whatever work the Hero chooses to do be that of a butcher, jockey or king.

Appendix 2.2: Vladimir Propp's 31 functions of Russian Folktale

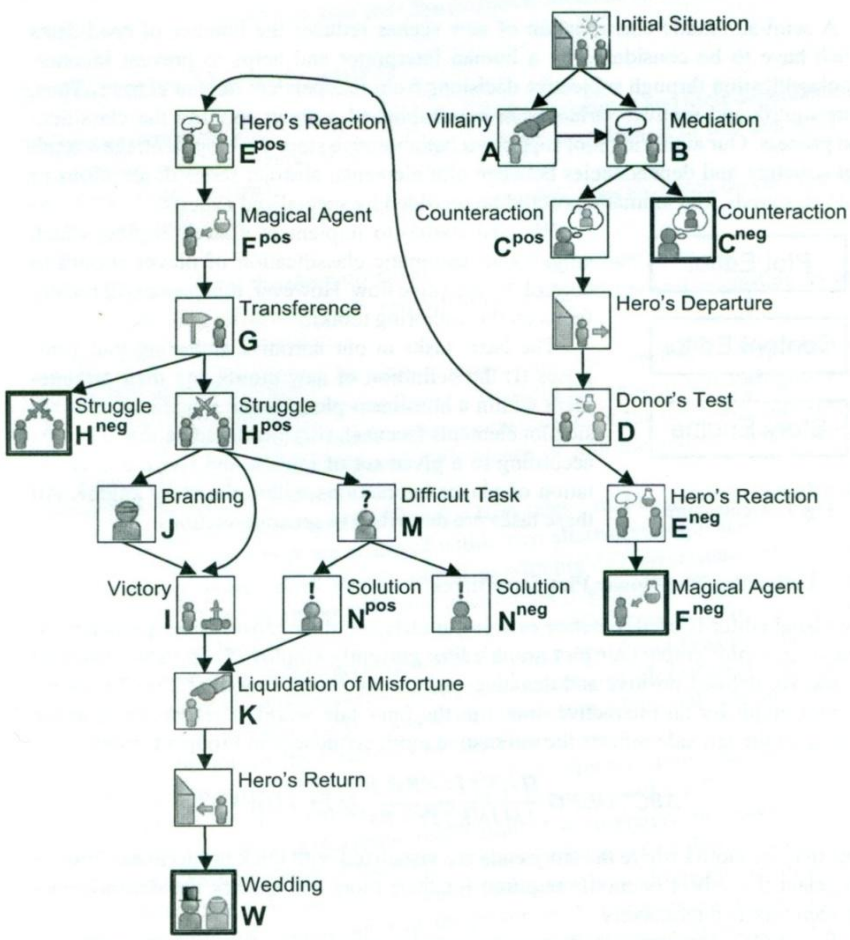


Figure: Visual depiction of Vladimir Prop's 31 functions describing the general structure of Russian Folktales

Vladimir Propp's 31 functions of Russian Folktale with symbols

Symbol	Definition	Action
β	Absentation	One of the members of the family absents himself from home
γ	Interdiction	An Interdiction is addressed to the hero " Don't look into this closet"
δ	Violation	Interdiction is violated "Hero looks into the closet"
ε	Reconnaissance	The villain makes an attempt at reconnaissance "Knowing about secrets"
ζ	Delivery	The villain receives information about the victim
η	Trickery	The villain attempts to deceive his victim in order to take possession of him or of his belongings
θ	Complicity	The victim submits to deception and thereby unwittingly helps his enemy
A	Villainy	The Villain causes harm or Injury to a Member of a family
α	Lack	One member of the family Either Lacks something or desires to have Something
B	Mediation	Misfortune or lack is made known; The Hero is approached with a request or command; He is allowed to go or he is Dispatched
C	Beginning Counteraction	The seeker agrees to or decides upon counteraction
D	The first function of the Donor	The hero is tested, Interrogated, attacked, etc. Which prepares the way for his receiving Either a magical Agent or Helper.
E	The hero's reaction	The hero reacts to the actions of the future donor. Positive or Negative
F	Receipt of a Magical	The hero Acquires the use of a Magical Agent

	Agent	
G	Spatial ***transference*** between two kingdoms, Guidance	The Hero is transferred, Delivered or led to the Whereabouts of an object of search
H	Struggle	The Hero and the villain join in Direct Combat
J	Branding	The Hero is Branded
i	Victory	The villain is defeated
K	Liquidation	The initial misfortune or Lack is liquidated
↓	Return	The Hero Returns
Pr.	Pursuit	The Hero is Pursued
Rs	Rescue	Rescue of the Hero From Pursuit
O	Unrecognized	The Hero Unrecognized arrives home or in another country
L	Unfounded Claims	A false Hero's presents unfounded claims
M	Difficult Task	A difficult task is proposed to the hero
N	Solution	The Task is resolved
Q	Recognition	The hero is recognized
Ex	Exposure	False Hero or Villain is Exposed
T	Transfiguration	The Hero is given a new Appearance
U	Punishment	The Villain is Punished
W	Wedding	The Hero is married and Ascends the Throne

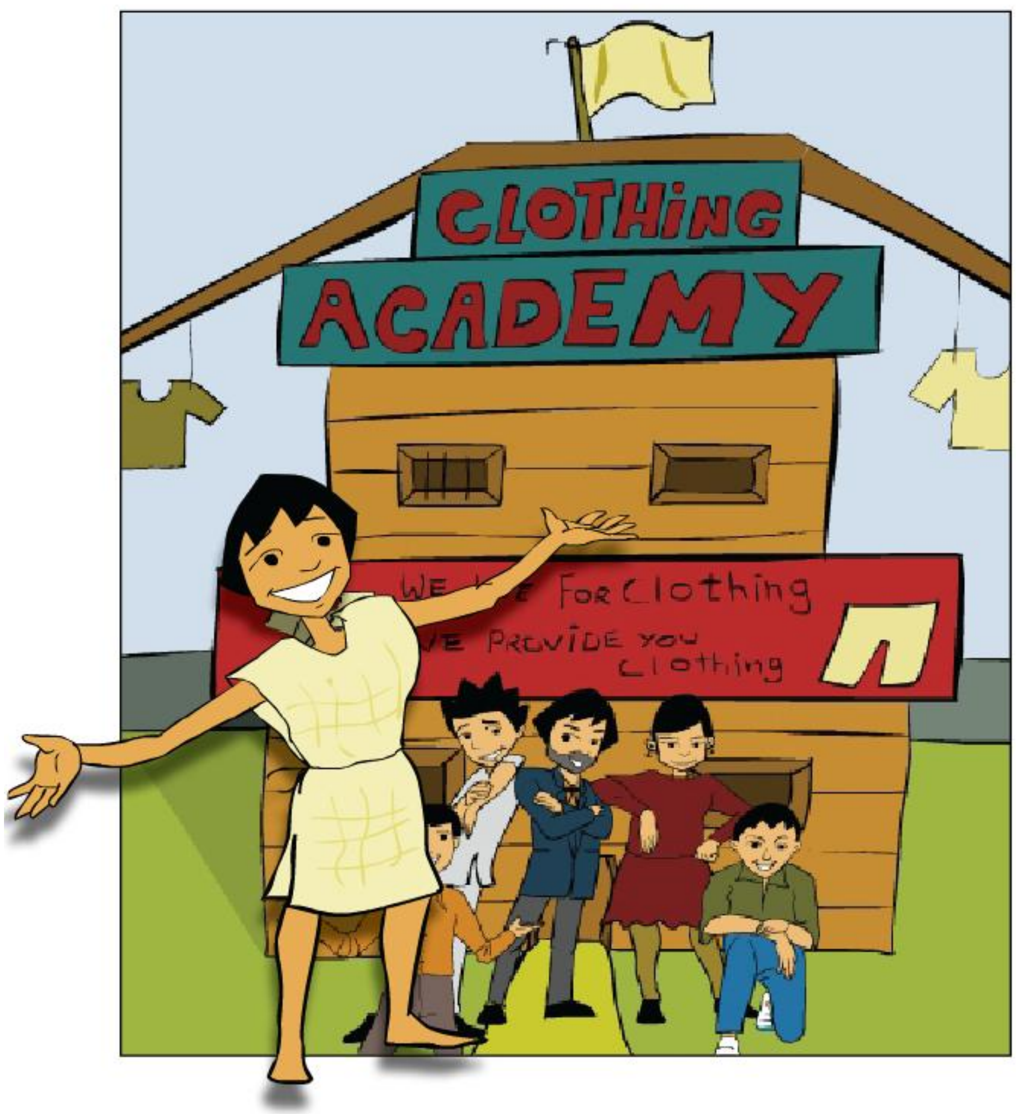
Table: Description of Propp's 31 plot functions of Russian Folktales

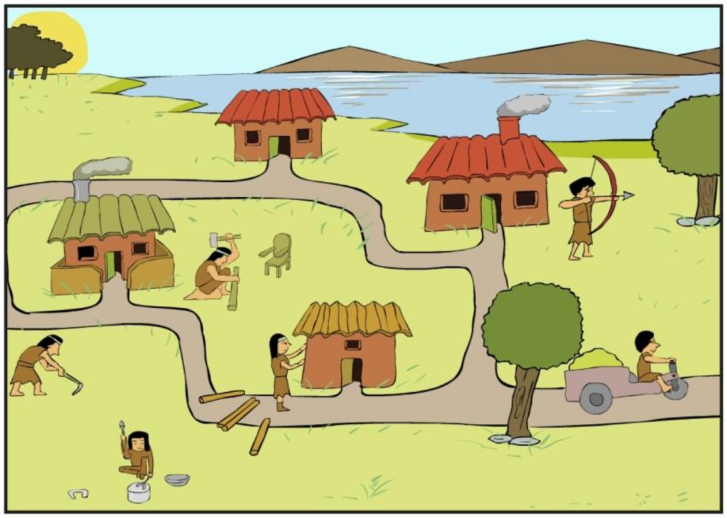
Appendix 3

Story Examples

story of Stich

How clothing came into being





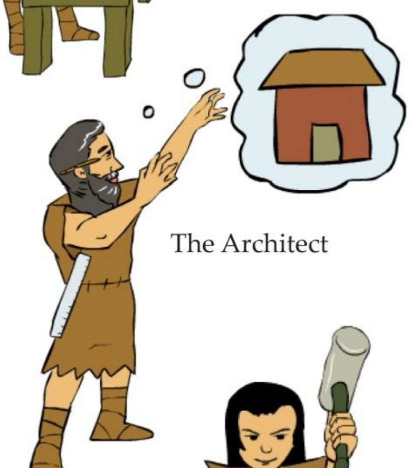
Long time ago there was a place called Creationland. It was a very special place as everyone living there possessed great powers of Creation.

Some had power of crafting beautifull articles of wood like furniture. They were known as the Carpenters.

The Carpenter

Some had the power of making items of Iron, like war weapons and household articles. They were called the Blacksmiths.

Some were possessed with the powers of growing Food. They were the Farmers.



The Architect

Some had power of building safe houses. These were called the Architects.

Each person provided for the needs of each other at Creationland by using their powers of Creation.

The Blacksmith

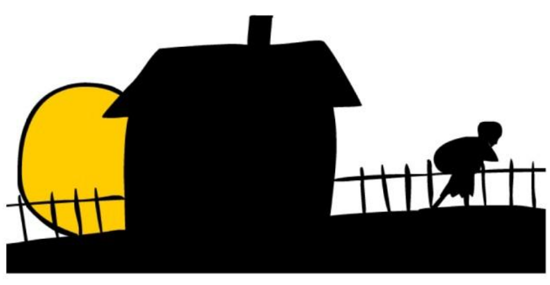
There was a boy in Creationland. His name was Stich. When he grew up his father Hammer advised him to learn a skill so he can attain a power like everyone in Creationland:

Hammer: Son, time has come for you to acquire a power for yourself....

...I talked to my friend Mr. Drape yesterday, he is ready to take you as an apprentice at his workshop.

Stich: What does he do?

Hammer: He is the finest drape maker in Creationland. He provides drapes for us all. He will give you the power of making drapes.

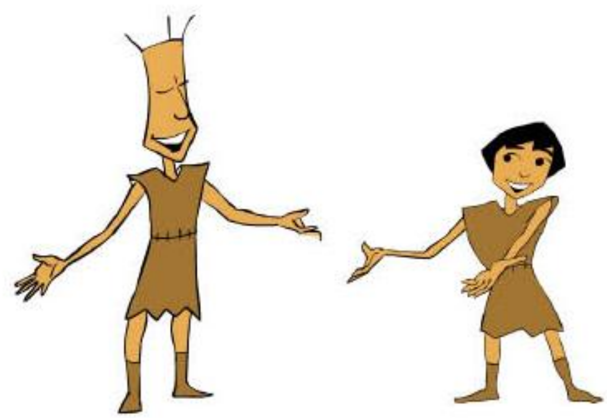


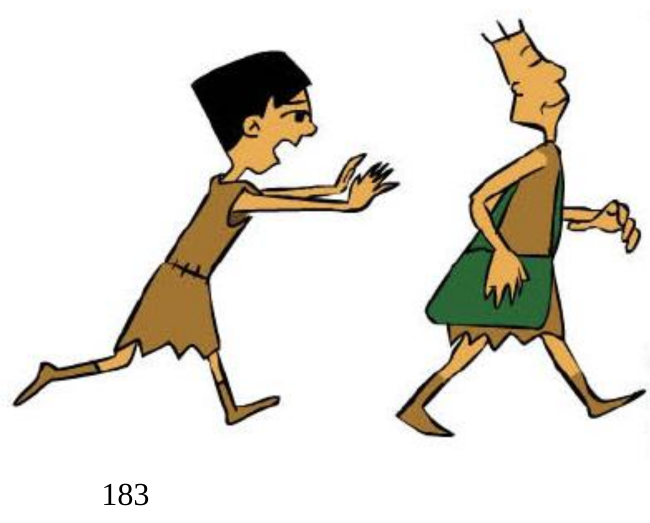
And so, Stich left home to work with Mr Drape to acquire the Power of Drape making

Stich meets Mr Drape in his workshop.

Stich : Dear Mr. Drape. Your name is famouse all across Creationland. You have been providing us beautifull drape to protect our bodies. Your Powers are so magnifiscent. I am certain, that you are the greatest drape maker, not just in Creationland but in the whole world.
Mr Drape: Ha Ha. Thank you for the sweet words. What is it that you want from me?
Stich: Sir, I want to acquire the power of making drapes and there is no better person in Creationland to learn this power from.
Mr Drape: Very well, you seem to be really searious about acquiring the power of drape making. I will teach you. But first you must help me with a few things.

Stich: I am prepared to do anything.
Mr. Drape: I am going out to look for some dead animals. I need you to help me with that.
Stich: Dead Animals? why do you need dead animals?
Mr Drape: If you want to work with me then do as I say rather than asking too many questions. You will know everything when the time is right
Stich: Wait Mr Drap! I am coming along.
...





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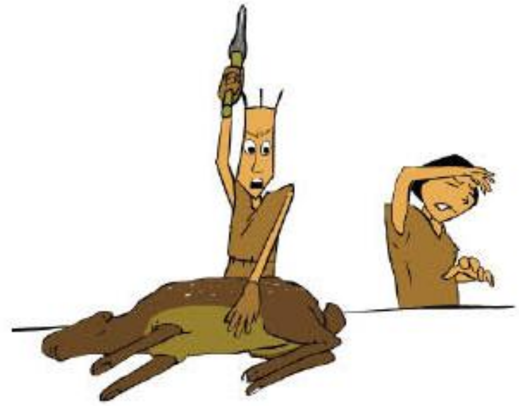


Mr Drape and stich return home with a dead dear. Stich is totally disgusted to see Mr Drape tearing the skin of the dear.

Stich: Hey why are we tearing its skin?

Mr Drape: What do you think we make the drapes from?

Stich: You mean the drapes we wear are made of animal skin?

Mr Drape: Of course. Animal skin is a good material for making the drape. Its strong and at the same time Soft to wear. It also provides us warmth.

Stich returns home after the day's work. His father was waiting for him

Hammer: Hey Stich. How was your first day of the job?

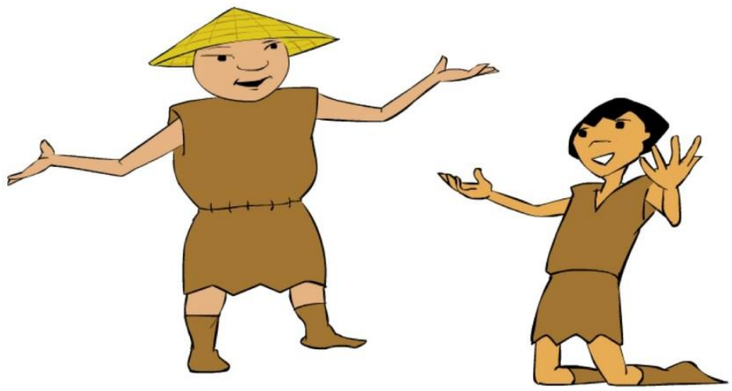
Stich: I...I cant do that job? I want to do something else.

Hammer: What? Why? What happenned?

Stich: I mean, I like the drapes and I want to acquire that power, But, I wish there was another way of making it without having to kill any animal.

Hammer: Oh. I understand that you are a sensitive child. Maybe you are meant for something else.

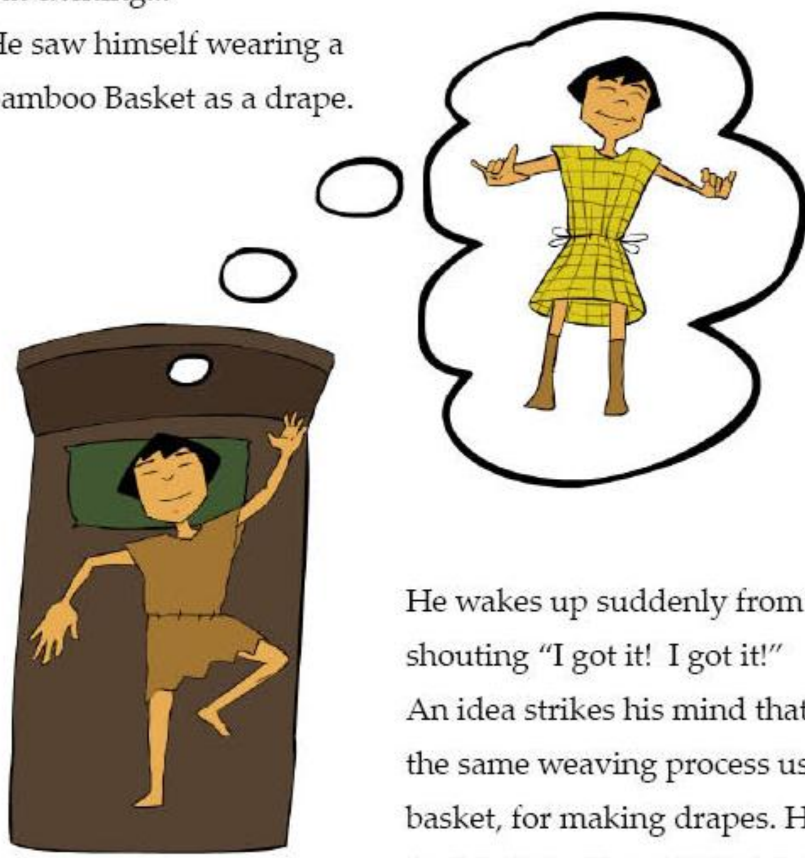
Next day, Stich met Mr. Basket at his Basket making workshop.
Stich: Dear Mr Basket, your name is famous all across Creationland. Everyone loves your baskets. Your power of basket making is magnifiscent. I am sure that not just in wonderland but you are the best basket maker in the whole world.
Mr Basket: Ha Ha. Lets come to the point.
Stich: Actually, I want to acquire the power of making baskets and who else can help me but you, the greatest basket maker in the whole of Creationland.



Mr. Basket appointed Stich as his apprentice. Stich was very happy at the basket making workshop. He worked day and night and liked every moment of it. In no time he became the fastest learner at the workshop.

He liked basket making so much that he even dreamed about it while he was asleep. And one day in his dream he saw something very strange, but exciting...

He saw himself wearing a Bamboo Basket as a drape.

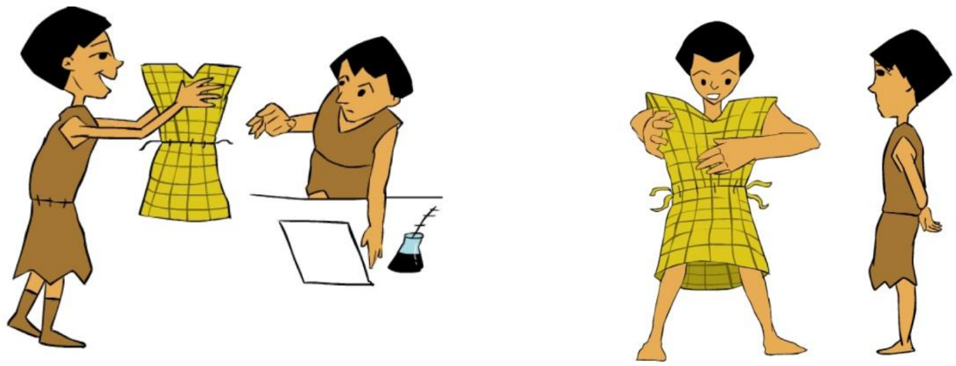


He wakes up suddenly from the dream shouting "I got it! I got it!"

An idea strikes his mind that he can use the same weaving process used for making basket, for making drapes. He rushed to his workshop and collected some bamboo strips and then **wove** them in a criscross way to form the matt. This matt he made suitable to fit human body and made a drape out of Bamboo strips!

Bamboo strips being overlapped one over the other This process is known as weaving

Bamboo Matt formed by weaving cane strips



Stich was so excited by his invention that he rushed back home to show his elder brother Nail what he made. But unfortunately his brother was not so excited to wear it.

Nail: Well, I really appreciate your effort brother Stich, but this material is so hard. A drape must be soft so it does not hurt the body. This Bamboo matt is really uncomfortable to wear.

Stich was really disappointed to hear that his invention had failed. He went back to his workshop. But Mr Basket was not too happy either.

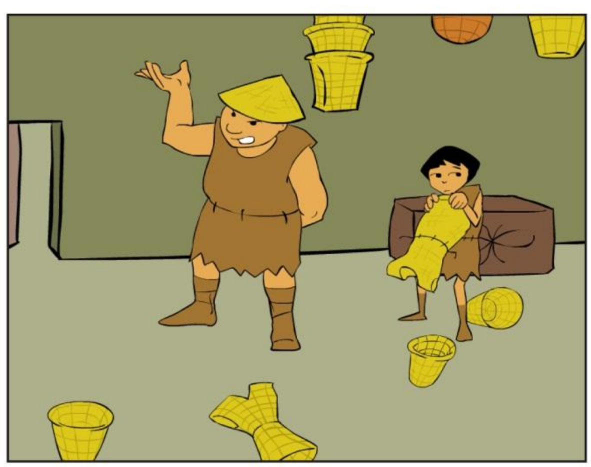
Mr Basket: Stich, What have you been doing with all my material?

Stich: Sir...I was just trying out something new.

Mr Basket: Why dont you try them at your home? Why are you wasting my expensive material?

Stich: I am sorry sir.

Mr Basket: I thought you were an obedient student who will do whatever he is told to do. But you have really disapointed me. Now just get out of here before I loose my temper. I dont want to see your face.



Stich returned home thoroughly discouraged by the harsh words of Mr. Basket.

His brother Nail Came up to him and said...

Nail: Hey Stich what happened? You don't look to happy?

Stich: I am just a looser. I cannot do anything right.

Nail: Stich, look, your idea of making drapes by weaving Bamboo strips was not bad. All you need to do is to find a better material than Bamboo. Something that's soft. Thats all.

Stich: You mean, you really think I am not wasting my time?

Nail: Of course not, I feel you are doing something very important and it will change the future of drape making in Creationland.

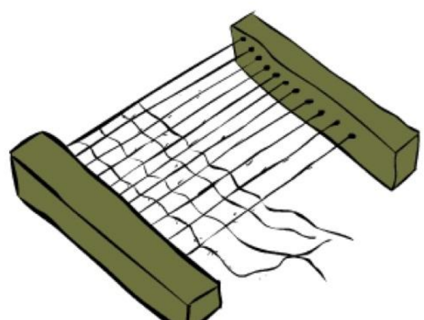
With these words of encouragement by his brother, Stich fought back to find an alternate material to Bamboo.

He tried out different type of grass to make the weave. With Grass he was able to make a drape which was more soft than Cane but the problem with grass drape was that it was very weak. It got torn very easily.

But this time Stich was not discouraged by failure. He continued searching for new material which was as Soft as Grass and as Strong as Bamboo. He tried with different kind of plant leaves but still, did not get what he wanted untill he saw the wonder plant called COTTON.

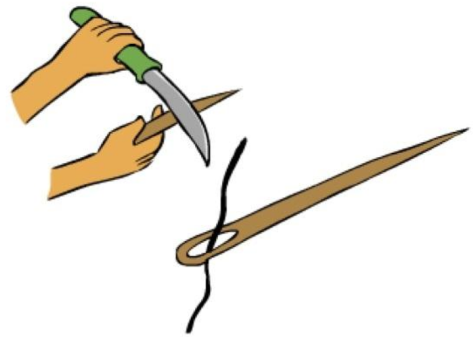
Stich noticed that Fibres could be pulled out of Cotton ball.

Many fibres join together and form a Yarn

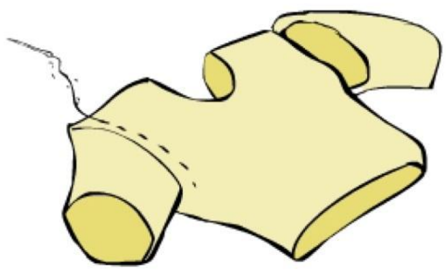


and Yarn can be weaved together to form...

...a cotton fabric !!



Stich also invented a sewing needle by chiseling a piece of wood...



...to join Pieces of fabric to form a drape or a Garment

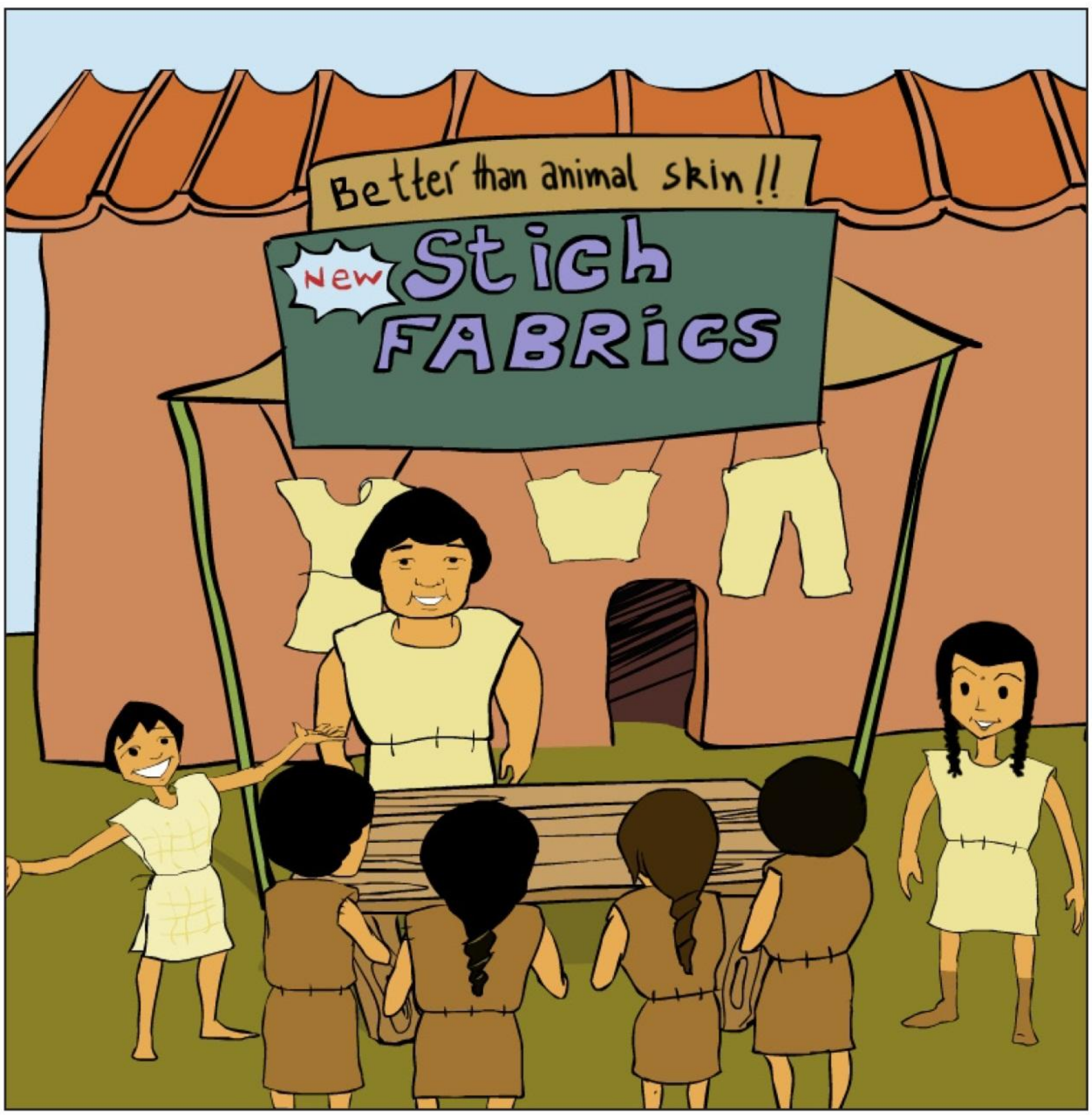
And so Stich completed making his very own garment made from cotton fiber.

But he was a little nervous. He thought to himself

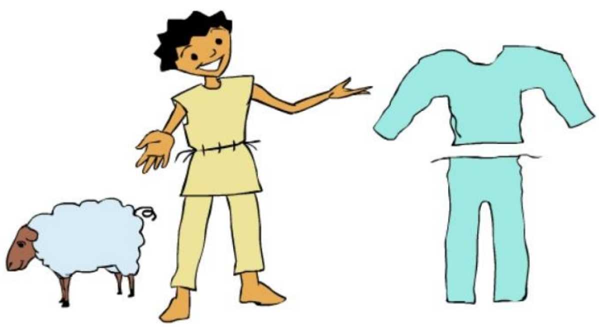
Stich : (Thinking) Well, this is it. Looks good to me. I dont know what will people say when I show it to them. I'll just try it with my brother. If he likes it then I am sure everyone will like it.

And so with fingers crossed, Stich ran up to his brother to show his latest invention.

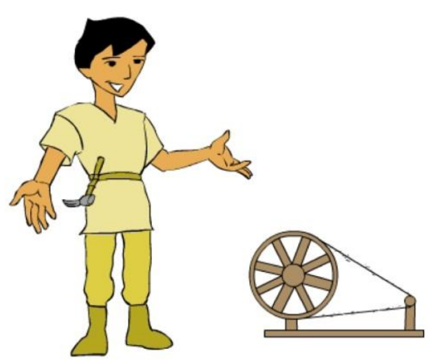
Nail: Thats amazing!! You did it Stich. This is the perfect garment I have ever worn. Its soft as grass and strong as Bamboo and you dont need to tear animal skin to make it.
Stich could not help but break into tears of joy with his brother's words of appreciation.
And then stich along with his family started his own workshop for making garments made of cotton. Very soon, all people of creationland started wearing cotton drapes.



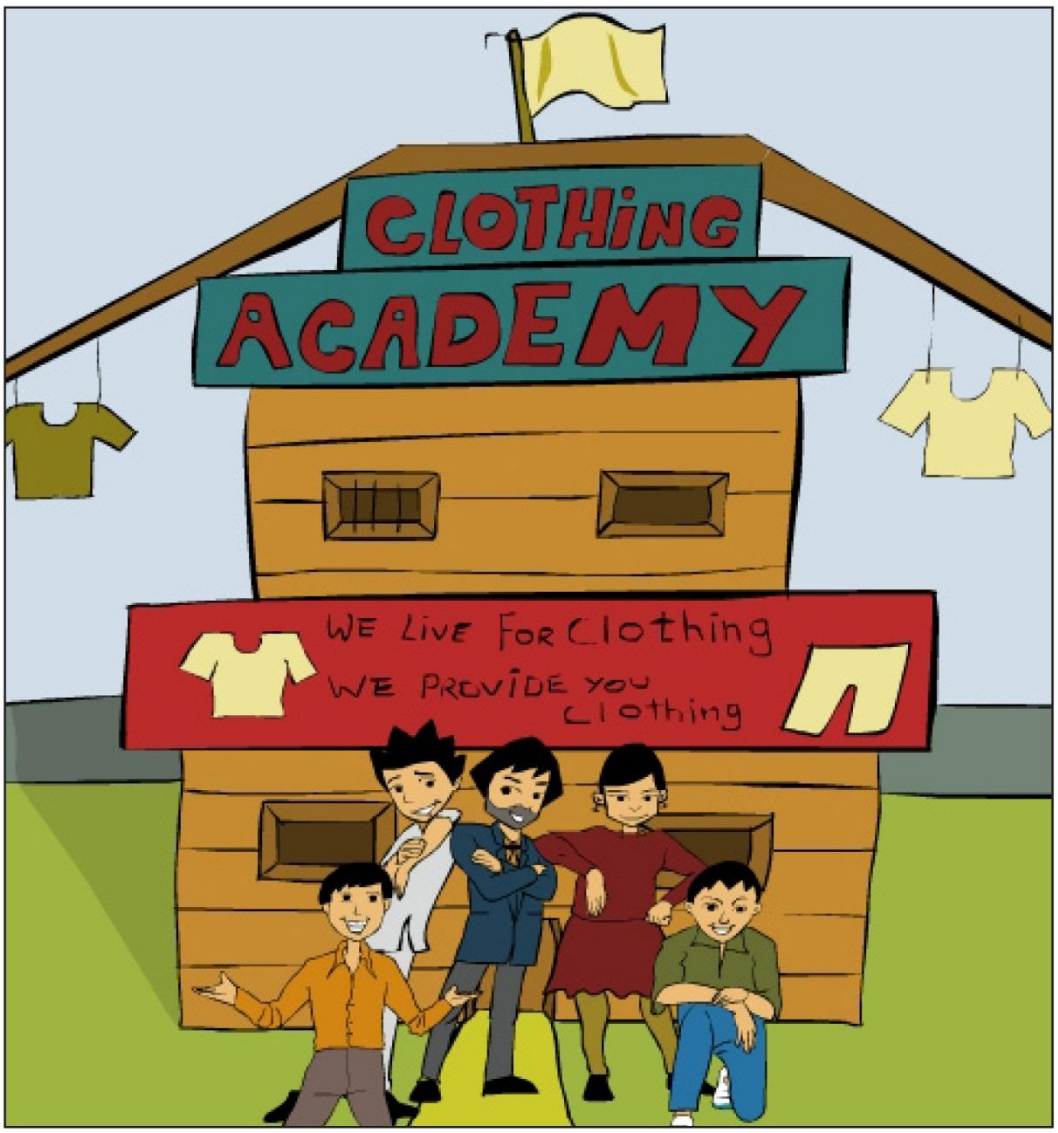
When Stich grew older, many young students from different parts of Creationland came up to him to learn how to make stiched Cotton Fabrics. One of his students found a way of extracting fibres from sheep's hair. This was called the woolen fibre which is weaved to form woolen clothes to be used in cold season to keep the body worm.



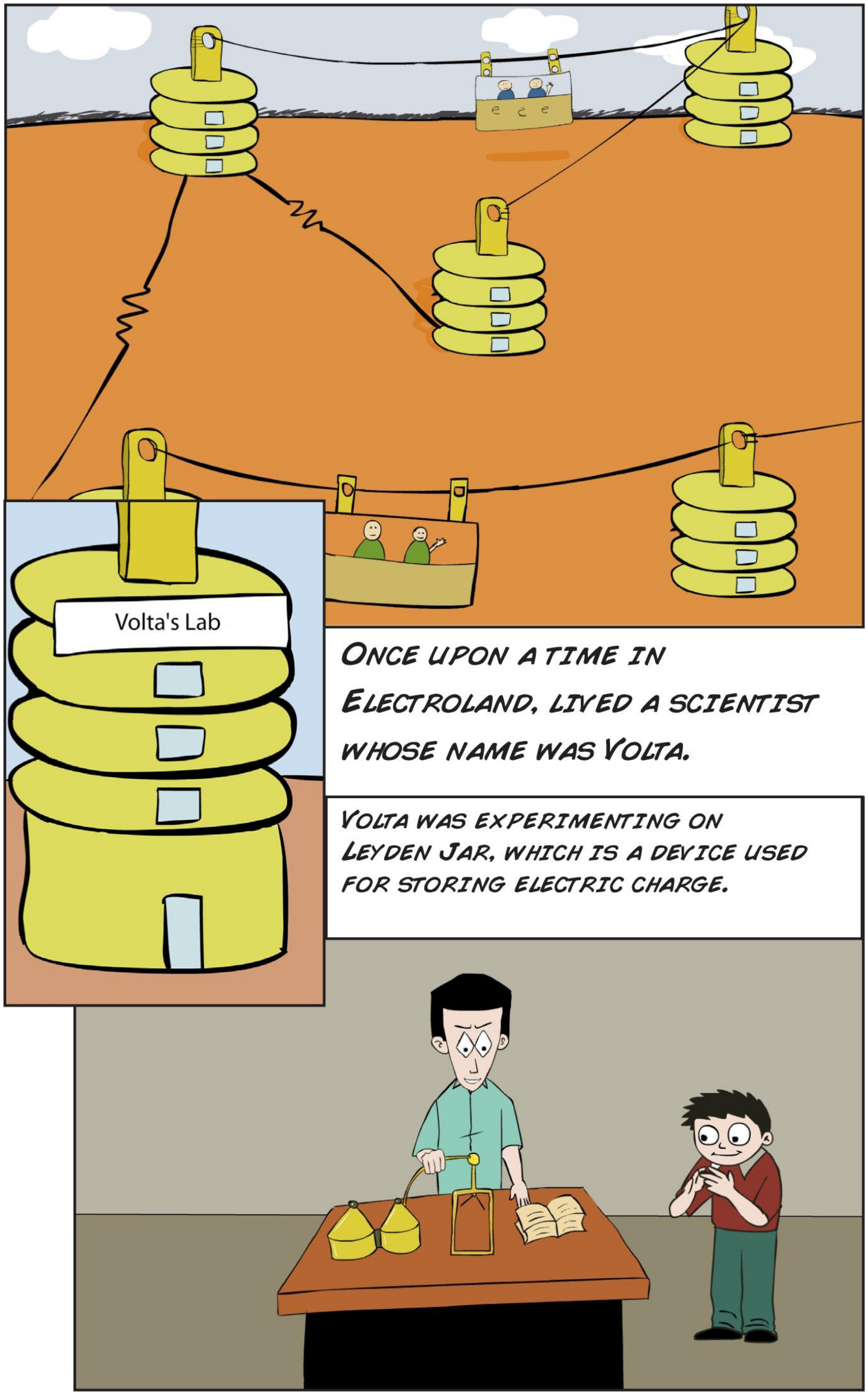
Another student of Stich developed a new method of makic fabric from fibre. He introduced the method of Spinning. The Cotton Fibres are spun on a wheel which creates the Yarn.

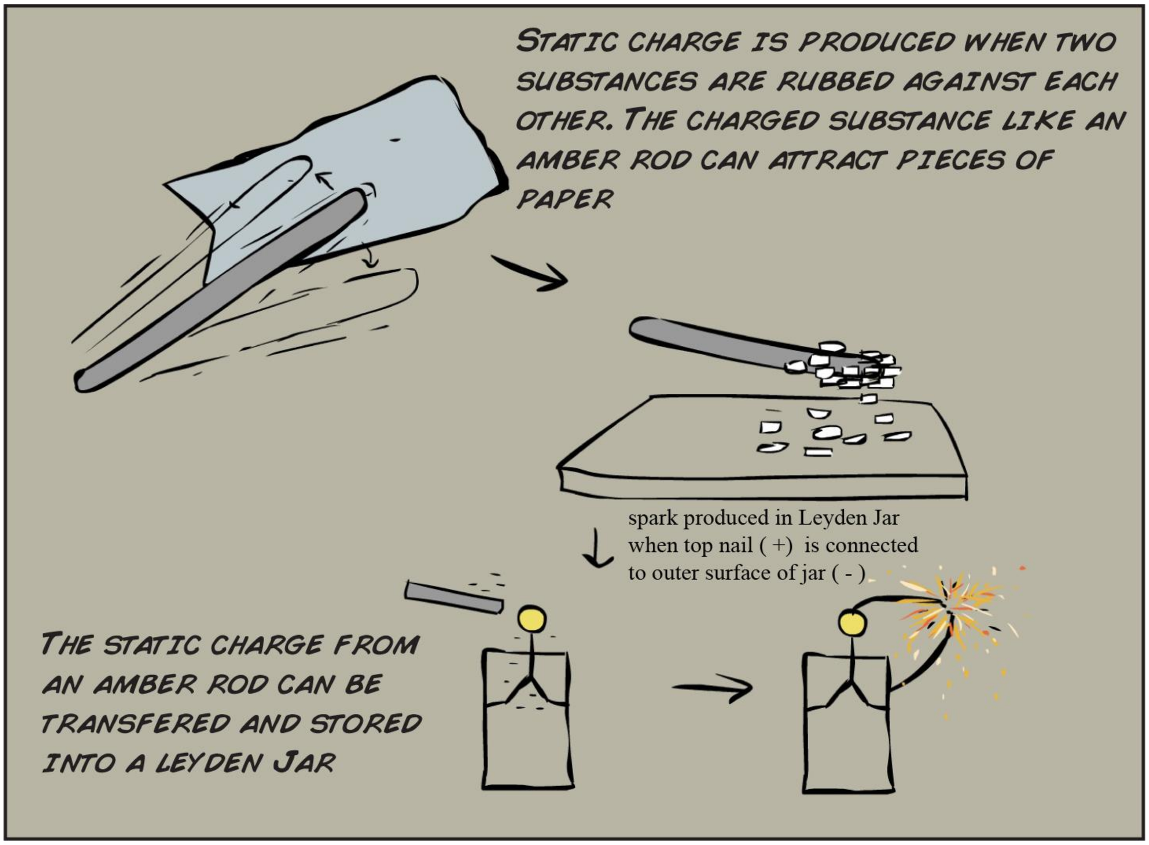


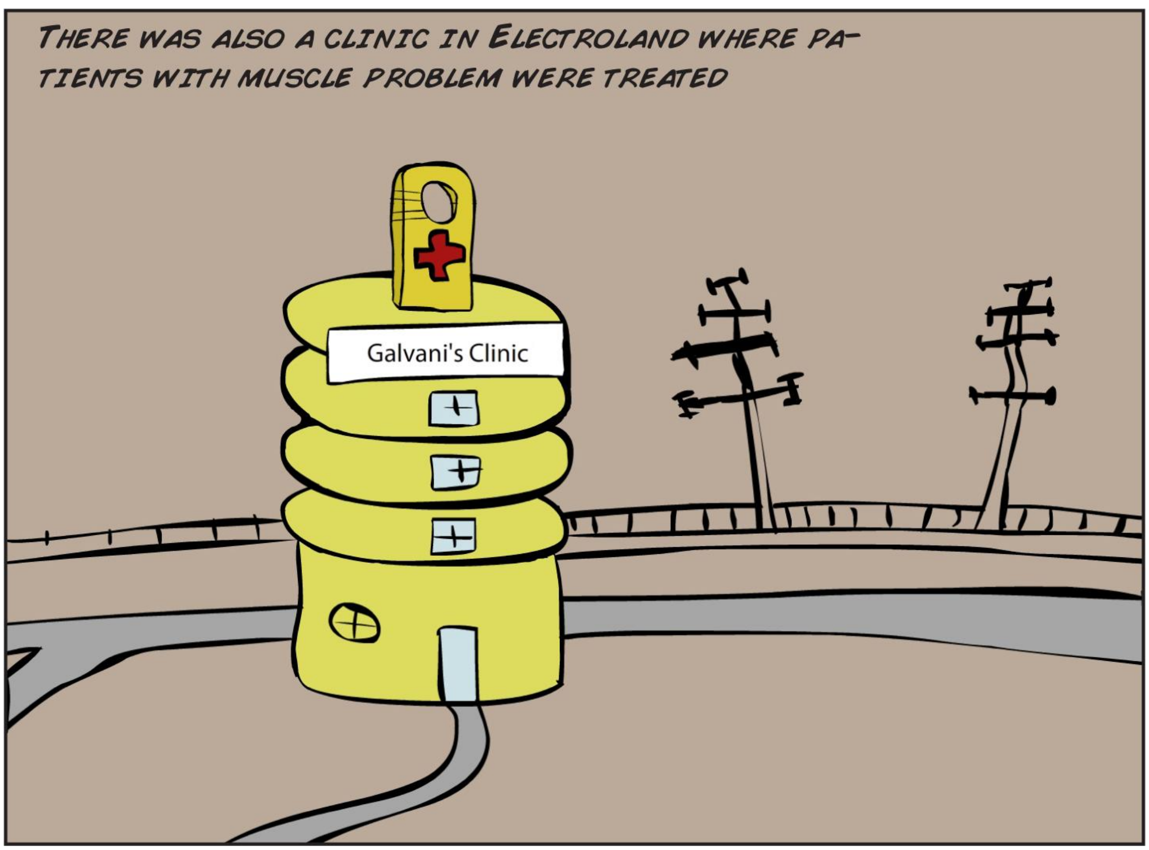
As time passed by many people started praticing new ways of making clothes and a new clothing academy was created where students could freely explore new ways of making clothes. So far they used cotton or wool for making Yarn. They are natural fibres as they are available in nature. Many different techniques of making yarn were also discovered. And this way the story of clothing continues even till this day.



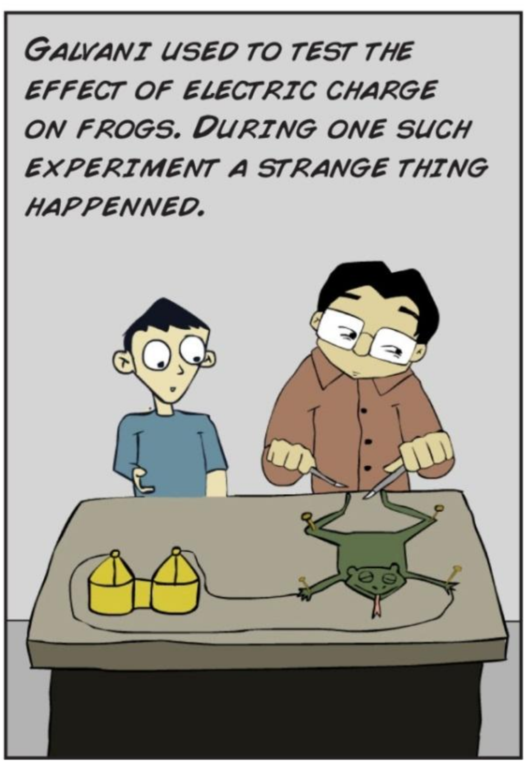
Story 2: Volta and the Voltaic Cell



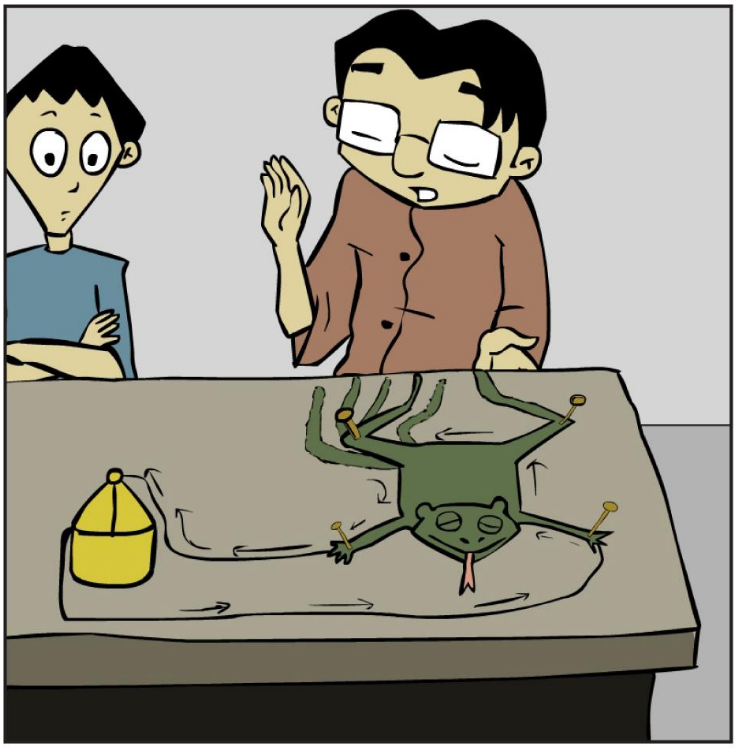

STATIC CHARGE IS PRODUCED WHEN TWO SUBSTANCES ARE RUBBED AGAINST EACH OTHER. THE CHARGED SUBSTANCE LIKE AN AMBER ROD CAN ATTRACT PIECES OF PAPER
spark produced in Leyden Jar when top nail (+) is connected to outer surface of jar (-)
THE STATIC CHARGE FROM AN AMBER ROD CAN BE TRANSFERED AND STORED INTO A LEYDEN JAR


THERE WAS ALSO A CLINIC IN ELECTROLAND WHERE PATIENTS WITH MUSCLE PROBLEM WERE TREATED
Galvani's Clinic

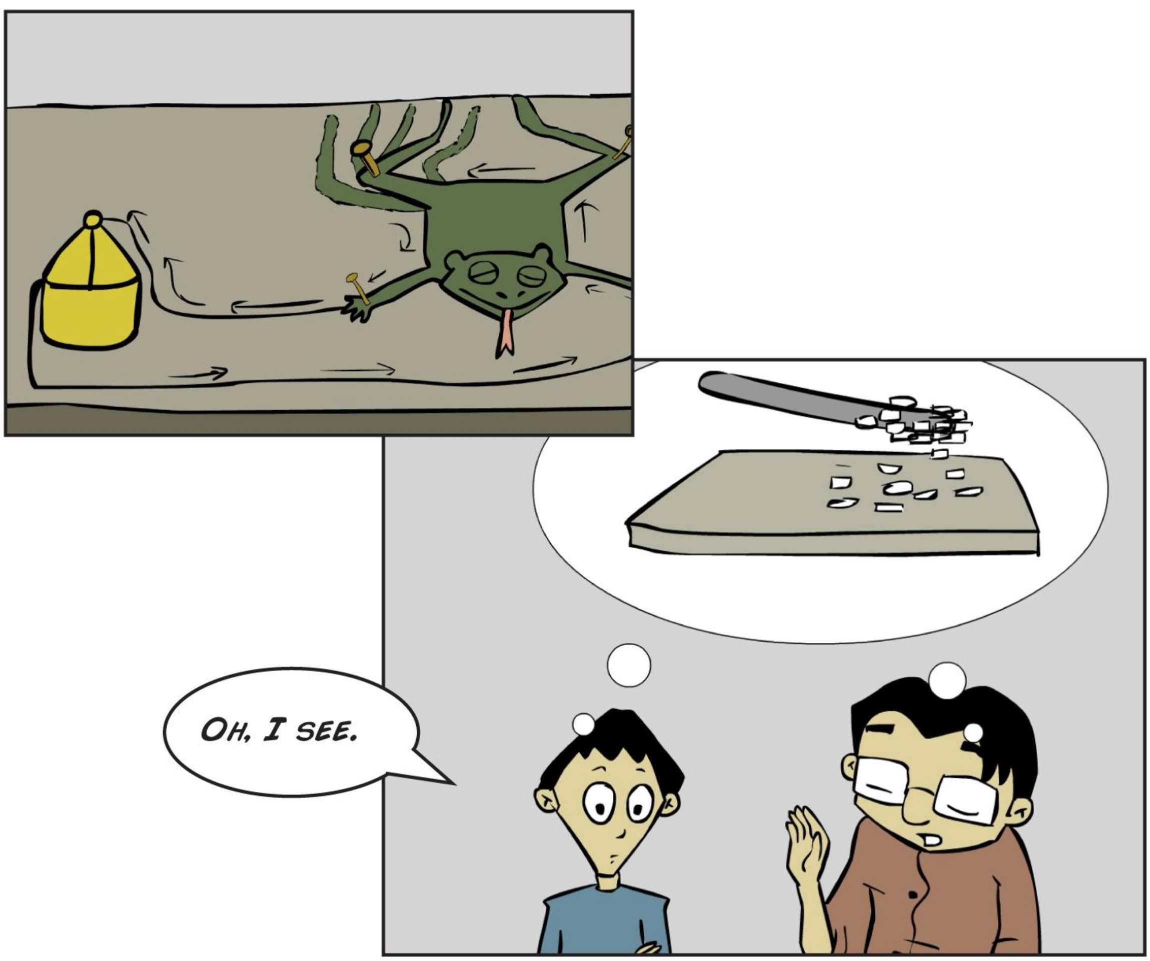

THE CLINIC WAS RUN BY A DOCTOR WHOSE NAME WAS GALVANI.
SIR, ARE YOU SURE THIS WILL WORK?
I HAVE TREATED HUNDREDS OF PATIENTS BY GIVING THEM ELECTRIC SHOCK FROM MY LEYDEN JAR

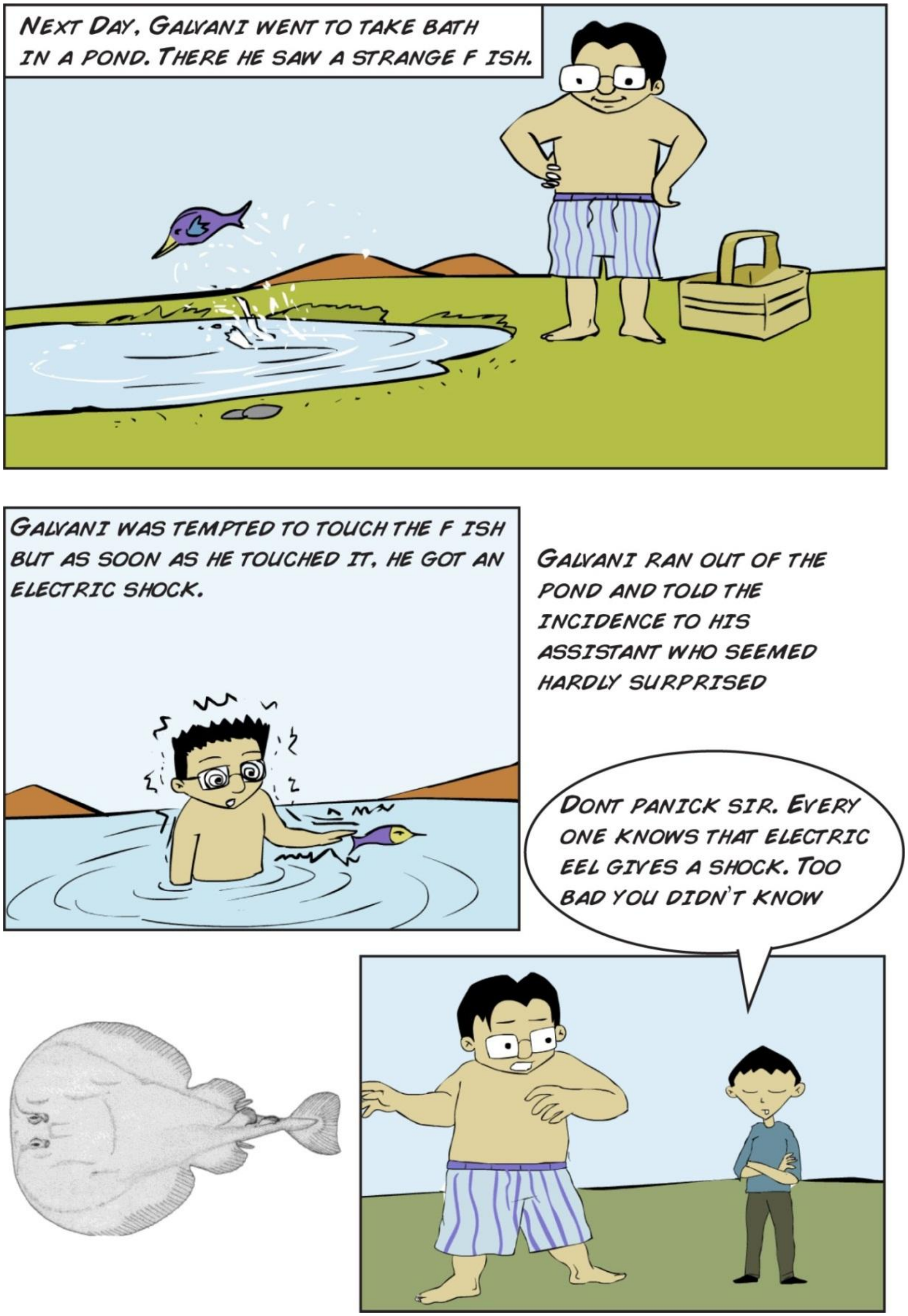

GALVANI USED TO TEST THE EFFECT OF ELECTRIC CHARGE ON FROGS. DURING ONE SUCH EXPERIMENT A STRANGE THING HAPPENNED.

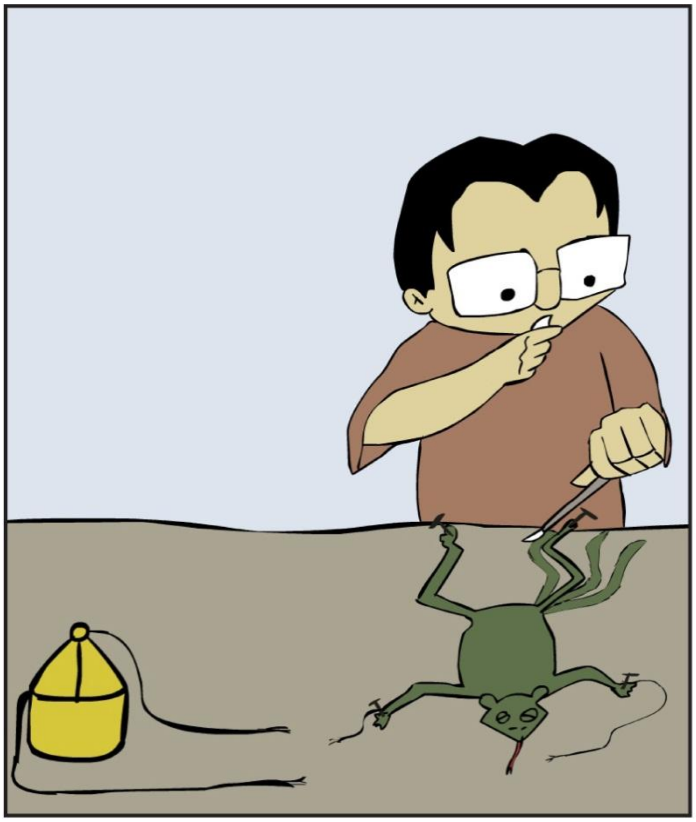

OH MY GOD! SIR! LOOK, THE DEAD FROG'S LEG IS MOVING.



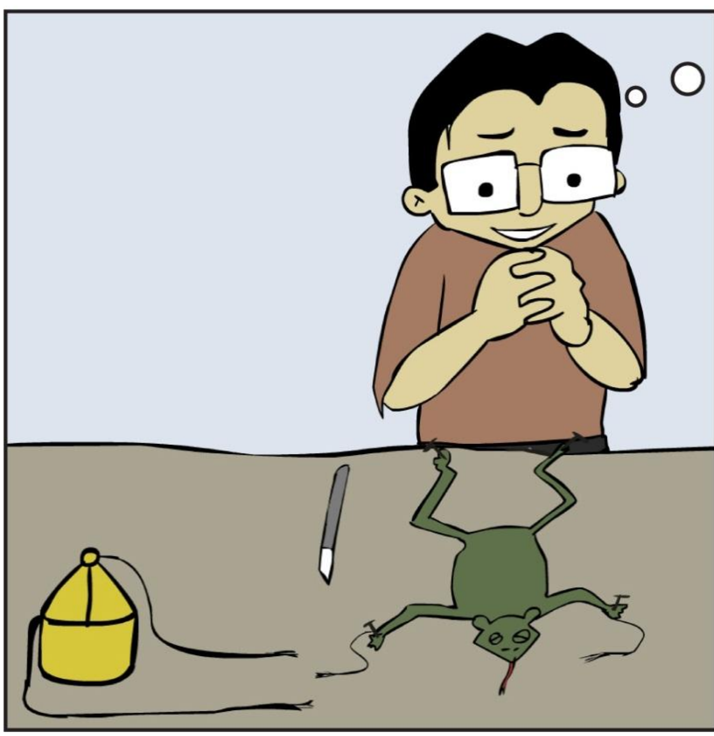
GALVANI EXPLAINED HIS TERRIFED ASSISTANT THAT THE LEG OF FROG MAY BE TWITCHING BECAUSE IT WAS CONNECTED TO THE LEYDEN JAR. THE CURRENT FROM LEYDEN JAR IS GOING INTO THE FROG'S BODY. AND JUST AS A CHARGED ROD ATTRACTED PIECES OF PAPER, SO THE CURRENT IN FROG'S BODY MUST BE CREATING A SIMILLAR attraction EFFECT CAUSING THE FROG'S LEG TO MOVE.




NEXT DAY, GALVANI WENT TO TAKE BATH IN A POND. THERE HE SAW A STRANGE F ISH.
GALVANI WAS TEMPTED TO TOUCH THE F ISH BUT AS SOON AS HE TOUCHED IT, HE GOT AN ELECTRIC SHOCK.
GALVANI RAN OUT OF THE POND AND TOLD THE INCIDENCE TO HIS ASSISTANT WHO SEEMED HARDLY SURPRISED
DONT PANICK SIR. EVERY ONE KNOWS THAT ELECTRIC EEL GIVES A SHOCK. TOO BAD YOU DIDN'T KNOW



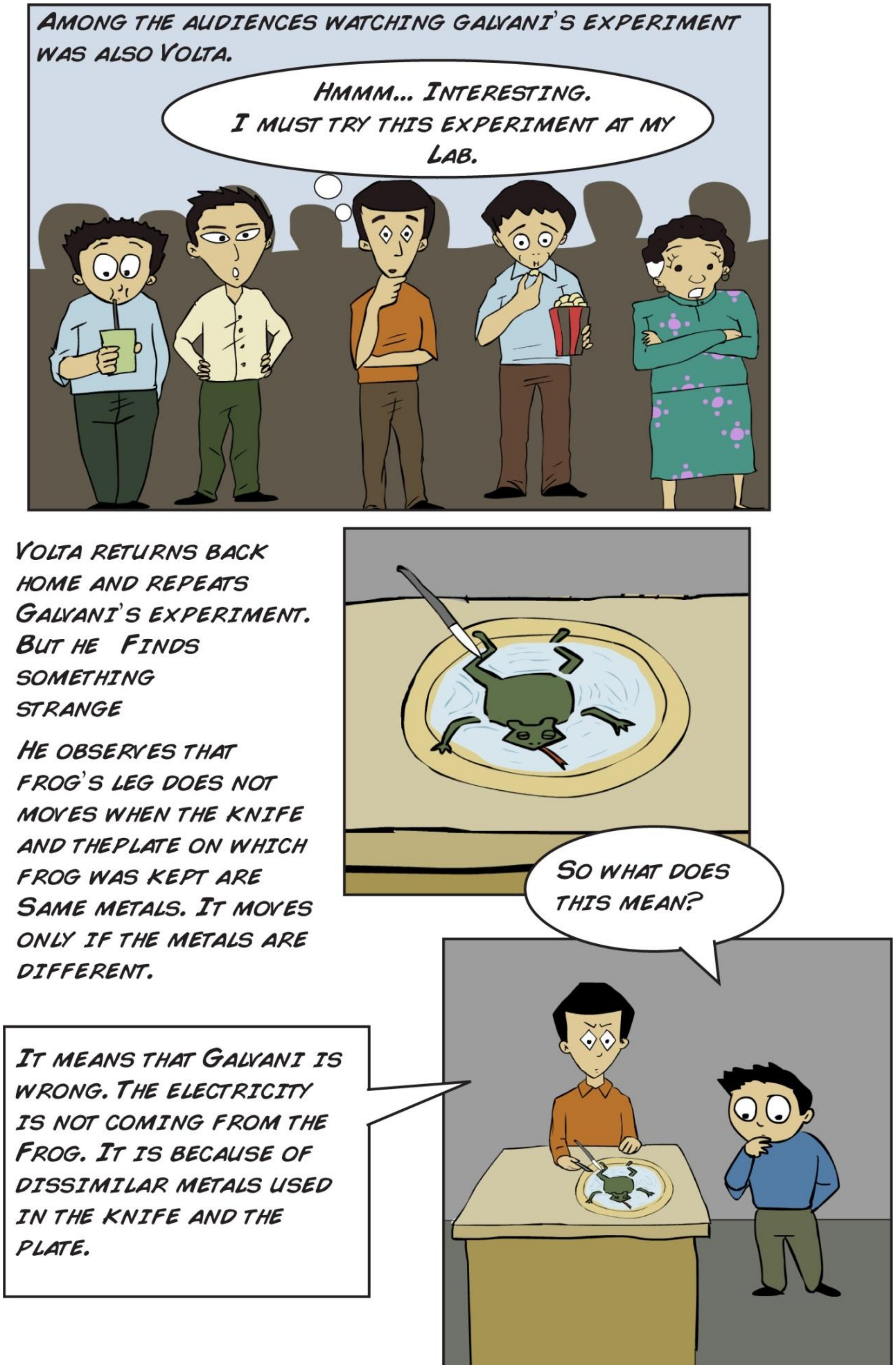
GALVANI RETURNED TO HIS WORKSHOP AND REPEATED THE EXPERIMENT. BUT THIS TIME HE DISCONNECTED THE FROG FROM THE LEYDEN JAR. TO HIS SURPRISE, THE LEG OF FROG WAS STILL TWITCHING WHEN TOUCHED BY THE METAL KNIFE

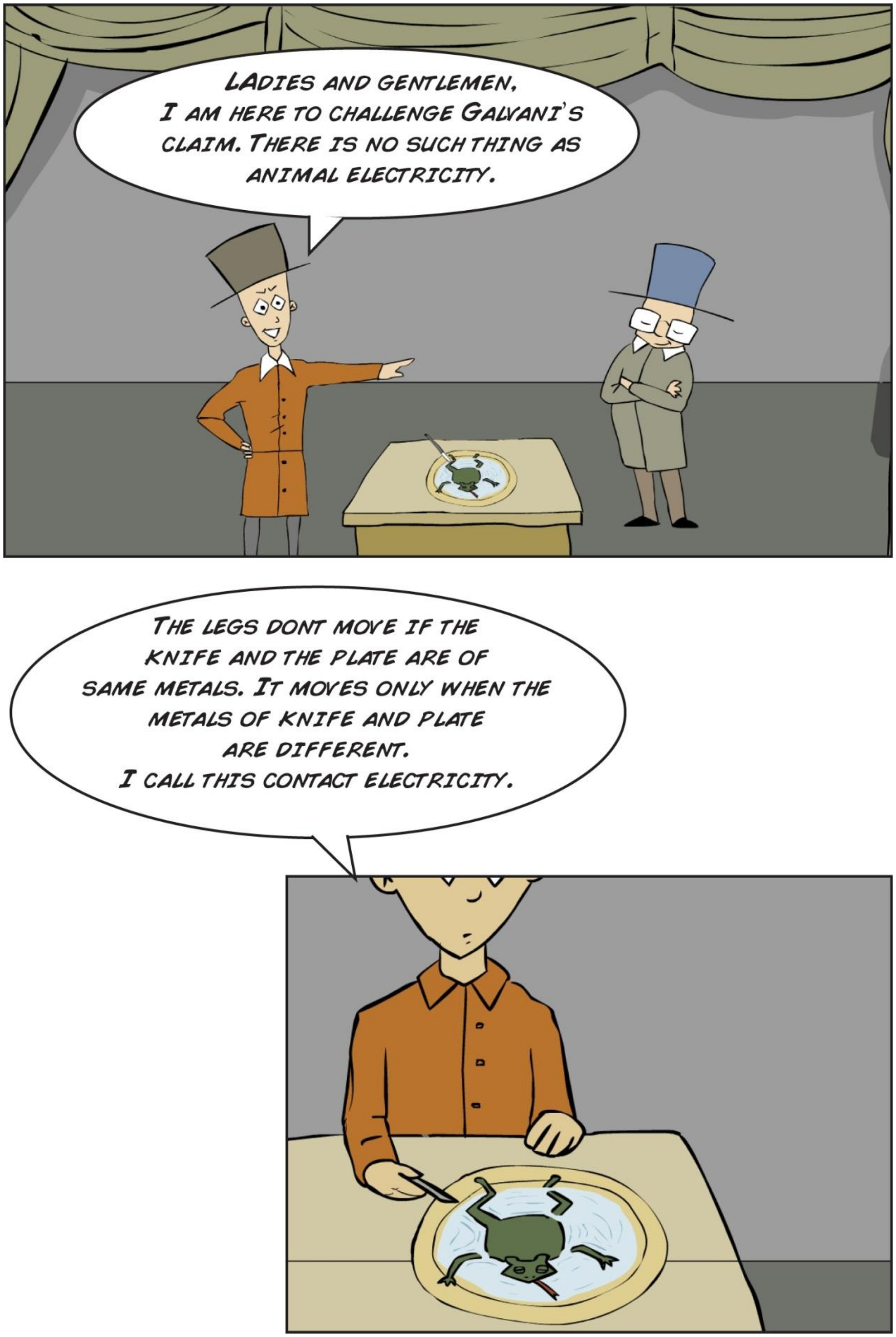


THIS APPEARS TO BE A NEW KIND OF ELECTIRCITY THAT NO ONE HAS THOUGHT ABOUT.

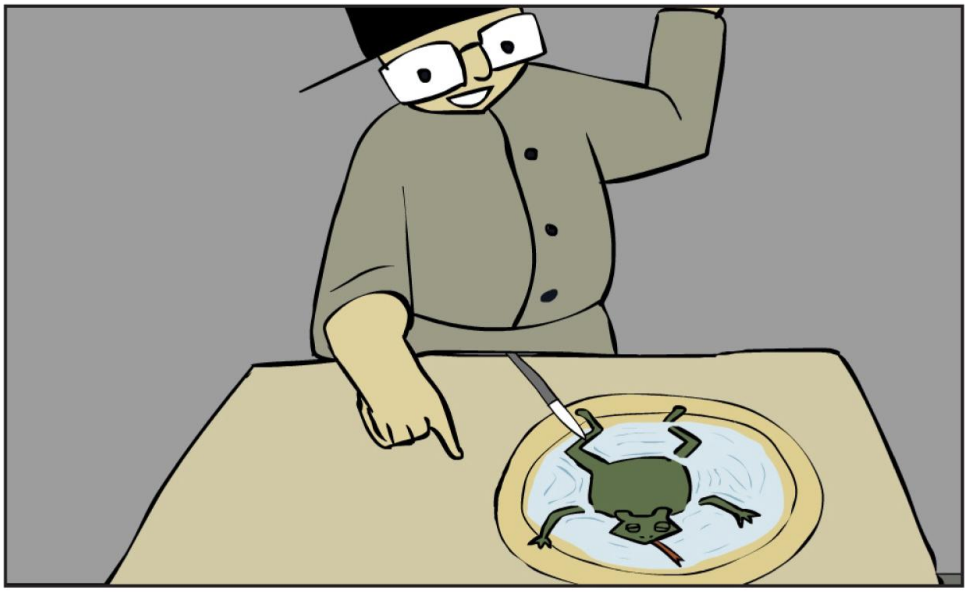
WHAT SHOUL I CALL IT. AH! "ANIMAL ELECTRICITY" DIFFERENT FROM STATIC ELECTRICITY.
I MUST REPORT THIS DISCOVERY TO THE ROYAL SOCIETY AT ONCE.


LADIES AND GENTLEMEN, I HAVE DISCOVERED A NEW KIND OF ELECTRICITY. IT'S CALLED ANIMAL ELECTRICITY. IT IS THERE IN ALL ANIMALS. IT IS DIFFERENT FROM STATIC ELECTRICITY.
WHATS THE PROOF THAT ANIMAL ELECTRICITY EXISTS. WHY SHOULD WE BELIEVE YOU?
YOU ASK FOR PROOF. I'LL GIVE YOU PROOF. I'LL TOUCH THIS DEAD FROG WITH THIS METAL KNIFE. OBSERVE WHAT HAPPENNES.
SHAKE! SHAKE!

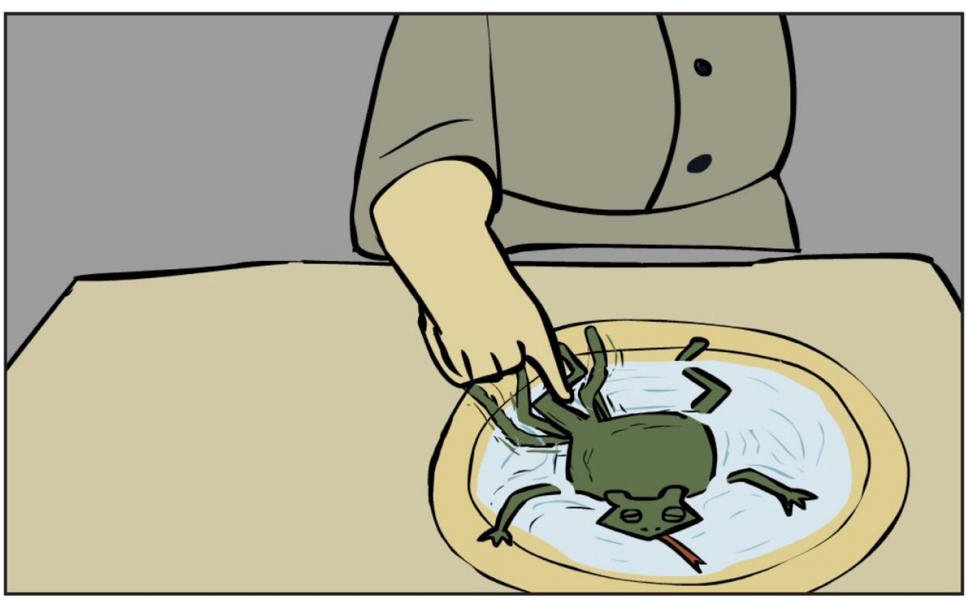

AMONG THE AUDIENCES WATCHING GALVANI'S EXPERIMENT WAS ALSO VOLTA.
HMMM... INTERESTING. I MUST TRY THIS EXPERIMENT AT MY LAB.
VOLTA RETURNS BACK HOME AND REPEATS GALVANI'S EXPERIMENT. BUT HE FINDS SOMETHING STRANGE
HE OBSERVES THAT FROG'S LEG DOES NOT MOVES WHEN THE KNIFE AND THEPLATE ON WHICH FROG WAS KEPT ARE SAME METALS. IT MOVES ONLY IF THE METALS ARE DIFFERENT.
SO WHAT DOES THIS MEAN?
IT MEANS THAT GALVANI IS WRONG. THE ELECTRICITY IS NOT COMING FROM THE FROG. IT IS BECAUSE OF DISSIMILAR METALS USED IN THE KNIFE AND THE PLATE.


LADIES AND GENTLEMEN, I AM HERE TO CHALLENGE GALVANI'S CLAIM. THERE IS NO SUCH THING AS ANIMAL ELECTRICITY.
THE LEGS DONT MOVE IF THE KNIFE AND THE PLATE ARE OF SAME METALS. IT MOVES ONLY WHEN THE METALS OF KNIFE AND PLATE ARE DIFFERENT. I CALL THIS CONTACT ELECTRICITY.

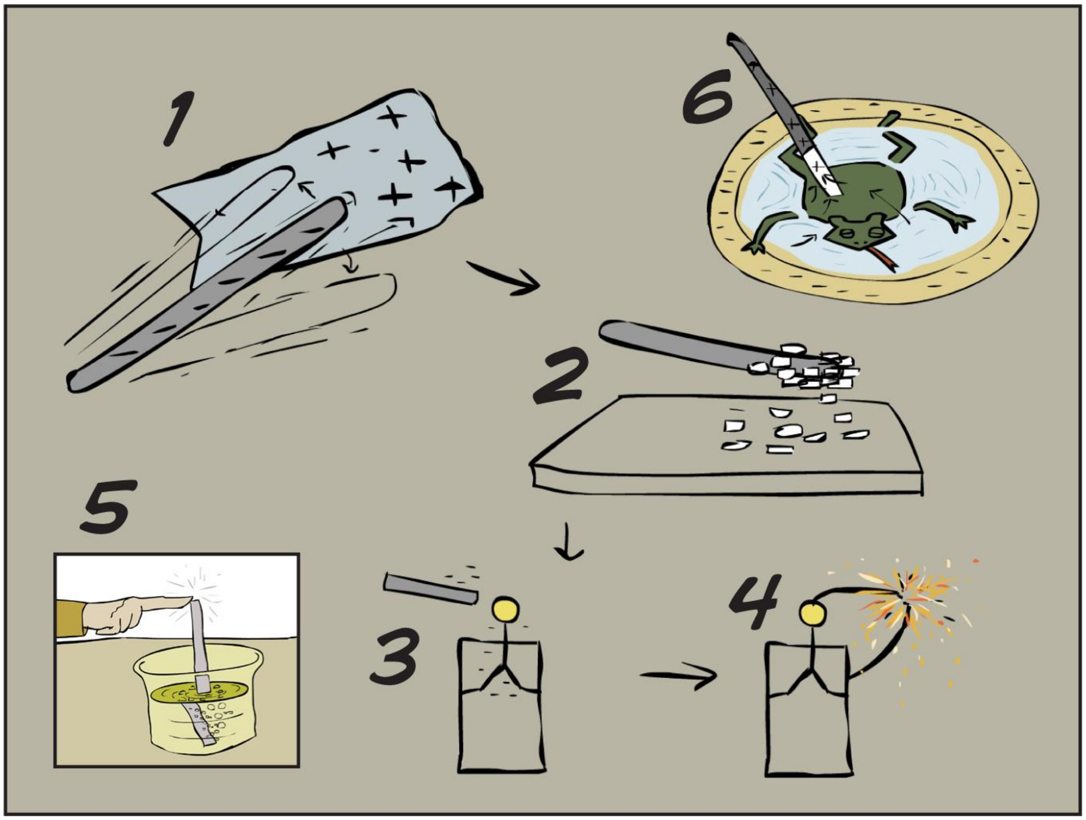
Ladies and gentlemen, I respect Volta's argument. But I do not agree with it. Now I am going to prove that the moving of frog's leg is because of animal electricity and it has nothing to do with the metals.



Galvani touches the frog's nerves merely with his Fingers and to everyone's surprise, the leg does move.
This experiment showed that animal electricty does exist and it has nothing to do with metal knife and the plate.




HOWEVER VOLTA IS NOT CONVINCED.
VOLTA MET HIS FRIEND WHO WAS AN ALCHEMIST. HE SHOWED VOLTA SOME STRANGE CHEMICALS. THESE CHEMICALS WHEN BROUGHT IN CONTACT WITH CERTAIN METALS GAVE AN ELECTRIC SHOCK.
AS SOON AS VOLTA SAW THESE CHEMICALS, HE GOT AN IDEA. HE RUSHED BAKC TO HIS WORKSHOP TO TRY IT.



VOLTA RECALLED FIVE THINGS:

1) WHEN AMBER ROD IS RUBBED WITH WOOLEN CLOTH, THE ROD GETS CHARGED.

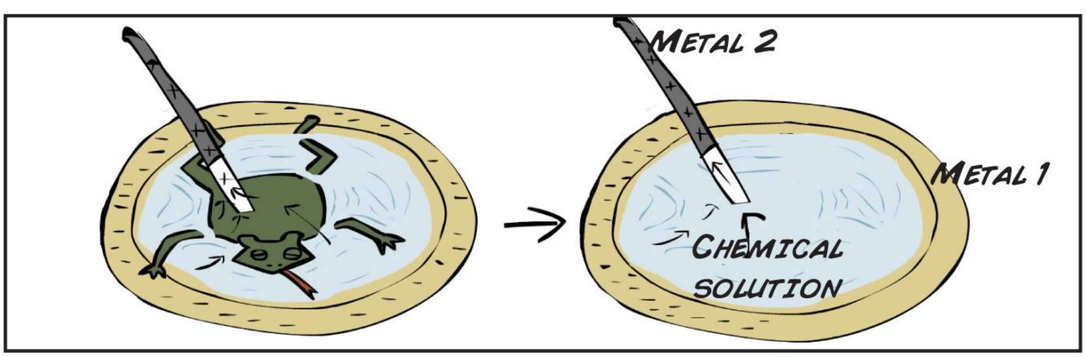
2) A CHARGED ROD attracts pieces of paper.

3) CHARGE FROM A ROD CAN BE STORED IN A LAYDEN JAR.

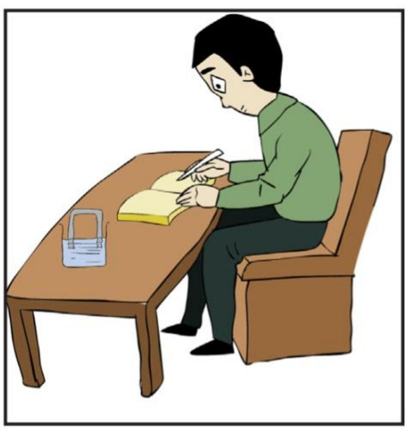
4) CHARGE CAN BE RETRIEVED FROM LAYDEN JAR BY CONNECTING ITS TWO ENDS.

5) A ROD CAN ALSO GET CHARGED WHEN A METAL REACTS WITH A CHEMICAL.

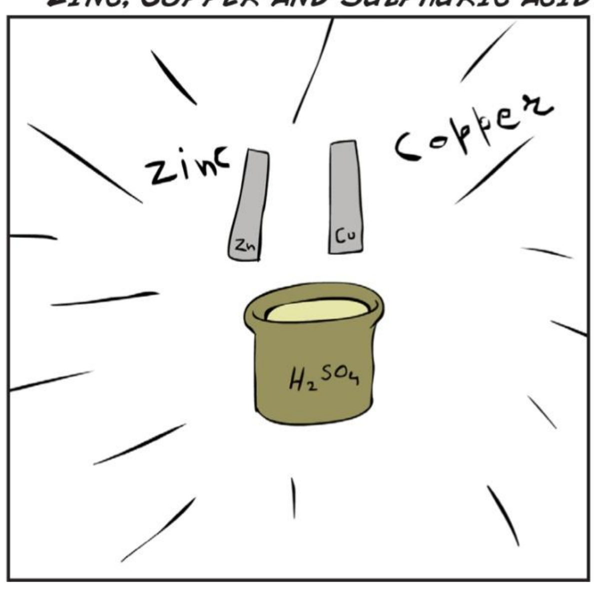
6) IF ALL THIS IS TRUE THEN THE METAL PLATE(IN WHICH THE FROG IS KEPT) MAY BE GETTING CHARGED INSTEAD OF THE FROG AND THE FROG AND THE SOLUTION MAY BE ACTING AS THE CHEMICAL SOLUTION WITH WHICH THE METAL IS REACTING.

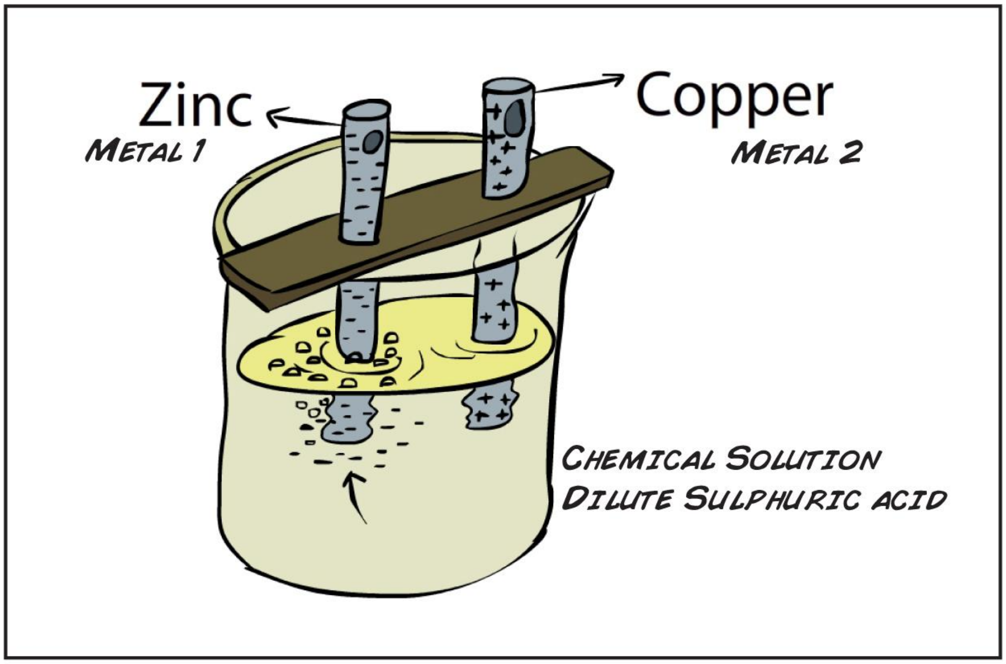


VOLTA KNEW THTA IF WHAT HE WAS THINKING WAS TRUE, THEN IT SHOULD BE POSSIBLE TO REPLACE THE FROG WITH A SIMILLAR APPARATUS BUT WITHOUT A FROG, ONLY WITH METAL STRIPS AND CHEMICAL SOLUTIONS



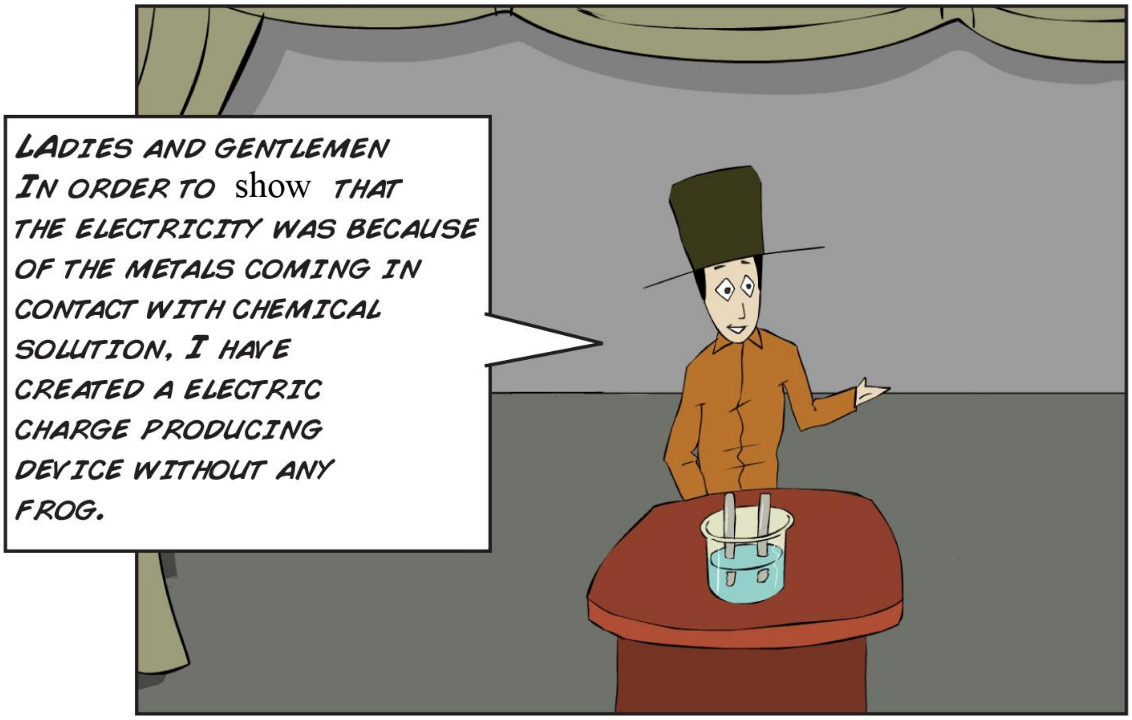
AFTER MONTHS AND MONTHS OF SEARCHING, VOLTA FINALLY FOUND THE RIGHT COMBINATION. ZINC, COPPER AND SULPHURIC ACID



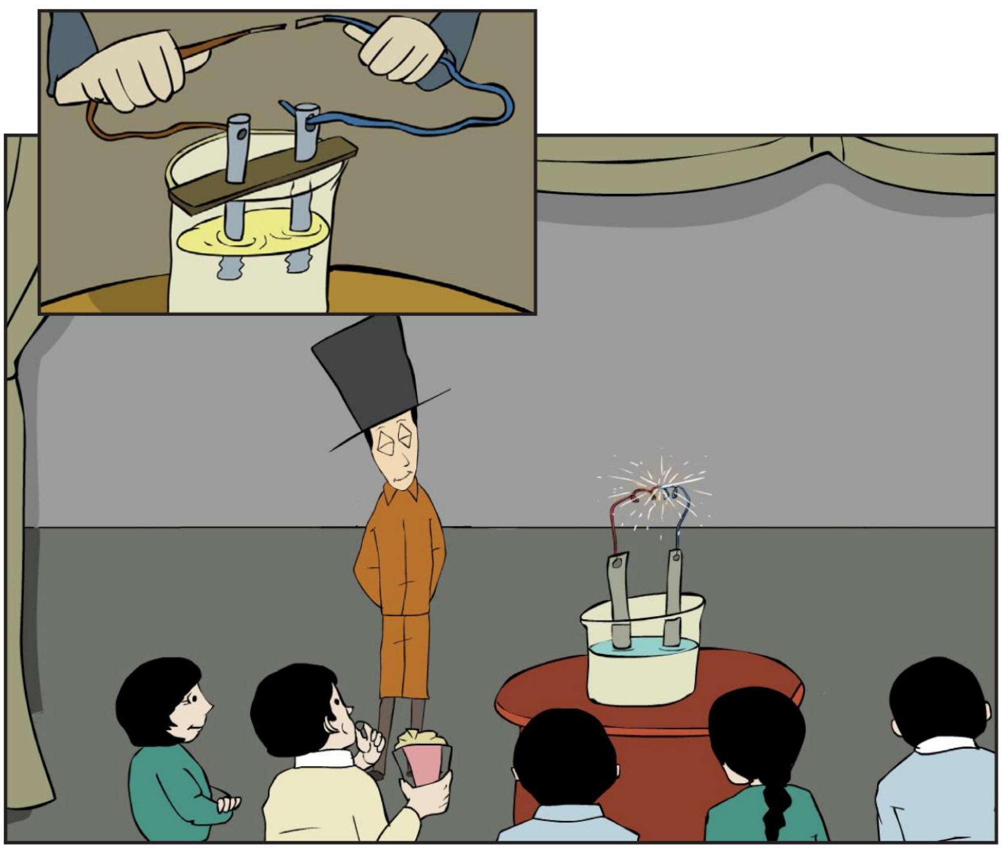


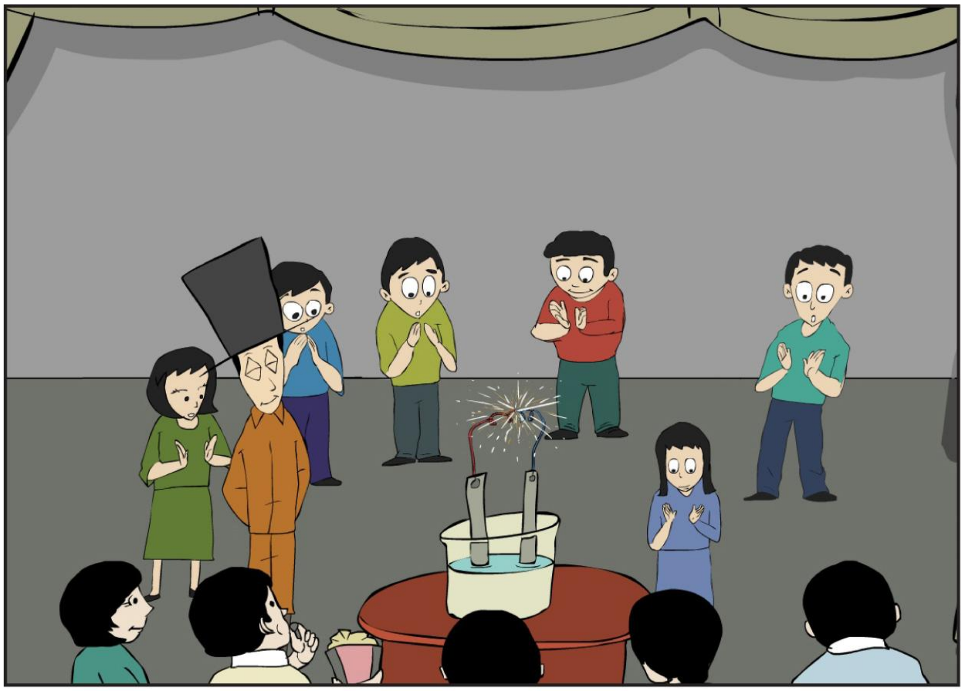
AND SO VOLTA CREATED A NEW APPARATUS WITH TWO METALS ZINC AND COPPER DIPPED IN SULPHURIC ACID. VOLTA BELIEVED THAT ZINC REACTED WITH ACID, CHARGE WOULD GET COLLECTED IN IT. AND WHEN COPPER REACTED WITH ACID, IT WOULD LOOSE CHARGE.

SO WHEN VOLTA CONNCETED ZINCE AND COPPER WITH A WIRE, ELECTRIC CHARGE MOVED FROM ONE END TO ANOTHER. THE PROOF OF THIS ELECTRIC CHARGE WAS A MILD SPARK. VOLTA HAD CREATED THE WORLD'S FIRST ELECTRIC BATTERY!!



VOLTA ARRANGED A DEMONSTRATION OF HIS APPARATUS BEFORE THE ROYAL SOCIETY.

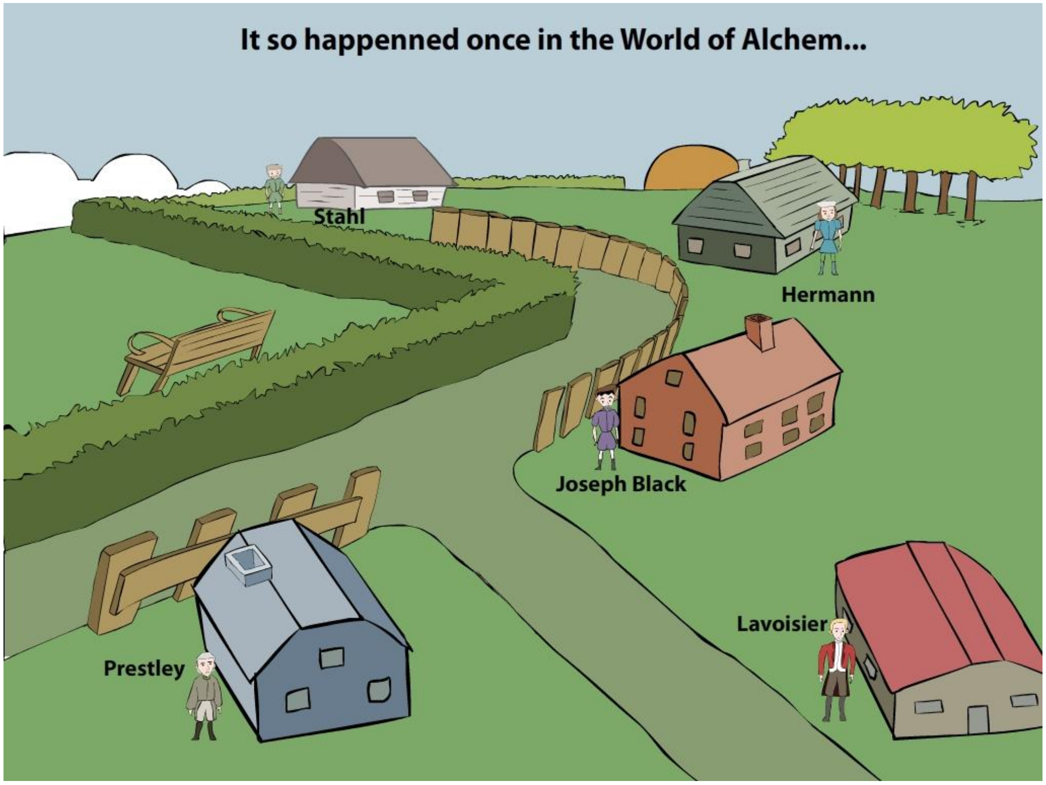


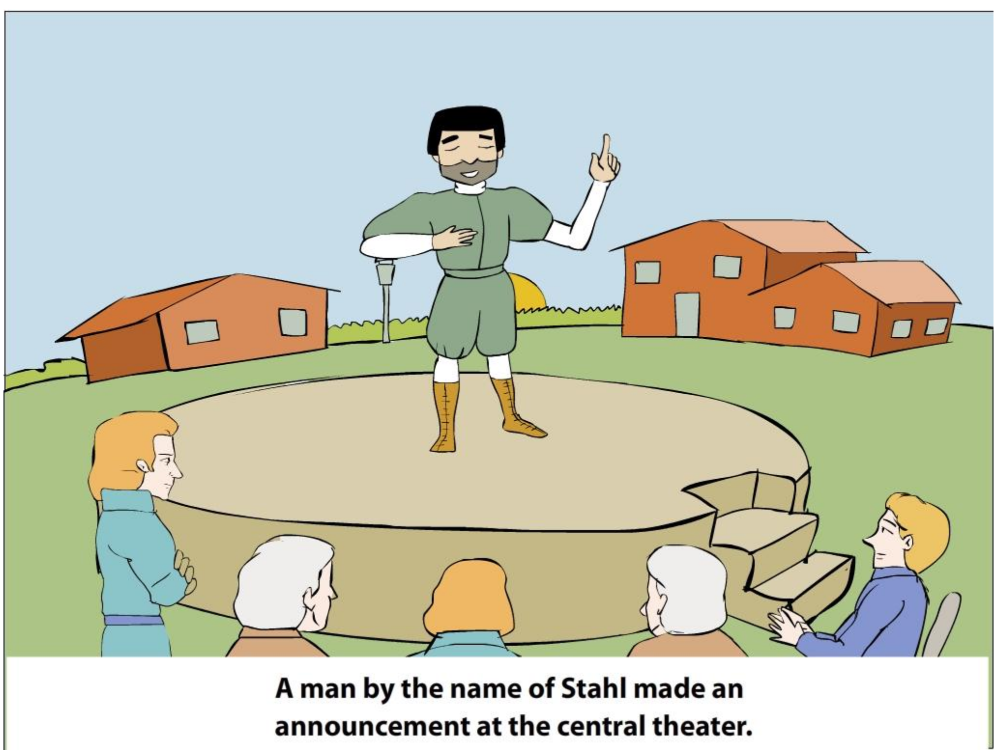


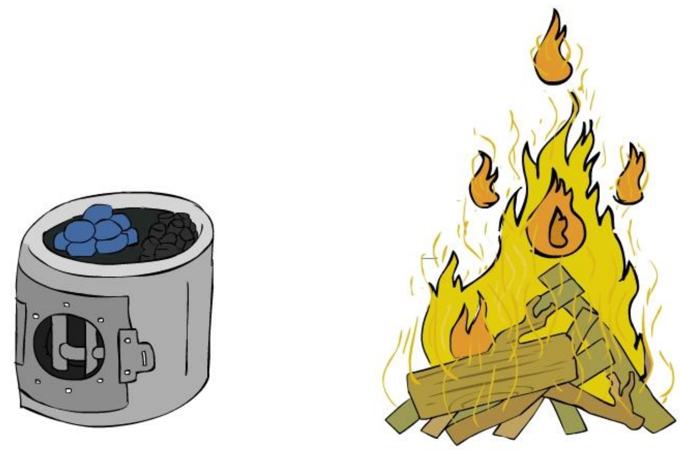
THE CROWD IS MESMERISED BY VOLTA'S DEMONSTRATION. NO ONE HAS ANY WORD TO SAY. AND IT IS shown ONCE AND FOR ALL THAT MOVING OF FROG'S LEG WAS NOT BECAUSE OF ANIMAL ELECTRICITY, BUT BECAUSE OF CHEMICAL REACTION BETWEEN DISSIMILLAR METALS AND A CHEMICAL SOLUTION.

FROM THAT DAY ONWARD OLTA IS REMEMBERED FOR GIVING ELECTROLAND ITS FIRST ELECTRIC BATTERY CALLED THE VOLTAIC PILE

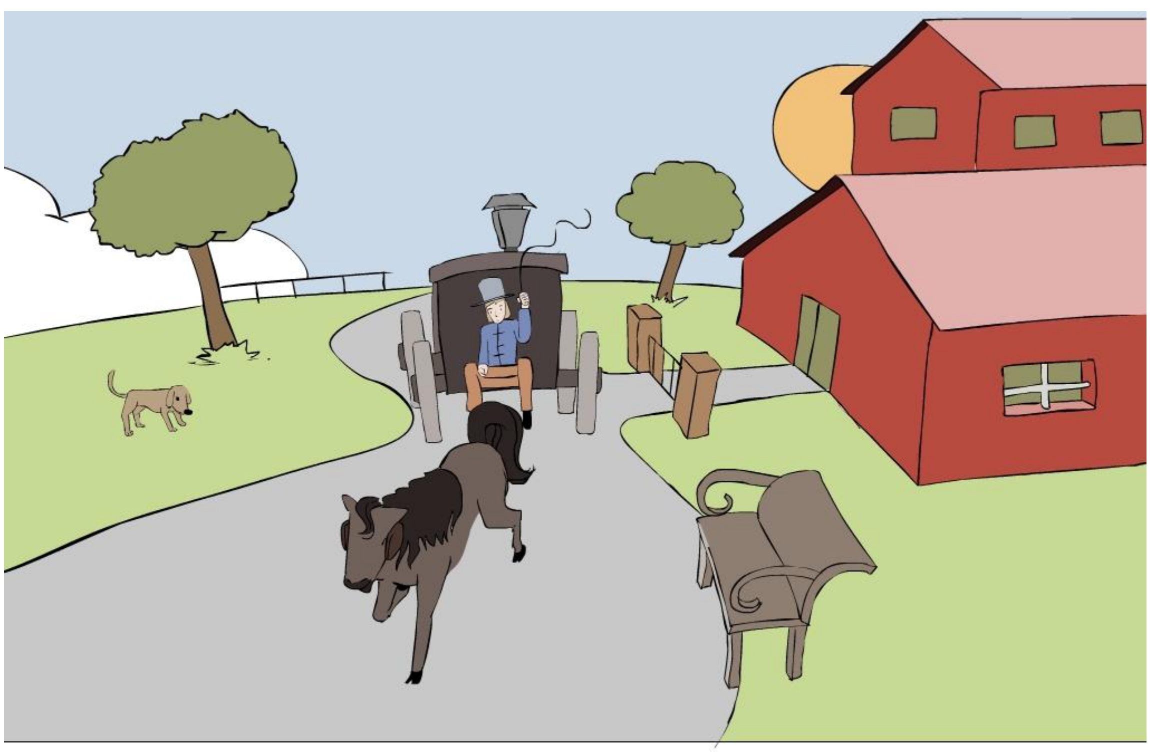
Lavoisier discovers oxygen



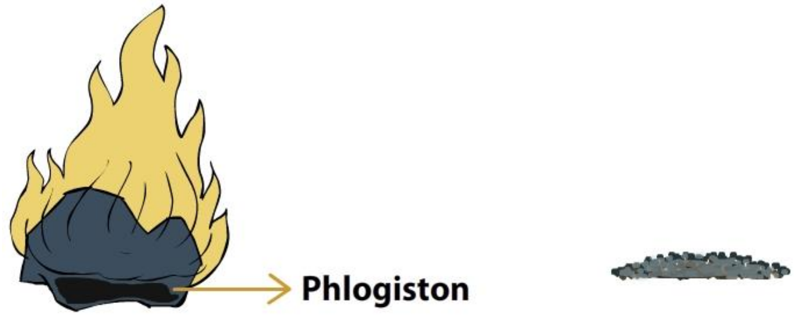




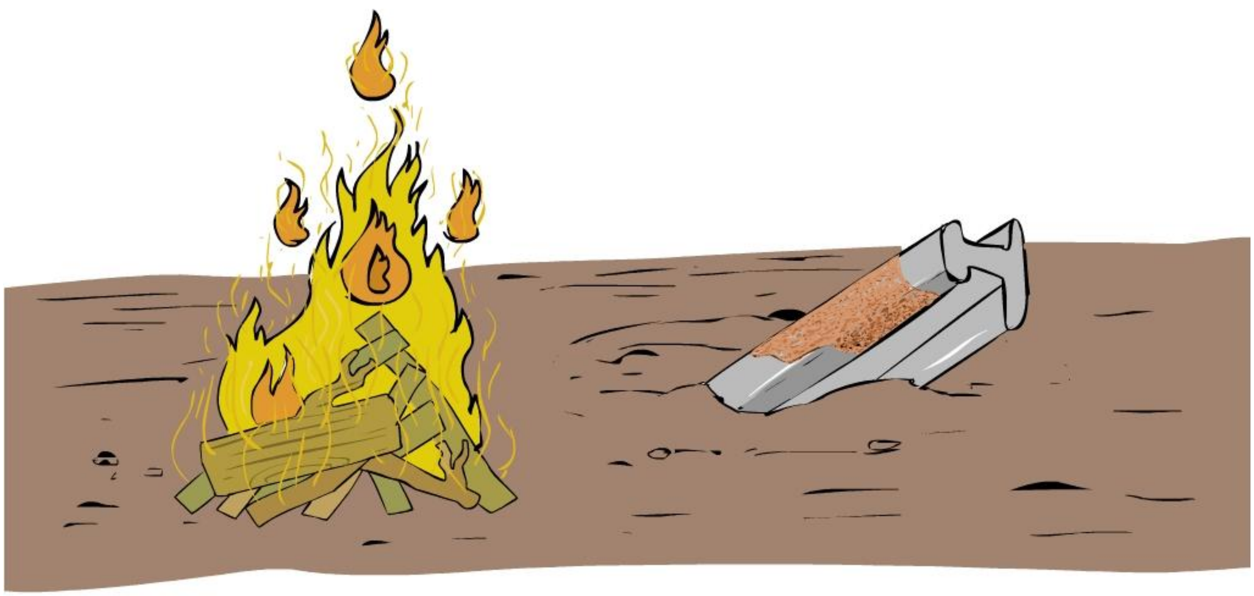
He claimed to have found the secret of combustion.
About why things burn



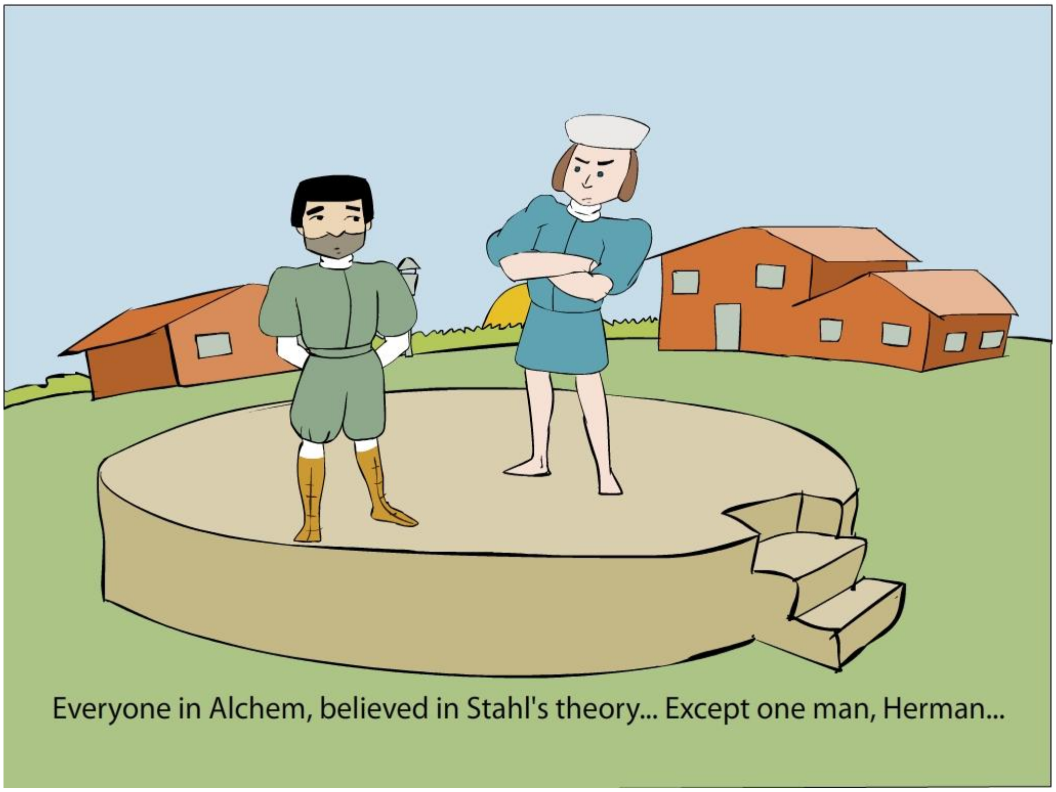
Stahl believed that everything around us had
some portion of a substance called phlogiston in it.
It is a fiery substance because of which things burn

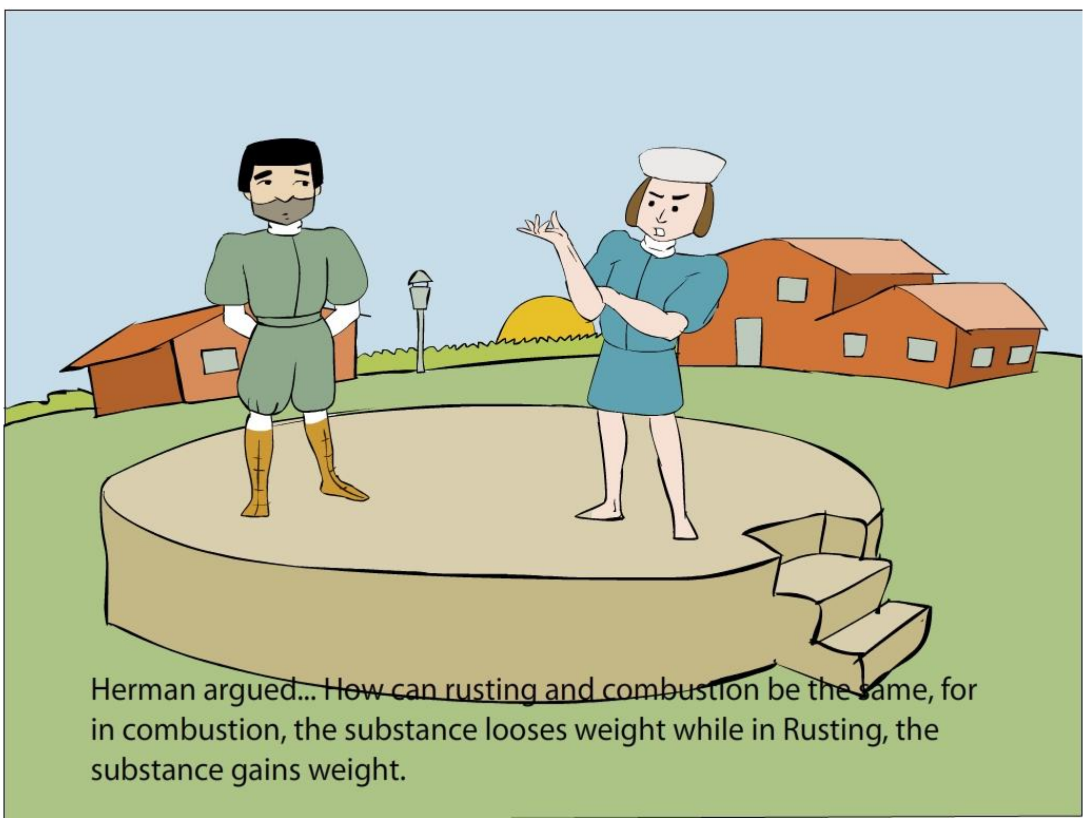


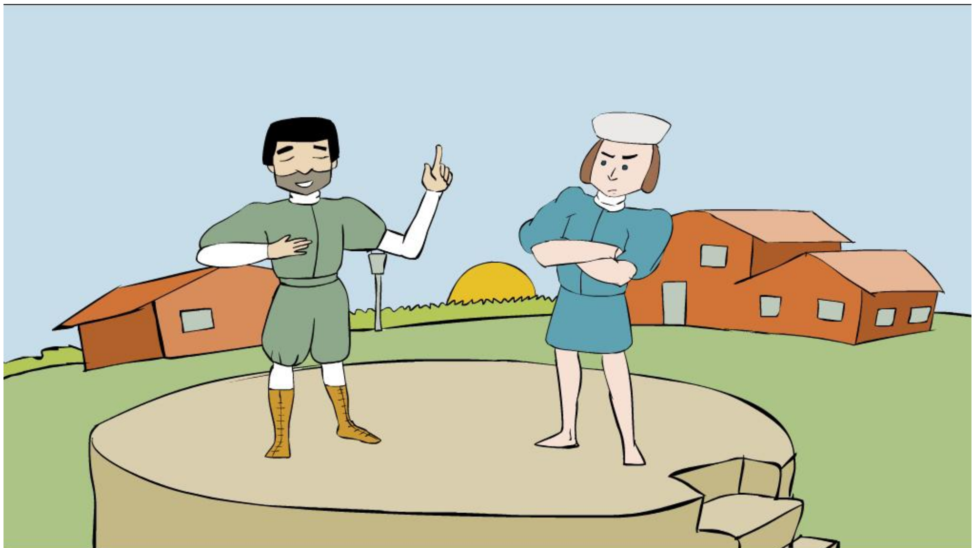
When something burns, Phlogiston is released in the air.
What remains is Earth without phlogiston.



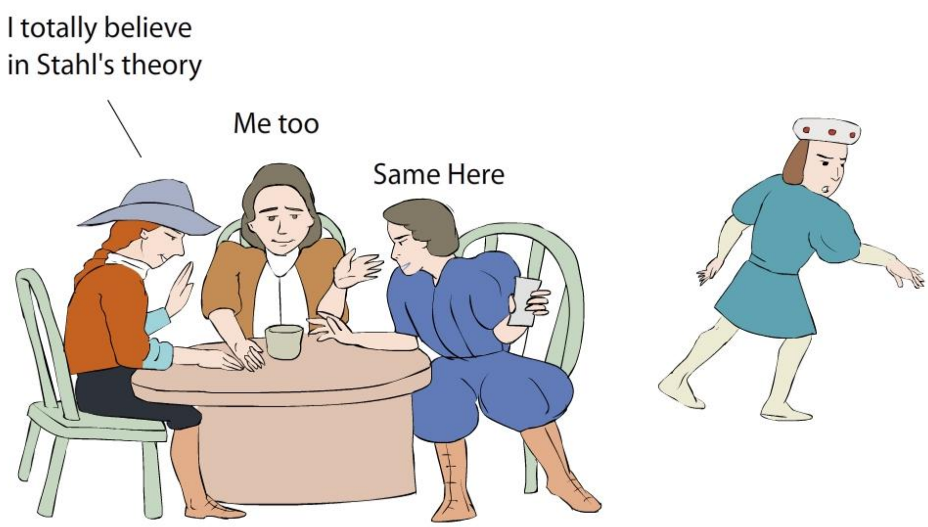
Stahl also believed that rusting and combustion were the same process, except that rusteng was a slow form of combustion. In combustion, phlogiston is released very quickly, but in rusting, Phlogiston is released very slowly...


Everyone in Alchem, believed in Stahl's theory... Except one man, Herman...


Herman argued... How can rusting and combustion be the same, for in combustion, the substance looses weight while in Rusting, the substance gains weight.

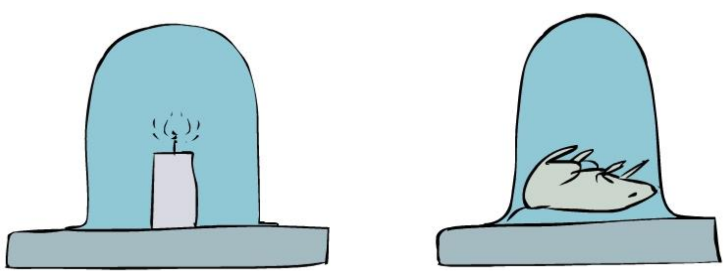


To this, Stahl's reply was that. It seems there are two kind of Phlogistons, One with Positive weight and one with Negative weight. Maybe in rusting, the Phlogiston with negative weight is released, hence the substance gains weight...



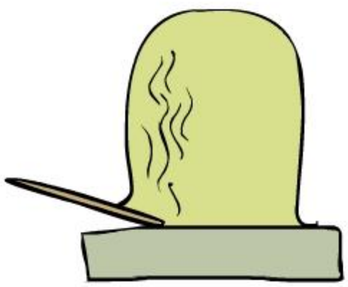
Everyone was satisfied with Stahl's Explanation. Herman, it seems was not.

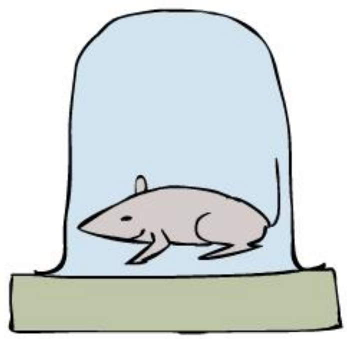
Meanwhile, there was a scientist in alchem who was trying to capture the vapours of Substance after heating. He collected a gas after heating calcium Carbonate with strange properties.



He found out that in this gas, a cndle would not burn and a mouse would die faster than normal air.

Inspired by Joseph Black's experiment, a scientist called Prestley tried collecting vapours by burning ores of different metals





The vapour colleted after burning ore of Mercury Oxide, revealed very strange properties. A candle burnt with brilliant flame and a mouse lived longer in it than normal air.

Prestley called this gas deflogisticated air, because he believed that this air, had lost phlogiston thats why when something was burnet in it, It accepted the phlogiston from the burning substance with greater eagerness. Hence, the substance burnt better in it.

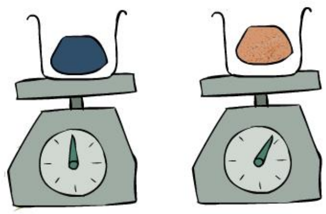
Meanwhile, there was another scientist in Alchem, his name was Lavoisiour. He was the finest maker of Gunpowder. Whoever bought Gunpowder from him, was sure to win in a war.

The secret of his excellent gunpowder was his precise measurement of weights of substances. He had created the best weing balance in the history of Alchem.

Prestley was a good friend of Lavoisier. He showed his experiments with Mercuric oxide and release of the strange vapour to Lavoisier. Lavoisier immediately got interested in it.

Lavoisier tried to repeat the experiement and found same results.

A candle burnt with brilliant flame and a mouse lived longer in it than normal air.



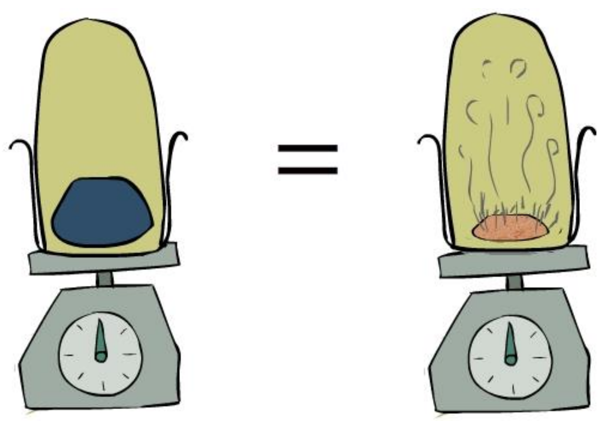
Lavoisier wondered if the ore is measured alone, it gains weight, But if everything is weighted together, there is no change in weight. How could that be?

Lavoisier inferred that maybe, something from the air was loosing weight and adding to the weight of the ore. What could that thing be?

Lavoisiour's doubt got confirmed when opended the lid. As soon as he opened it, atmospheric air gushed into the vessel as if some vaccuum had developed inside

Lavoisiour concluded from all his experiments that the phlogiston theory which everyone was believing all this while was wrong.

He went on to postulate the true cause of Combustion and rusting of substances. It is because of addition of Oxygen in air, mixing with the substance that causes it to burn and not because of phlogiston releasign from it. Maybe there is no suchthing as Phlogiston.



He also introduced the law of conservation of mass.
According to this law, in a chemical reaction, the overall mass of reactant and the products remains constant.

Because of Lavoisiour's contribution, he is remembered as the father of Modern Chemistry even till this day and maybe forever in the future.

Appendix 4

Type of knowledge content present in 6th to 8th std. NCERT books

The five main categories of knowledge content were developed by compiling the various conceptual terms used in chapters of std. VI, VII and VIII textbook. Category of terms from class VII textbook are given in following tables:

Nutrition in Plants				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Nutrients Heterotrophs Autotrophs Chlorophyll Stomata Host Parasite Rhizobium	Nutrition Photosynthesis Symbiosis	Sun is the ultimate source of energy for all living organisms		

Table 4.2: Category of terms used in chapter Nutrition in Plants

Nutrition in Animals				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Buccal Cavity Stomach Intestine Liver Stomata Host Parasite Rhizobium Digestive system Bile Juice Gall Bladder Amoeba	Ingestion Digestion Egestion Rumination			

Table 4.3: Category of terms used in chapter Nutrition in Animals

Fiber to Fabric				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Wool Silkworm Mullbery Silk	Sericulture Rearing Scouring Rolling Shearing			

Table 4.4: Category of terms used in chapter Fiber to Fabric

Heat				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Thermometer Insulator Conductor	Conduction Convection Radiation	Heat travels from Hot to cold Heated substance, expands in size	Hot/Cold Temperature measurement	

Table 4.5: Category of terms used in chapter Heat

Physical and chemical changes				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
	Physical Change Chemical Change Rusting Crystallization Galvanization	No new substance is produced in a physical change A chemical change leads to formation of one or more new substances	Hot/Cold Temperature measurement	

Table 4.6: Category of terms used in chapter Physical and Chemical changes

Acid, Bases and Salts				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Acids Bases Salts Litmus Paper	Neutralization	Whenever Acids and Bases react with each other, Salt and Water is produced		

Table 4.7: Category of terms used in chapter Acids, Bases and Salts

Time and Motion				
Knowing Names of things And their category	Knowledge of Process	Knowledge of Phenomenon	Knowing by comparison	Miscellaneous (doubt)
Pendulum Odometer Distance – Time Graph	Motion Oscillation	The oscillation period of a simple pendulum depends on the square root of its length	Time measurement Distance Measurement Speed Measurement	

Table 4.8: Category of terms used in chapter Time and Motion

Based upon the categories of knowledge type, a separate story plot model was developed for each. Each plot model defined the basic story element, The story plot model, a story plot as an example and the detailed story. These story plots were then tested with group of teachers to see if they were able to build stories using these models. The five different plot model are given from table 14 to 18.

Knowledge of names and categories		
Story Elements	**Story Plot Model**	**Story Plot**
Setting Visit to a zoo **Characters** Agent = Jipsy and Pipsy Entity= Animals and Birds Guidance = Father	Entering a new world	Jipsy and pipsy visit the zoo
Problem Unknown Names	Finding new things in the new world	They find many new animals and birds in the zoo
Resolution Getting acquintance with new animals and birds		
Definition Identification is about knowing the names of things and the category of things to whoich they belong along with their properties	Returning back home	They free the animals and return home

Story

Jipsy and pipsi lived with his father Noni and mother Moni.
Once on a bright sunny weekend, father Noni decided to take Jipsy and pipsi on a ride in their car.
Where are we going father? Asked Jipsi.
"To a secret place. Wait till we reach there" Replied their father.
Jipsi and Pipsi had a lot of fun when on the way but soon they arrived at a strange place.

There was a big entrance gate there and as soon as they entered the gate
Jipsi shouted in amazement
"Oh my good look what happened to that monkey his face is so black"
Noni: Oh don't be afraid, it's a Langoor.
Jipsi: A Langoor? But he looks like a monkey.
Noni: Langoors is different from a monkey. They are bigger and taller and have a huge tail.
As they moved on, they Pipsi shouted at the sight of another strange creature.
Pipsi: Look! Such a huge cat!!!
Noni: It is known as the leopard. It runs faster than a cat and lives by eating pigs and other small animals.
Hardly they moved a few meters when they heard the sound of a bird drilling a hole in a tree.
" look a bird with a hammer" exclaimed Jipsi.
"Its called a wood pecker. Its beak is sharp enough to drill a hole in any tree. It uses the drilled hole to build a house for herself"
Explained Noni.
And what is the name of that beautiful bird with huge feathers? Asked Pipse pointing at a bird.
"Oh, she's a peacock. It's also the national bird of India" answered Noni.
"Oh no, look what a long neck that animal has." Exclaimed Pipsi.
"It's a Giraffe" answered Noni
The whole day Pipsi and Jipsi roamed around the zoo looking at different animals and knowing more about them. And finally they came home but Jipsi was a little sad. She said "Why were those animals and birds in cage father?"
Noni said "they are there so you kids can enjoy them"

But Jipsi and Pipsi were troubled by this. They said "But would they not feel bad sitting in a prison. They are not even free to move."
Noni had no answer to this question.
But Jipsi and Pipsi were concerned about the animals. They wished they could do something about the animals.
Next day when all people of zoo came out to work. They found no animal there.
Pipsi and Jipsi had been to the zoo a night earlier secretly and freed all the animals. Now all animals lived in the jungle happily with their families.

Table 4.9: Version 2 - Story Element, Story Plot Model, Story Plot and Story in knowing categories

Knowing by comparison

Story Elements	Story Plot Model	Story Plot
Setting World of Light	**A** is the maker of a product Y	John is the maker of Kerosene lamps
Characters John Jacob Guardian of Light world	Knowledge of making **Y** is stolen	John's friend Jacob Steals the knowledge of making kerosene Lamps
Problem Finding a better way of Producing light	**A** goes in search Of a better Y	John searches for A better way of Producing light
Resolution Producing Light Through electricity	**A** finds a better Y	John finds a new way Of producing light by passing electricity through a high resistance wire
Definition Major part of knowing is about differentiating the object of knowledge with something else. This differentiation is done by comparing some attribute of object with another	**A** returns with better Y and regains lost prosperity	John returns home With new knowledge and Makes the incandescent bulb

Story

Electric bulb story

John was the maker of kerosene lamps.
He was the only one in his village who had the knowledge of making kerosene lamps

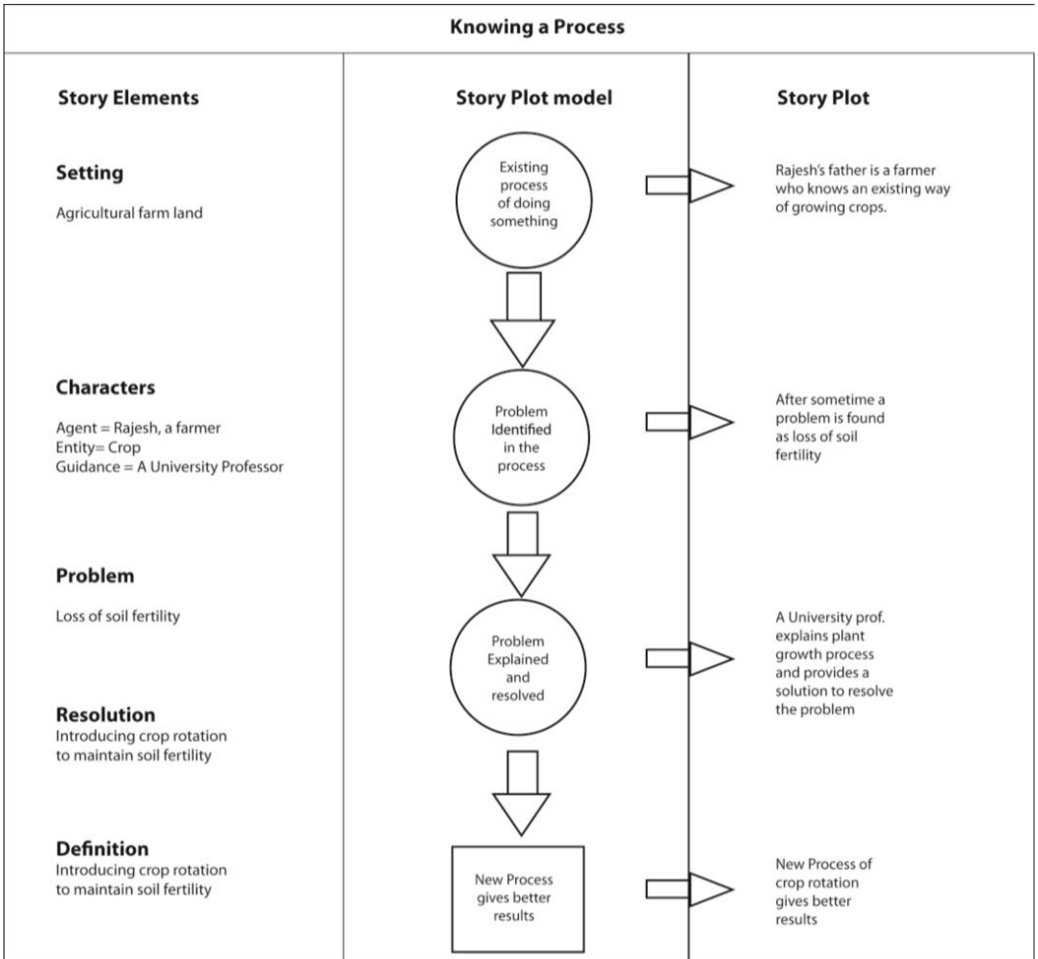
Seeing his prosperity, his friend Jacob felt Jealous and one day when John had gone out to buy material for the lamp, he entered his workshop and stole the book in which knowledge of making lamps was kept

John returns home only to find that the knowledge Was stolen. However, instead of loosing hope, he decides to go in search of something better than lamp

John goes to the world of lighting and there, the Guardian of light gives him the knowledge of Producing light through electricity. He introduces John to a better element called Tungsten.

John returns home and makes a new type of Lighting device called an incandescent bulb. People see the benefits of incandescent bulb over the kerosene lamp and the bulb becomes popular and John is hailed for this new innovation

Table 4.10: Story Element, Story Plot Model, Story Plot and Story in knowing by comparison type



Story

Rajesh, a 14 year old boy lived in a small town of Vadodra. His father worked in a farm. Since Rajesh was studying in an engineering college, the owner of the farm used to call him whenever any machine broke down. Rajesh had a natural talent for fixing machines. After finishing graduation, Rajesh decided to build his own farm with the knowhow gained while fixing machines for his father.

He met many people, expert farmers to get advise on which crop to sow. On the advise, he sowed wheat as it was in great demand. He was really excited initially but after 5 years, he noticed the yield of wheat started reducing dramatically. He consulted many friends but they too were experiencing the same thing. Finally, Rajesh met a professor in the Gujarat University of agriculture, Prof. Amte. He explained Rajesh the process of plant growth.

The main ingredients for growth of a plant are air, sunlight, water, soil and fertilisers. Air, sunlight and water is available, but when the same type of crop is sown on the same soil, it constantly looses essential nutrients. That is why the technique of crop rotation is followed. As when one crop strips the soil of fertility in certain minerals, when a new crop is sown, the soil gets time for replenishing the lost minerals from the soil.

Rajesh returned to his farm and started sowing two crops instead of one. Now he sowed corn along with wheat. This not only helped him retain the fertility of soil but also, it helped in increasing business as now Rajesh had two crops to sell instead of one.

Table 4.11: Story Element, Story Plot Model, Story Plot and Story in knowing a process type

Knowing a Law

Story Elements	Story Plot Model	Story Plot
Setting Transportation World	Existing world	Existing world Transportation
Characters Agent = Navik, a Boatmaker Entity= Boat Guidance = A University Professor	Mysterious situation	Sinking of boats
	search for principle	search for principles meeting with
Problem Sinking of boats		
Resolution Application of beyoncy Principle in making boats with more capacity	Possible explanation	Finding relation between displaced and total weight the boat
Definition A law states a relaitionship between two or more entities for example gravitation depicts relationship between mass and distance between objects	Situation resolved	Design of new boats with more capacity

Story

In the world of Electronics lived a boy who was popularly known as Navik. All children of Electronics world were predestined to get jobs in the electronic sector. But Navik had something else in mind.

On many occasions, he narrowly escaped death during travelling by a boat as many boats used to overtunr.

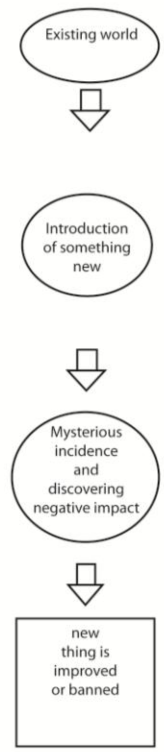
Even though Navik was from the electronics world, his mind naturally wondered about finding the cause of overturning of boats. He had a faint idea that the boats overturned because of overweight but he wanted to know how could one decide how much passengers a boat could take. He spent many sleepless nights thinking about it.

Finally, he decided to take help from a College professor Mr. pant., who directed Navik to the physics professor Mr. Ramchandran. He explained Navik about the principle behind floating of heavy objects in water. He explained that there was a hidden law of nature in it called the Buoyancy principle. According to this law, a body floats in water if the amount of water displaced by it is more than its own weight. This law helps in knowing how much weight a boat will be able to take according to its size. Mr Ramchandran also explained the method of calculating the same.

Navik went back to his town and tried to explain the law to the boatmen. But no one gave any importance to him as they did not want to reduce the number of passengers travelling. Then, instead of trying to convince boatmen to take only a specific number of passengers, Navik decided to design new boats with more capacity. In a year's time, news spread about Navik's boats being safe at the same time more spacious. Very soon, Navik became the central source from where boatmen bought new boats. The old boat makers also came to Navik to learn about making boats

Table 4.12: Story Element, Story Plot Model, Story Plot and Story in knowing a Law type

Knowing an Environmental effect

Story Elements	Story Plot Model	Story Plot
Setting A glass bottle manufacuring plant		Story of a glass bottle maker
Characters Agent = Bimal, a Bottlemaker Entity= Bottles Guidance = A University Professor		A new material called plastic is introduced
Problem Release of toxic chemicals by plastic bottle plant		
Resolution Discovery of Recyclable plastic		A new material causes toxicity in ecosystem
Definition A negative affect of a scientific discovery or invention For example: negative effects of using petrol engine on environment		New, recyclable plastic is introduced to replace

Story

There was once a bottle maker named Bimal. He made exquisite glass bottles. He had learnt the art of moulding glass from his father who was the owner of a glass furnace. After the death of his father, Bimal took over the business and took it to great heights. His bottles were in great demand in all parts of India.

One day after going back home from work, a man stopped him. He had something with him that immediately caught Bimal's attention. They had a brief conversation and then Bimal went back home. Since that day, Bimal seemed a little lost in some thought. People wondered what happened to him. But he never told anyone. Every night he started leaving early to meet that man who possessed something mysterious that had caught all of Bimal's attention. All the people who worked at Bimal's office wondered what happened to Bimal. Before their eyes could raise further questions. One day Bimal announced the launch of a new bottle which was not made of glass. It was a wonder material called plastic.
Plastic moulding was much easier than making glass. It promised less input and more profit. The plastic factory was making brisk profit as everyone found plastic products as more convenient.
However some scientists in the nearby laboratory found out that Bimal's plastic factory was releasing harmful toxins in the nearby river. They made Bimal aware about the danger of plastic waste for the nearby ecosystem.

Bimal continued making more and more plastic bottles and marketed them even more aggressively. One day when Bimal returned from a long vacation with his family, Bimal got the shock of his life. His plastic factoy was sealed by order from Supreme Court. Bimal's dream world suddenly came to an end. Since his sale went drastically down, he was unable to pay the bill for his expensive lifestyle.

Bimal was totally depressed, but his uncle, George who was a University Professor came to his rescue. He advised Bimal instead of sulking forever, there was a way by which he could still make plastic bottles. Prof. George introduced him to recycled plastic. This was a kind of plastic that could be recycled again and again so the amount of toxic emissions in the atmosphere reduces considerably.
Now Bimal not only took care of the old glass factory but also commissioned the work of cleaning the nearby river which was at the verge of death because of the plastic waste.

Table 4.13: Environment effect story plot model.

Appendix 5

Questionnaire used in Experiments

Experiment no. 1

Questionnaire for experiment no. 1 with model answers

1) Write the summary of chapter Fiber to Fabric in your own words(Textbook Based) .

Model Summary

- *Paheli and Boojo go to a garment shop.*
- *Different type of fabrics as cotton, wool, silk.*
- *The thin strands of thread that we see, are made up of still thinner strands called fibres.*
- *Fabrics are made up of yarns and yarns are further made up of fibres.*
- *The fibers of some fabrics such as cotton, jute, silk and wool are obtained from plants and animals.*
- *Cotton fibers are made from cotton plants found in cotton field.*
- *There are many ways by which fabrics are made from yarns. The two main processes are weaving and knitting.*
- *It appears that in those times people used the bark and big leaves of trees or animal skins and furs to cover themselves.*
- *In those days, stitching was not known. People simply draped the fabrics around different parts of their body.*
- *With the invention of the sewing needle, people started stitching fabrics to make clothes.*
- *Two types of fibers are synthetic and manmade.*

1a) Write the story of Stich in your own words (Story Based).

Model story

- *Once upon a time in Creationland.*
- *Lived a boy named Stich.*
- *He and his father made clothes from animal skin.*
- *Stich didn't like garment making because it meant killing of animals.*
- *One day Stich sees a Basket maker displaying cane baskets at central square.*
- *Learns/observes weaving process for making baskets.*

- *Stich gets the idea of using weaving technique for making garments from grass.*
- *But, Grass garment not good because of…*
- *Searches new material.*
- *Finds cotton plant.*
- *Forms thin strands called fiber from cotton.*
- *Forms yarn from fiber.*
- *Weaves yarn like basket to form a fabric.*
- *Makes needle.*
- *Stitches fabric to form garment cloths.*
- *Displays his invention at Central Square.*
- *Stich starts his garment shop and becomes famous.*

2) What is a yarn?

   A yarn is a thin thread like substance that is made by twisting many cotton fibers together

3) What is a Fabric?

   A fabric is a cloth surface formed by weaving yarn in a Criss-Cross manner.

4) Describe the process of making a cotton fabric.

   Cotton is extracted from cotton plant,

   Fiber is extracted from cotton,

   Fiber is rolled between fingers and sometimes in a tool like charkha to form a yarn, which looks like a thread.

   Then the yarn is weaved in a criss-cross manner like a basket, to form fabric.

5) What are the disadvantages of using grass as material for making a fabric

   Grass is a weak material; it breaks easily, so it does not make a strong fabric.

Grass can also get torn easily.

Experiment no. 2

Questionnaire for experiment no. 2 with model answers

1) Write the summary of chapter on Electricity in your own words.
   - *Two types of charges are positive and negative charge*
   - *Like charges repel each other, Unlike charges attract each other*
   - *A body can be charged by friction, contact or Induction*
   - *Atom is electrically neutral, protons are positively charged, Electrons are negatively charged*
   - *When charged electrons travel from one body to another*
   - *Flow of electric charge constitute electric current.*
   - *Flow of electrons through a wire continue as long as there is arrangement to remove electrons*
   - *Alessandro Volta made first attempt to produce electric current*
   - *Voltaic cell consists of Copper and zinc strips dipped in dilute sulphuric acid*
   - *The solution of acid in water is called electrolyte*
   - *The two metal strips are known as electrodes.*
   - *The reaction results in accumulation of negative charge on one electrode and Positive on another*
   - *The flow of current is maintained in voltaic cell as long as the reaction continues*

1a) Write the Story of Thomas and Electricity in your own words

- *There was a City by the Name of Energon*
- *Thomas was an engineer in Energon*
- *He wanted to make electric bulb*
- *But source of electricity Leyden Jar was not good*
- *Thomas wanted better source but could not find*
- *Thomas saw Volta demonstrating Voltaic cell at central square*
- *Volta explained how he made voltaic cell*
- *He put zinc rod and Copper plate in dilute H2SO4 by mistake*
- *Zinc and copper are electrodes and H2SO4 sol. is electrolyte*
- *Zinc is positively Charged, Copper is Negatively charged*
- *When connected by a good conductor, it showed flow of current/shock*
- *He bought the Voltaic cell and did his experiment with electric bulb*
- *Thomas dream of making the light bulb came true*

1) What is a Voltaic Cell?

Voltaic cell was the first electric battery created by scientist Alessandro Volta. It produced continuous flow of current.

2) What is an Electrode and Electrolyte in Voltaic cell?

Zinc and copper rods are the electrodes and dilute Sulphuric acid is the electrolyte.

3) Why is Voltaic Cell better than an Electroscope?

Voltaic cell is better because it gives continuous flow of current which an electroscope does not.

Experiment No. 3: Questionnaire with model answers

1) What is a Voltaic cell made up of?

Voltaic Cell is made up of Electrode Copper and Zinc Rod/Strip/Plate, Electrolyte H2SO4/Saline solution = 5

Voltaic Cell is made up of Copper and Zinc Rod/Strip/Plate, H2SO4/Saline solution = 4

Voltaic cell is made up of Copper and Zinc rods = 2

Voltaic cell is made of metal rods and acid solution = 1

2) What is the use of a Voltaic cell?

Attempted answer maybe wrong/not absurd = 1

Voltaic cell is used to create/generate electric current/electricity = 3

Electric current is used in torch, and other appliances = 5

3) How can you create electric current?

For 1 source of electric current like waves = 1

For 2 source of electric current = 2

For many source of electric current including/or only battery = 3

For attempted description of processes/maybe wrong/but not absurd = 4

For Correct description of process=5

Appendix 6

Experiment Data

Data for Experiment 1 KVIIT school (Control Group)

	GENDER	AGE	NPREQ1	NPREQ2	NPREQ3	NPRETOT	NPOSTQ1	NPOSTQ2	NPOSTQ3	NPOSTQ4	NPOSTOT
1	F	10	0	0	0	0	5	1	0	0	6
2	F	10	0	0	0	0	5	0	0	0	5
3	M	10	0	0	0	0	5	3	0	1	9
4	M	10	0	0	0	0	4	3	2	0	10
5	M	9	0	0	0	0	0	0	0	0	0
6	M	10	0	0	0	0	2	2	2	3	9
7	M	10	0	0	0	0	0	0	0	0	0
8	F	10	0	0	0	0	1	0	0	0	1
9	M	11	0	0	0	0	1	1	0	0	1
10	M	10	0	0	0	0	0	0	0	0	0.5
11	M	10	0	0	0	0	0.5	1	5	0	6.5
12	F	10	0	0	0	0	1	1	0	0	2
13	M	10	0	0	0	0	0.5	0.5	0	0	1
14	F	10	0	0	0	0	4.5	5	1	4	14.5
15	M	10	0	0	0	0	1	0	0	0	1
16	M	10	0	0	0	0	0	0	0	0	0
17	M	10	0	0	0	0	0.5	0.5	0	0	1
18	F	9	0	0	0	0	1	1	0	0	2
19	F	10	0	0	0	0	0.5	0.5	1	4	6
20	F	9	0	0	0	0	2	2	0.5	0	4.5
21	M	9	0	0	0	0	0.5	0.5	0	0	1
22	F	11	0	0	0	0	0.5	0	0	0	0.5
23	F	9	0	0	0	0	0.5	0.5	0	0	1
24	F	10	0	0	0	0	3	2	2	5	12
25	F	10	0	0	0	0	4	2	1	0	7
26	F	9	0	0	0	0	3	2	0	0	5
27	F	10	0	0	0	0	2	1	0	0	3
28	M	11	0	0	0	0	5	2	2	0	9
29	M	9	0	0	0	0	0.5	0.5	0	0	1
30	F	10	0	0	0	0	2	1	2	0	5
31	F	10	0	0	0	0	3	2	0	0	5
32	M	10	0	0	0	0	0.5	2	1	4	7.5
33	M	10	0	0	0	0	0.5	1	0	0	1.5
34	M	10	0	0	0	0	0.5	0.5	0	0	1
35	M	10	0	0	0	0	3	2	3	0	8
36	M	10	0	0	0	0	4	0	0	0	4
37	M	10	0	0	0	0	1	1	1	0	3
											AVG=
											4.175676

Data for Experiment 1 KVIIT school (Experimental Group)

sl.	GENDER	AGE	SPREQ1	SPREQ2	SPREQ3	SPRETOT	SPOSTQ1	SPOSTQ2	SPOSTQ3	SPOSTQ4	SPOSTOT
1	F	10	0	0	0	0	5	1	3	3	12
2	F	10	0	0	0	0	0	0	0	0	0
3	M	10	0	0	0	0	3	2	0	4	9
4	M	10	0	0	0	0	4	1	3	4	12
5	M	9	0	0	0	0	4	2	0	3	9
6	M	10	0	0	0	0	2	2	3	0.5	7.5
7	M	10	0	0	0	0	1	0.5	4	5	10.5
8	F	10	0	0	0	0	0.5	1	3	4	8.5
9	M	11	0	0	0	0	0.5	0.5	0	0	1
10	M	10	0	0	0	0	2	2	3	0	7
11	M	10	0	0	0	0	0.5	0	5	4	9.5
12	F	10	0	0	0	0	5	4	5	4	19
13	M	10	0	0	0	0	0	0.5	2	0	2.5
14	F	10	0	0	0	0	4	3	5	4	16
15	M	10	0	0	0	0	5	5	5	4	19
16	M	10	0	0	0	0	0.5	0	0	0	0.5
17	M	10	0	0	0	0	0.5	0.5	1	0	2
18	F	9	0	0	0	0	3	1	5	4	13
19	F	10	0	0	0	0	0	0	1	0	1
20	F	9	0	0	0	0	0	0	0	0	0
21	M	9	0	0	0	0	1	0.5	4	4	9.5
22	F	11	0	0	0	0	1	1	3	4	9
23	F	9	0	0	0	0	2	1	4	4	11
24	F	10	0	0	0	0	0.5	0.5	1	3	5
25	F	10	0	0	0	0	0.5	0.5	1	0	2
26	F	9	0	0	0	0	5	0	5	3	13
27	F	10	0	0	0	0	3	1	4	5	13
28	M	11	0	0	0	0	0	0	0	0.5	0.5
29	M	9	0	0	0	0	1	1	3	2	7
30	F	10	0	0	0	0	5	2	4.5	3	14.5
31	F	10	0	0	0	0	3	2	4	2	11
32	M	10	0	0	0	0	5	5	4	3	17
33	M	10	0	0	0	0	5	1	2	2	10
34	M	10	0	0	0	0	2	1	4	3	10
35	M	10	0	0	0	0	5	1	5	0	11
36	M	10	0	0	0	0	4.5	1	4.5	4	14
37	M	10	0	0	0	0	3	1	3	3	10
38	M	10	0	0	0	0	2	1	5	5	13
39	F	9	0	0	0	0	1	1	4.5	3	9.5
											AVG=
											8.948718

Data for Experiment 2 Campus school IIT Bombay (Control and Experimental Group)

ID	Age	Gender	Lessontype	PRE1	PRE2	PRE3	PRETOT	POST1	POST2	POST3	POSTOT
1N	13.00	F	STATE	0.00	0.00	0.00	0.00	4.00	4.00	0.00	8.00
2N	12.00	F	STATE	0.00	1.00	0.00	1.00	4.00	5.00	5.00	14.00
3N	12.00	F	STATE	0.00	0.00	1.00	1.00	1.00	5.00	0.00	6.00
4N	11.00	M	STATE	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00
5N	12.00	M	STATE	0.00	0.00	0.00	0.00	4.00	3.00	0.00	7.00
6N	11.00	M	STATE	0.00	0.00	0.00	0.00	4.00	0.00	0.00	4.00
7N	13.00	M	STATE	0.00	0.00	0.00	0.00	1.00	2.00	0.00	3.00
8N	13.00	M	STATE	0.00	0.00	0.00	0.00	1.00	3.00	0.00	4.00
9N	12.00	F	STATE	0.00	0.00	0.00	0.00	5.00	3.00	0.00	8.00
10N	15.00	F	STATE	0.50	0.00	0.00	0.50	0.50	1.00	0.00	1.50
1S	13.00	F	STORY	0.00	0.00	0.00	0.00	5.00	4.00	5.00	14.00
2S	12.00	F	STORY	5.00	5.00	5.00	15.00	5.00	5.00	5.00	15.00
3S	12.00	F	STORY	1.00	2.00	1.00	4.00	3.00	5.00	5.00	13.00
5S	12.00	M	STORY	1.00	0.00	0.00	1.00	5.00	5.00	5.00	15.00
9S	12.00	F	STORY	0.00	0.00	0.00	0.00	5.00	5.00	4.50	14.50
11S	12.00	F	STORY	1.00	0.00	0.00	1.00	5.00	3.00	4.50	12.50
12S	12.00	F	STORY	0.00	1.00	1.00	2.00	5.00	5.00	5.00	15.00
16S	13.00	F	STORY	0.00	0.00	0.00	0.00	4.50	3.00	5.00	12.50
17S	12.00	F	STORY	0.00	0.00	0.00	0.00	4.00	5.00	2.00	11.00
21S	12.00	M	STORY	0.00	0.00	0.00	0.00	1.00	3.00	0.00	4.00
22S	12.00	M	STORY	0.00	0.00	0.00	0.00	1.00	4.00	0.00	5.00

Data for Experiment 3 Powai English medium school (Control Group)

Sl No	ID		Sex	NPREQ1	NPREQ2	NPREQ3	NPOSTQ1	NPOSTQ2	NPOSTQ3	NPOSTAvg
1	NF1	11	F	0	0	2	2	0	0.5	2.5
2	NM2	12	M	0	0	2	0	3	0.5	3.5
3	NM3	14	M	0	0	2	4	2	0	6
4	NM4	12	M	0	0	2	5	0	0	5
5	NF5	12	F	0	0	0.5	2	0.5	0	2.5
6	NM6	13	M	0	0	0	0	3	0	3
7	NM7	13	M	0	0	2	0.5	0	4	4.5
8	NM8	13	M	0	0	0	3	1	0	4
9	NM9	12	M	0	0	2	4	3	0	7
10	NM10	12	M	0	0	0	0.5	0	2	2.5
11	NM11	11	M	0	0	2	0	0	0	0
12	NM12	12	M	0	0	0	3	3	0	6
13	NF13	11	F	0	0	2	4	3	1	8
14	NF14	12	F	0	0	1	2	0	0	2
15	NM15	13	M	0	0	0.5	2	0	0.5	2.5
16	NF16	12	F	0	0	0	4	0	0	4
17	NF17	12	F	0	0	0	0.5	0	0	0.5
18	NF18	11	F	0	0	1	3	3	0	6
19	NF19	11	F	0	0	0	0	0	0	0
20	NM20	12	M	0	0	0	3	3	0	6
21	NM21	12	M	0	0	1	0	0	0	0
22	NF22	12	F	0	0	0	2	0	0.5	2.5
23	NF23	11	F	0	0	0	2	0	0	2
24	NF24	12	F	0	0	1	0	0	1	1
25	NM25	12	M	0	0	0	0	0	1	1
26	NM26	12	M	0	0	1	4	0	1	5
27	NF27	10	F	0	0	1	1	0	0	1
28	NM28	14	M	0	0	0.5	0	0	0	0
29	NM29	13	M	0	0	0	0	0	0	0
30	NF30	11	F	0	0	2	2	0	4	6
31	NF31	12	F	0	0	1	3	3	1	7
32	NF32	12	F	0	0	0	0	0	0	0
33	NF33	12	F	0	0	1	1	0	1	2
34	NF34	12	F	0	0	0	2	0	0	2
35	NM35	13	M	0	0	0.5	0	0	0	0
36	NM36	11	M	0	0	1	0.5	0	1	1.5
37	NF37	12	F	0	0	0.5	2	2	0	4
38	NM38	12	M	0	0	0	2	3	0	5
39	NM39	12	M	0	0	0	0	0	0	0
40	NM40	12	M	0	0	2	2	3	5	10
41	NM41	14	M	0	0	0.5	2	0	0	2
42	NF42	12	F	0	0	0.5	1	0	0.5	1.5
43	NM43	12	M	0	0	0	2	0	0	2
44	NF44	12	F	0	0	1	3	3	3	9
45	NM45	13	M	0	0	0	3	0	0.5	3.5
46	NM46	12	M	0	0	0.5	2	0	0.5	2.5
47	NM47	12	M	0	0	0.5	2	2	1	5
48	NM48	13	M	0	0	0.5	0	0	0	0
49	NM49	12	M	0	0	0	4	3	3	10
50	NM50	12	M	0	0	0	0	3	2	5
51	NM51	12	M	0	0	0.5	0	0	0.5	0.5
52	NM52	12	M	0	0	0	0	0	0	0

Experimental group (STORY)

SlNo	ID	Age	Sex	SPREQ1	SPREQ2	SPREQ3	SPOSTQ1	SPOSTQ2	SPOSTQ3	SPOSTTOT
1	SM1	13	M	0	0	0.5	3	3	0.5	6.5
2	SM2	12	M	0	0	0.5	0	2	0.5	2.5
3	SF3	11	F	0	0	0	3	3	4	10
4	SM4	12	M	0	0	0.5	2	1	0	3
5	SF5	11	F	0	0	0	0	4	4	8
6	SF6	12	F	0	0	1	4	3	2	9
7	SF7	12	F	0	0	0	0	0	4	4
8	SM8	13	M	0	0	2	4	3	2	9
9	AM9	12	M	0	0	1	2	3	1	6
10	SF10	12	F	0	0	1	0	3	0	3
11	SF11	12	F	0	0	0.5	3	3	3	9
12	SF12	11	F	0	0	0	2	2	1	5
13	SF13	12	F	0	0	0	2	0	2	4
14	SF14	12	F	0	0	0	2	3	0	5
15	SM15	13	M	0	0	0	0.5	0	0	0.5
16	SM16	12	M	0	0	0	3	3	0	6
17	SM17	11	M	0	0	0	1	3	2	6
18	SM18	12	M	0	0	0.5	1	1	4	6
19	SM19	12	M	0	0	0	0	0	0	0
20	SF20	13	F	0	0	0	0	3	4	7
21	SM21	11	M	0	0	1	3	2	4	9
22	SF22	11	F	0	0	0	0	4	4	8
23	SF23	14	F	0	0	0	2	2	1	5
24	SM24	12	M	0	0	1	2	4	4	10
25	SM25	12	M	0	0	1	2	0.5	0.5	3
26	SM26	11	M	0	0	0	3	3	0	6
27	SM27	12	M	0	0	0.5	4	4	4	12
28	SM28	13	M	0	0	0	4	0	0	4
29	SM29	11	M	0	0	2	4	4	4	12
30	SM30	12	M	0	0	0	4	0	0	4
31	SF31	12	F	0	0	0.5	2	4	0	6
32	SM32	13	M	0	0	1	4	3	3	10
33	SM33	13	M	0	0	0.5	4	3	4	11
34	SM34	12	M	0	0	0	4	4	4	12
35	SF35	11	F	0	0	1	3	3	1	7
36	SF36	12	F	0	0	1	0	0	2	2
37	SF37	11	F	0	0	0	1	4	4	9
38	SF38	12	F	0	0	0.5	3	4	1	8
39	SM39	12	M	0	0	1	3	0	1	4
40	SM40	11	M	0	0	0.5	0	3	0	3
41	SM41	12	M	0	0	0	2	3	1	6
42	SF42	13	F	0	0	0	1	3	0	4
43	SM43	12	M	0	0	0	4	2	0	6
44	SF44	12	F	0	0	0	1	0	0	1
45	SM45	12	M	0	0	1	3	3	3	9
46	SM46	11	M	0	0	0	4	3	0	7
47	SF47	13	F	0	0	0	1	0	0.5	1.5
48	SM48	12	M	0	0	0	1	3	4	8
49	SM49	12	M	0	0	0.5	4	4	4	12

Appendix 7

Pilot experiment data of Atomic Energy school II, BARC, Mumbai

Pilot exploratory study at Homi Bhabha Centre for Science Education (HBCSE)

Aim of this exploratory study was to introduce iteration in the initial version of ENF framework by getting feedback from secondary school students. They participated in the story design process by constructing stories using the ENF framework. Evaluation of the stories they made helped us identify the flaws in the framework and later the ENF framework was modified and used in new experiments.

Participants

A three day workshop was conducted at Homi Bhabha Centre for Science Education. The student participants were from Atomic Energy School No. 2 located at Bhabha Atomic Research Centre (BARC). Total student participants were 24, out of which, number of Girls were 10 and Boys were 14. Samples were selected by pasting a notice on the school notice board and whoever responded was invited to participate in the workshop. Total exposure time for intervention was 6 hours. Total time of experiment was 9 hrs. with a session of 3 hours spread over 3 days. There were in all two story writing sessions. Story one was an individual exercise. For story two, students were divided into groups of three students. There were a total of 8 groups, 5 boys group, and 3 girls group.

Procedure and Materials

On day one students were told stories about function of an object and how such a story could be developed using the ENF Framework. A description of ENF framework was given to participants along with sample story of how tree got its function. Students after understanding the framework chose an object and wrote a story about its function. On the next day, they were told the ENF framework with model story plot on how an electric bulb came into being.

They were then asked to identify variables in the story and replace it with their own chosen items. They were asked to collect information regarding their chosen subject matter. They did the research from internet and by asking questions to the instructor. Based upon the collected information, the students created their own stories and presented them in the form of a skit. The session lasted for three days. On the first day students were acquainted with Function story and then they created their own story individually be replacing variables. On the same day, they were explained the concept of function of an object and were told the story of Electric bulb. They worked in groups and choose an object to build the story on. After choosing the object, students researched about it and collected information about its evolution and wrote a story about it showing distinction between different objects fulfilling the same function.

The form in which functions were given to students was a little modified for their convenience. For example instead of giving them function symbols, they were given variable sentences in which they had to replace variables. These functions are not fixed or rigid. They just give the idea of a battle or conflict between two entities wanting greater recognition in a particular world.

Table 5.12 was given to participants as a master plot based upon which the students constructed their own stories.

X is producer of a Product Y	Z steals knowledge of How to make Y, from X in his absence	Z starts selling Y with slight modification Y becomes (Y)	X is Frustrated and totally Helpless as everyone is now buying Z's (Y)
Instead of crying forever X decides to go to the creation world for a better design than (Y)	X meets Guardian of creation world(GOC) who tells him/her the weakness of (Y)	GOC tells X design of a new and better (Y)	GOC tells X the different worlds where the material for design will be found
X meets Guardian of worlds and makes a promise	X Combines all the materials with the design plan to make the new and improved Y	X demonstrates "Y"	"Y" Does not work
X remembers promise made to the people of creation world	X goes back to Creation world and fulfills the promise	X returns just before the people are leaving the demonstration	X tries again and this time "Y" works. All bulbs are sold on the spot And X is declared the king of "Y"

Table 5.11 Model plot given to participants as a reference to build stories from

Results

To judge the stories criteria for content analysis was chosen. Content analysis is a method of analyzing texts to detect the presence of certain words or concepts. It is mainly used to draw inferences about the kind of messages present in a text. The text can be books, newspaper articles, theater or film, interview or any occurrence of communication language **(**writing@csu, 2009)

Content analysis is a systematic technique for analyzing message content and message handling. It is a tool for observing and analyzing the overt communication behavior of selected communicators (Thorp, Budd, Donohew, 1967). Content analysis is of two kinds; Conceptual analysis and Relational analysis.

In Conceptual Analysis, we divide texts into category codes and search for instances of words that follow under that category. Relational analysis searches not just for individual instances of words, but the relation between two or more different set of concepts in a given text. We have used the relational analysis method. Codes were identified to define the criteria. For the first story, category of codes were

1) Variables Identified – Deciding the characters in the story

2) Usage Context - Deciding the context in which a particular object is needed.

3) Function – Deciding the function of the object

4) Coherence of Function to Use Context – Is the Function cohering with the usage of the object. For example if the usage context is the need to call police in time of crises, that is the usage context and communication is the Function. They both are coherent with each other. Narratives are said to be coherent if the audience perceive that events in the narrative lead towards an outcome. This is concept is shared by both Disney and Alfred Hitchcock (Riedl & Young, 2003).

In the second story experiment the codes were as follows:

1) Variables identified: Deciding the characters in the story

2) Distinction of design and construction – It is how two objects of the same function are differentiated in terms of their design and the construction

3) Distinction between Advantage / Disadvantage – This is to judge if the students were able to distinguish the advantages of one object over the other in serving the same function.

4) Coherence between design distinction and advantages – This is to judge if step 2 and 3 align with each other to know if the distinctions are sensible

Data on Function Realization Story Model (1= Yes, 0=No) n = 26

S. No.	Variables identified	Usage context	Function	Coherence of Function - use context
1	1	0	0	0
2	1	0	1	0
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	0	0	0
8	1	0	1	0
9	0	0	0	0
10	1	1	1	1
11	1	0	0	0
12	1	0	1	0
13	1	0	1	1
14	1	1	0	0
15	1	0	1	0
16	1	0	1	0
17	1	1	1	0
18	1	1	1	1
19	1	1	1	0
20	0	0	0	1
21	0	0	0	0
22	1	1	1	0

23	1	1	1	1
24	1	1	1	1
25	1	1	1	1
26	1	1	1	1
Tot	23/26	14/26	19/26	12/26
%	88%	53%	73%	46%

Table 5.12: Results of story 1exploratory study no. 1

Efficient Product Distinction Plot (1= Yes, 0 = No). n = 8

S. No.	Variable Identification	Distinction of Design and Construction	Distinction of Advantage/Disadvantage	Coherence
1.	1	1	0	0
2.	1	1	0	0
3.	1	1	1	1
4.	1	1	0	0
5.	1	1	1	1
6.	1	1	1	1
7.	1	1	1	1
8.	1	1	1	1
Tot.	8/8	8/8	5/8	5/8
%	100	100	62.5	62.5%

Table 5.14: Results of story 2 of exploratory study no.1

Total Coherent stories = 17/34 = 50 %

Girls Coherent stories = 7/13 = 53%

Boys Coherent stories = 10/21 = 47%

Total number of coherent stories is 50 % while girls have scored a little better than boys in terms of coherence in stories. Coherence in Function story plot is 46 % while in Efficient Product distinction plot it is 62.5%. The detailed analysis of each story is given along with each story in the Annexures.

Apart from validation, the experiment helped in finding problems with the existing approach. It can be further improved and may provide better results in the next experiment.

Discussion

We believe that the reason for low coherence in meaningful plot construction was that students were not given enough time to explore the subject matter. We need to add more feedback on the development of the script so students can modify it and add more information in the story. And a longer exposure time may lead to better in the sense of more informative story design.

Pilot Experiment no. 1 with ZIET teachers

32 teacher from different parts of the country teaching in Kendriya Vidyalaya schools participated in the story writing experiment. The objective of the experiment was to test if teachers are able to develop stories using the story writing model. The experiment was part of a workshop conducted by ZIET for principles of Kendriya Vidyalaya School from across the country.

Procedure and Materials

They were given 7 different versions of the same story model to write stories from. The different versions of the same model are given in the appendix. The stories written by teachers are documented in the appendix. The table given below was provided to the participants which was the master plot based upon which the participants had to build their plot.

Results

The story data collected from the participants was tested for the presence of three factors

Story Coherence, Knowledge Content, Model Followed: Results are given in table 5.13

Participant	Story Coherence	Knowledge Content	Model Followed
1	1	0	1
2	1	0	1
3	1	0	1
4	1	0	1
5	1	0	1
6	1	0	1
7	1	0	1
8	1	0	1
9	1	0	1
10	1	0	1
11	1	0	1
12	1	0	1
13	1	0	1
14	0	0	0
15	1	0	1
16	1	0	1
17	1	0	1
18	1	0	1
19	1	0	1
20	1	0	1
21	0	0	0
22	1	0	1
23	1	0	1
24	1	0	1
25	1	0	1
26	1	0	1
27	1	0	1
28	1	0	1
29	0	0	0
30	1	0	1
31	1	0	1
32	1	0	1
	90.6%	0%	90.6%

Table 5.13: Results of pilot study no. 2 with ZIET teachers

Results show that although 90.6% teachers were able to develop stories using the model and the story coherence was also the same percentage. The percentage of stories that contained learning content was none.

Discussion

We noted that the performance of teachers in story design was much less than those of Students at HBCSE. The reason for this difference could be that the students had time to search the required information and then develop story accordingly, but teachers were not given that much time to search because it was assumed that teachers would know the content and hence they would be able to use the master plot to create stories, but that assumption was proved false. The reason for that we infer is that the model we provided was too rigid and did not give enough flexibility to the teachers. In order to give more flexibility to the teachers, a new strategy was applied which was to develop different versions of the story model. We talk about it in the next section.

Pilot Exploration study no. 2 with ZIET Teachers

A similar experiment to previous one was conducted at ZIET with secondary school teachers. Total number of participants was 20. The experiment was part of a workshop at ZIET for Kendriya Vidyalaya teachers. The participants were pre-selected by the ZIET committee based upon the criteria of best performing teachers from across India.

Materials and Procedure

The difference in this experiment was in the variety of master plots given to the participants. The master plots were of five types:

Comparison Model: For knowledge associated with comparison of properties of different entities.

Identification Model: For identifying names of things

Process Model: For knowledge related to processes like water cycle, Metallurgical extraction processes

Social Effect: For knowledge related to effect of a scientific discovery on society or ecosystem

These five categories were created by analyzing content from class sixth, seventh and eighth of CBSE board. The various concepts from the chapters were identified according to their definition and placed into one of the categories. The five models were used to create different master plots which were given to the participants to choose a suitable model to base their story on.

Example of the comparison model is given below:

Results

There was no significant difference in the result of this experiment when compared with previous experiment. The stories were measured for presence of the factors; Story Coherence, Knowledge Content and Model depiction. The number of coherent stories was 75 %, that of following the model was 0 % and the knowledge content in stories was zero percent.

S.No.	Story Coherence	Knowledge content	Model followed
1.	0	0	0
2.	1	0	0
3.	0	0	0
4.	1	0	0
5.	1	0	0
6.	0	0	0
7.	1	0	0
8.	1	0	0
9.	0	0	0
10.	1	0	0
11.	1	0	0
12.	0	0	0
13.	1	0	0
14.	1	0	0
15.	1	0	0
16.	1	0	0
17.	1	0	0
18.	1	0	0

19.	1	0	0
20.	1	0	0
Total	75%	0	0

Table 5.15 : Results of pilot study no. 3 with ZEIT teachers

Discussion

There could be many reasons for no significant change in the story development by the teachers. One of the reasons why participants were not able to write stories with knowledge content could be that they were not interested in writing the stories. They expressed this after the experiment that they did not consider themselves to be story writers. Secondly, they may have had difficulty in understanding the model. The sample story given to them may have become a deterrent in thinking of new ideas. Too much detailing of the model may have compelled the participants to copy it as it is instead of creating new content. Also, writing a story is skill that needs to be acquired, so people not proficient with the dynamics of story writing may have found the task difficult.

Conclusions from Pilot Experiments

It was inferred from the results of the pilot experiments that maybe the story model was still in too nascent a stage to allow people to make use of it in developing stories especially those who are not content writers and regular teachers. It would be a better idea to test the effectiveness of the model in enhancing the learning experience of children instead of using it as a generative tool directly. The next experiments were therefore focused on testing this hypothesis, whether the Framework for Narrative organization of knowledge is an effective tool in increasing student understanding of science. Apart from modifying the aim of experiment, we also decided to modify the story model by relooking into the theory of knowledge to find new clues to elaborate the model. The following experiment descripts are based on this new aim.

Pilot exploratory study data: story examples written by students:

1.

Name – AE1

Age – 12 yrs

A car is sad because he has no function. A house reaches the car and asks him why he was so worried? The car explains everything to him. The house suggests it to go to the world of creation. Listening to his advice, the car hopefully goes to the world of creation. He roams about for a long time. Suddenly he finds a man very interested in him. He said he found him to be a very luxurious car in the world. The car becomes happy and returns back. Everyone loved him because it became the best car in the world.

Variables Identified: X = Car; Y = House; Z = Man

Use context: none

Function: None

Coherence: None

2.

Name – AE2

Age – 12 yrs

A book is sad because it has got no function. A rat advises the book to go to WOC and find its function. The book goes to WOC. Then a bee comes and asks for a favor. The book happily gives the bee what it asks for and goes away. The Bee returns with excitement. The bee tells the book about its function. He advises the book to go to WOC to find its function. The bee tells that it function is to provide nectar for honey. Then book says that its function is to provide knowledge. The book then sets up a shop. Everyone began to love the book for its function as the provider of knowledge.

Variables: X = Book; Y = Rat ; Z = bee "O" = To provide knowledge

Use context: none

Function: Then book says that its function is to provide knowledge.

Coherence: none

3.

Name – AE3
Age – 13 yrs

Water is sad because it has no use. Fish advises water to go to world of creation. Water goes as advised by fish. One man was thirsty and asked water to give him some of his part. Water happily gave the man a part of his water and goes away. Then the man returned with excitement and tells water that you saved my life, as you ended my thirst and I used you to cook food, washing dishes and bathing. You have amazing properties. You function as provider our basic uses. Water started providing people with some part of it. Everyone loves water for providing some part of it.

Variables: Water, Fish, Man

Use Context: One man was thirsty and asked water to give him some of his part

Function: You function as provider our basic uses.

Coherence: Since function is not clearly defined it is difficult to say if use context and function are cohering.

Telephone was very sad because he had didn't have any uses. Wire started weeping and asked what was the reason for weeping? Telephone answered that he had no use. The wire advises the telephone to go to the world of creation. Telephone goes to the world of creation as advised by the wire. One man attacked by terrorists came near telephone and asked to use him. The man called police and reported about the car number of the terrorist. The police caught the terrorist and punished him. The man came to him and said he did the work of communication. The telephone was delight and the man described the various functions of him. Telephone started PCO. Everyone when in need calls for telephone.

Variables: Telephone, Wire, man

Use Context: One man attacked by terrorists came near telephone and asked to use him. The man called police and reported about the car number of the terrorist. The police caught the terrorist and punished him.

Function: The man came to him and said he did the work of communication. The telephone was delight and the man described the various functions of him.

Coherence: The use context and Function are in coherence with each other. This is the most coherent story.

4.

Name - AE4

Age - 12 yrs

Computer is sad because he has no function. He starts weeping in a very loud voice. A robot meets the computer and asks him about his queries. The computer explains the robot. The computer explains the robot that he was sad because he has no function. The robot thinks for a second and tells the computer about the world of creation and tells the computer that he can find his function in the world of creation. Computer goes to the world of creation. After roaming for an hour in the world of creation, a man asks him a favor, that I am trying to make an information book which would contain all types of animals. The computer told him to use internet as now the man could use the internet and took photos of all animals and could complete the book. The man told everyone about the computer as computer can provide him information, after returning to his own world. He build a shop where people could use computer for getting information and then computer lived happily ever after.

Variables: Computer, Robot,

Use Context: a man asks him a favor, that I am trying to make an information book which would contain all types of animals.

Function: Computer can provide him information.

Coherence: The function is matching with the use context.

5.

Name – AE5

Age – 13 yrs

Object = Watch

Function= Watch shows us time so that we can reach a place in time.

Watch is very sad because he has no function. So a crow comes and advices him to go to the world of creation. Watch goes to the world of creation. A man comes and asks the watch a favour. The man asks him to show him the time. The man comes and thanks him that because of the watch he could reach the office in time. The man tells that he has amazing property of showing time to the people. The man gives him a function as provider of time. The watch open a shop of showing everybody the time. Everybody loves the watch for showing the time.

Variables: Watch, Crow, Man

Use Context: The man asks him to show him the time. The man comes and thanks him that because of the watch he could reach the office in time.

Function: The man tells that he has amazing property of showing time to the people. The man gives him a function as provider of time.

Coherence: Use Context and Function are coherent.

6.

Name – AE6

Age – 13 yrs

Bench is sad when it is not shining

Table advises bench to go to WOC

Bench Goes to WOC

Chair approaches and asks his leg

Bench happily gives his leg

Chair returns his leg after doing the experiment

It tells bench about his amazing properties

Chair tells bench your leg is very nice. It balances you body.

Bench with his new function starts a shop

In his shop he makes many benches of his size

Everyone loves benches because he made nice objects such as tables, benches

Variables: Bench, Table, Chair

Use Context: Not defined

Function: Not defined

Coherence: Not clear

7.

Name – AE7

Age - 12 yrs

Aeroplane is sad because he has no function.

Train advises him to go to WOC to find his function

Aeroplane goes to WOC

Oliver Wright approaches aero plane and asks him his wings

Aero plane happily gives his wings and goes away

Oliver Wright returns with excitement

Oliver right tells about his amazing properties

Oliver gives him function as sending people from one place to another very quickly faster than every vehicles.

Aero plane with his new function starts sending people from one place to another

Everyone loves Aero plane for providing them quick transport.

Variables: Aeroplane, Train, Oliver Wright

Use Context: Not clear

Function: Oliver gives him function as sending people from one place to another very quickly faster than every vehicles.

Coherence: Not clear since use context is not clear.

8.

Name – AE8

Age – 13 yrs

One day a pen becomes sad because its refill is over. It is always kept in a corner when it is over. It is of no use.

Y comes which is refill. It advises to find a ink.

Pen goes to search of Ink

Ink ask what do you want

Tree happily give Z a refill and goes away

The refill comes back with ink filled in it.

Z tells that you can write anything by me in books.

Your function is to write

The pen provides a function

Everyone like X for providing them a function

Variables: Not clearly defined

Use Context: Not clear

Function: Not Clear

Coherence: Not Clear

9.

Name – AE9

Age – 13 yrs

Vacuum Cleaner is sad because he thinks that he has no function . Sofa advises him to go to world of creation to find his function. Vacuum cleaner goes to WOC. A boy approaches the Vacuum cleaner to ask him to clean his room. Vacuum cleaner does it happily. The boy returns with excitement. The boy tells that he can clean a house very nicely. The boy gives him a function as better provider of cleanliness than the broom. Vacuum cleaner with his new function starts a shop. Everyone loves vacuum cleaner for providing them cleanliness.

Variables: Vacuum cleaner

Use Context: . A boy approaches the Vacuum cleaner to ask him to clean his room. Vacuum cleaner does it happily.

Function: The boy gives him a function as better provider of cleanliness than the broom.

Coherence: Function and Use context are coherent.

10.

Name – AE10

Age – 12 yrs

A pen is sad because he thinks that has no function. Then a paper comes to him and advises him to go to the world of creation to find his function. In the world of creation. Accordingly the pen goes to the world of creation. In the world of creation, a quill appears to him and asks the pen for his ink. The pen willingly gives the quill its ink. After some time, the quill comes running to the pen with excitement. He tells the pen that he could write on paper so efficiently than the quill. The quill also said that this was the function the pen was looking for. The pen than thanked the quill and then started a shop of pens. Everybody was very happy with pens to provide them the ability to write more efficiently than the quill.

Variables: Pen, Paper, Quill

Use Context: Not clear

Function: Not clear

Coherence: No coherence

11.

Name – AE11

Age 13 yrs

Vacuum Cleaner

VC is sad because it has no function. A mop comes to him and advises him to go to the world of creation.

In the world of creation, a scientist approaches him and asks him to clean his room. Vaccuum cleaner does it happily. After some time the scientist returns to see his room so clean. The scientist also understands it amazing properties and gives him the function of cleaning. Vacuum cleaner returns home and starts a shop in which he sells Vacuum cleaner. Everybody understands his function and buys vacuum cleaners for themselves

Variables: Vacuum Cleaner, mop, Scientist

Use Context: Not defined

Function: The scientist also understands it amazing properties and gives him the function of cleaning.

Coherence: No coherence since use context is not defined

12.

Name – AE12

Age – 12 yrs

Bag is very sad because he has no function. There a pen comes and says why are you so sad.

Bag says that he has no function. Pen says that in this world everything has a function so pen advises him to go to world of creation to find his function. Bag goes to WOC. As the WOC was far, so the bag got tired. Then after some time, when bag was resting a girl comes and say can I take your part for sometime? The bag says you can. The girl put her objects and she carries and walked easily for long distance. The girl was happy because the bag made her easy to keep the things into it and carry for long distances. The girl says to the bag that you are amazing and you are really useful. Now because of you we can carry heavy things over long distances. The girl gives the bag a function by providing for carrying the objects in it. Now because of the bag with his new function, the shop was started. Everyone loves the bag very much for providing the function for carrying the objects/things in it for a long distance anywhere. The bag was very happy as many children use him for carrying books in it and going to school

Variables: Bag, Pen, Girl

Use Context: The girl put her objects and she carries and walked easily for long distance. The girl was happy because the bag made her easy to keep the things into it and carry for long distances.

Function: The girl gives the bag a function by providing for carrying the objects in it.

Coherence: Coherent

13.

Name – AE13

Age – 13 yrs

A motor car is very sad because it has no function. He met a bicycle and told about his grief to him. So, the car was advised by the cycle to visit the WOC that is the world of creation. A person in the WOC approached him and asked why he was sad. He replied that he had no function. The person, after smiling, told that everything in this universe has a function from an ant to a big rock. The person also told him that he had the function to serve people for transportation and for roaming.

The motor car was overjoyed after hearing that he too had a function, so he lived very happily, enjoying his function.

Variables: Motor Car, Bicycle, Person

Use Context: Not defined

Function: The person also told him that he had the function to serve people for transportation and for roaming.

Coherence: Not coherent as no use context is defined.

14.

Name – AE14

Age – 13 yrs

There was once a table living in this world. He used to see everyone around him having his or her own function. One day a chair came and started to tease the table. The table was already very gloomy and when the chair teased him the table started crying very bitterly. His cry was heard by the people in every region of the world. One day a pen came to him and advised him to go to world of creation and ask the creator about his function. Thanking the pen for his valuable suggestion, he packs his clothes and soon leaves out for the world of creation. After travelling for some hours he decided to rest for some time. Then a young boy comes to him and says, can I use your surface for writing an essay for some time. After writing the essay, he goes to his teacher for his notebook correction. He returns to the table and tells that you are very beneficial for us. The table is very happy. Then he asks the boy about his function. The boy says that because of him, the teacher appreciated my hand writing. Suddenly in happiness he shouts and tells his use to all people of the world. At last the chair also appreciates the table and everyone starts buying the table after he opened his shop.

Variables: Table, Chair, Pen

Use Context: Then a young boy comes to him and says, can I use your surface for writing an essay for some time. After writing the essay, he goes to his teacher for his notebook correction. The boy says that because of him, the teacher appreciated my hand writing.

Function: Not defined

Coherence: Not defined

Note: Even though the function is not clearly defined but still, we can understand what the student implies. He is talking about table providing a surface for writing. This is coming out clearly in the use context.

15.

Name – AE15

Age – 13 yrs

Once upon a time there was a table. He was very sad. A boy came to him and asked him why are you sad, what is your problem.” The table answered him by saying that he was the one who had no function. The boy suggested him to go to the world of creation. So the table went to the world of creation. There he met a man. The man asked him why are you sad? And the tree repeated him what he had its own function that objects could be kept on it. So hearing this the table became happy. Then he went back and stayed happy so forth.

Variables: Table, Boy, Tree

Use Context: Not defined

Function: And the tree repeated him what he had its own function that objects could be kept on it.

Coherence: No coherence since Use context is not defined.

16.

Bulb is vey sad as he had no function. The wire came and told him that there is no thing which has no function. The wire came. He asked the bulb to go to the world of creation. Bulb wnt to the world of creation. There he finds a person called Edison. Edison asks a favor. But bulb says that he had come to find his function. Edison says he needs to use bulb parts. After the use Edison comes with an excitement. Edison tells that bulb is the provider of light. Hence bulb starts being sold in shops. Hence bulb becomes the favorite of every one for production of light.

Variables: Bulb, Wire, Edison

Use Context: Not defined

Function: Edison tells that bulb is the provider of light.

Coherence: No coherence since Use context is not defined.

17.

Name – AE17

Age – 12 yrs

Car is sad because he has no function. Table says it is impossible because everything in this world has a function. Table advises car to go to the world of creation to find his function. Car goes to world of creation. A family with lots of people approach the car ask him if he could let the family sit in them. Car happily lets them sit inside him and takes them wherever they want. The family then returns with a lot of excitement. And says that the car is a very good way to taking people from one place to other and for travelling long distances. The car is very happy and the family calls it “provider of comfort in travelling long distances.” The car opened a shop and made many more cars like himself.

Variables: Car, Table, A Family

Use Context: A family with lots of people approach the car ask him if he could let the family sit in them. Car happily lets them sit inside him and takes them wherever they want. The family then returns with a lot of excitement. And says that the car is a very good way to taking people from one place to other and for travelling long distances.

Function: “provider of comfort in travelling long distances.”

Coherence: Coherence is present as the use context aligns perfectly with Function.

18.

Name – AE18

Age – 13 yrs

Chair was sad because he thought he had no function. By that time Bed arrived and asked the chair the reason for his sadness. He said, he had no function. Crying bitterly.

The bed felt sorry for him. He advised the chair to do to the world of creation because the bed had a ray of hope that chair would get his function. So he goes to WOC. Then as he travelled a man approached to him and asked him whether he could sit on him. He happily allowed him to sit on him. After a few minutes he expressed his gratitude to him and also told him that he has an excellent property. Chair asked him what was the property. He replied that he provides the facility to sit and gives this function for his help. Then the chair returned happily to bed and told him all that happened.

Variables: Chair, Bed, Man

Use Context: He happily allowed him to sit on him

Function: He replied that he provides the facility to sit

Coherence: Use context is not as elaborate as the way it is in Shriya’s story.

19.

Name – AE19

Age – 12 yrs

Building is sad because he has no function. A car advises building to go to world of creation to find his function. Building goes to world of creation. She asks him whether she can live in his building. Building allows her. She lives very comfortably. The girl is very happy. The girl tells him about its function. The girl tells that the building is Provider of place to live in. Building is happy with his new function. Everyone loves him for providing them a place to live'

Variables: Building, Car, Girl

Use Context: She asks him whether she can live in his building.

Function: The girl tells that the building is Provider of place to live in.

Coherence: It has coherence but the use context is not as elaborately defined as Shriya's story

20.

Paper was crying. Wood approaches to him asking that why you are crying?

Paper is sad because it has no function. Wood advises paper to go to world of creation. Wood goes to world of creation. Wood goes to world of creation. Pencil approaches wood and asks him a favor. Paper happily gives pencil what he asks for and goes away. Pencil returns with excitement. Pencil tells paper about his amazing properties. Pencil gives paper his function as provider "o"

Paper with his new function starts a shop. Everyone loves paper for providing them "o" Paper thanks wood. Paper reached this message to whole world. Then he starts a shop.

Variables: Paper, Wood, Pencil

Use Context: Not defined

Function: Not defined

Coherence: Not Clear

21.

Name – AE21

Age - 13 yrs

Metal is sad because he has no function. One day listening to the metal's crying plastic asks him and comes to know his sadness. He was stunned as he knew everyone in this world had a function. Plastic advises metal to tog to WOC to find his function. Metal goes to WOC. There, he finds everything very modern and amazed at the sight.

An engineer approaches metal and asks him a favor. Metal happily gives the engineer what he asks for and goes away. The engine returns with excitement. He tells the metal about his amazing properties. The engineer gives metal his function of provider of Gold, Silver, jewellery, utensils. Metal being happy and excited with his new function starts a company everyone loves metal for providing jewellery, utensils, ornaments, functions. He brings the attention of the whole world about his functions. Metal thanks plastic for his advice.

Variables: Metal, Plastic, Engineer

Use Context: Not defined

Function: The engineer gives metal his function of provider of Gold, Silver, jewellery, utensils.

Coherence: Since Use context is not defined, there is not coherence.

22.

Name – AE22

Age – 12 yrs

Paper is very sad for he has no function. One day, when paper was weeping, a tree came to him and asked him why he was weeping. Paper replied that he had no function. The tree was surprised to know this as he knew that everything in the universe had a function. So the advised him to go to the world of creation. So paper goes to WOC. On the way a young scientist approaches him and asks to use it for a while. The paper readily agrees. The scientist works on the paper and finds that if ink is sprayed on paper, then the paper could be used for writing proposes. The paper feels elated and then starts a company selling paper. A huge amount of people buy paper because of its use of writing.

Variables: Paper, Tree, Scientist

Use Context: The scientist works on the paper and finds that if ink is sprayed on paper, then the paper could be used for writing proposes.

Function: A huge amount of people buy paper because of its use of writing.

Coherence: Use context and Function are coherent

23.

Name – AE23

Age – 13 yrs

Once upon a time, a computer started crying bitterly. His friend, the telephone asked him the reason for his weeps. Computer said, "I've got no function. I'm idle and of no use." The telephone said, "It's not possible. Man, our great creator has given each one of us a function. Let's go to the world of creation to find you a function." There in the world of creation, the computer was searching for a function. Then a young man came to him and asked for a piece of his brain. The computer gave a piece to him. He said, "Anyway, it's just rusting there." The computer said that he had got no function was about to return to his own world. Just then the young man came to him and said, "you are wonderful. Your coming here was a successful. With your brains, I made a software which could help people to communicate from one place to the other. You got a function." The computer happily returned home and started a shop giving everyone a software for telecommunication.

Variables – Computer, Telephone, A young man

Use context - Just then the young man came to him and said, "you are wonderful. Your coming here was a successful. With your brains, I made software which could help people to communicate from one place to the other

Function - Giving everyone software for telecommunication.

Coherence – Use context and Function are coherent with each other

24.

Name – AE24

Age – 13 yrs

Once, in the electronic world, telephone was sitting in a corner and crying bitterly. His friend wire came up to him and asked "Oh, telephone, my friend, what on the electronic world has made you cry so bitterly?" Telephone replied "wire, you know that I am so useless, everyone except me has a utility. Even you do. So how do you expect me to be happy?" Wire replied "Don't worry, go to the world of creation and you will certainly find your function." Telephone asked, bewildered, "World of creation?" I have never heard of such a world. He said "That's the world from where I got my function. I'll show you the way." Wire accompanied telephone for a little while, then went his own way. Just then a little girl came, looking very worried. Telephone asked, "what makes you worried little girl?" She replies

It has been difficult for us to communicate with those who live far away. But you seem interesting. My father is a scientist. Maybe you can help. Would you mind if you gave me some of your precious time and come with me to my father?" Telephone replied "sure not!" So, they went off together to her house where the scientist took his receiver and did some experiments. He looked delighted. Telephone was told that he could be used for communication. So, he thanked them and returned to the world of electronics. The overwhelmed and joyous telephone started his own shop and everyone thanked him for he played a great role in their life.

Variables – Telephone, Wire, A little girl, father

Use Context - It has been difficult for us to communicate with those who live far away

Function - Telephone was told that he could be used for communication.

Coherence – Use context and Function cohere with each other

Appendix 8

Example of narrative concepts for Secondary School Science curriculum

Nomadic to Settled habitation (pre-history to Egyptian, Babylonian, Sumerian and Indus civilization)		
Existing Routine	**Discovery Event**	**Routine Change**
Using stone and wood as tools and weapons such as spear, throwing stick, sling	Discovery of fire and metal ore	Making tools and weapons by transformation of **metals-Copper and bronze** Knife, Chisel, Waterwheel
Hunting and gathering of food	Learning to grow wheat and barley through cultivation of seeds Knowledge of whether cycles, counting of days and concept of a calendar	Grown own food, prediction of seasonal rains Prediction of moon cycles associated with flooding of rivers, Prediction of eclipses
Using animal skin, grass and leaves as drapes	Discovery of weaving technique And materials like wool and Cotton	Making drapes of natural fabric
Making Shelter with branches and leaves	Discovery of fire along with Learning about types of soil and properties of clay ad forming structures through intersection of pipe like objects like bamboo rods etc. Also knowledge of geometry.	Building mud brick houses-Sacred building like pyramids and temples. measurement of land and town planning
Using natural objects like bark of trees and coconut shells as storage utensils	Discovery of fire and learning about shaping utensils on potter's wheel. Also basket weaving	Making utensils made of clay and baskets made of cane and bamboo. Weaving patterns
No means of transportation	Invention of wheel	**Making Bullock carts as means of transportation** **Ships**

Ancient to classical (Greek and Roman)		
Existing Routine	**Discovery Event**	**Routine Change**
Grown own food, prediction of seasonal rains **Prediction of moon cycles associated with flooding of rivers,** **Prediction of eclipses**	Extension of ancient astronomy (Routine perfection)	Geocentric model of universe
Making drapes of natural fabric	Extension of Different variety of materials (Routine perfection)	
Making tools and weapons by transformation of metals-Copper and bronze **Knife, Chisel, Waterwheel**	**Discovery of Iron** **And types of motion**	**Making of mills and presses, Water lift pumps, pulleys, Archimedes screw**
Building mud brick houses-Sacred building like pyramids and temples. measurement of land and town planning	Invention of draughtsman's compass and Lathe (Routine perfection)	Extension of ancient techniques of house building Extension of geometry
Making utensils made of clay and baskets made of cane and bamboo. Weaving patterns	(Routine perfection)	
Making Bullock carts as means of transportation Ships	(Archimedes) Buoyancy principle	Measurement of volume of irregular shape objects
Metal Weapons	Archimedes Principle of reflection of light rays by mirrors	Method of blinding or and distracting sailors of enemy ships by concentrating sun's rays on it deflected by a series of mirrors

Classical to Medieval		
Existing Routine	**Discovery Event**	**Routine Change**
Metallurgy transformation of substances	Replacement of 4 element theory Theory of oppositional properties	Alchemy Techniques form mixing chemicals to create new compounds
Making utensils of clay or metal	Discovery of glass	Glass vessels, optical instrument to see ships from afar.
Medieval to Renaissance		
Astronomy-geocentric	Discovery anomalies in planetary motion by direct observation. Confirmation by use of telescope	Heliocentric Model (Copernicus, Tycho brahe (elliptical orbit of comet), Kepler's laws of planetary motion Galileo (empirical observation)
Using Sundial and sand clock is instrument of timekeeping	Discovery of uniform motion of pendulum	Use of Pendulum as instrument of time keeping
Aristotle's impetus theory		Galileo's Theory of Impetus
Galileo's laws of motion		Newton's Laws of motion
Belief regarding impossibility of a vacuum. And air being a homogeneous substance.		Otto Von Guericke's air pump Boyle's law of air pressure and volume of air relation. Wieght of air

Renaissance to Industrial revolution		
Phlogiston theory (Alchemy)	Precise measurement of weights Methods of isolation of Vapors from experiments	Modern chemistry
Heat measurement with sense of touch	Discovery of property of thermal expansion of metals	Methods of Precise measurement of quantity of heat
Theory of heat being a form of liquid	Rumford's discovery with Boring machine	Kinetic theory of heat (Heat as a form of motion)
Creation of static electricity by friction	Storage of electricity in Layden Jar, Subsequent experiments of Benjamin Franklin	Coulomb's laws
Air as mixture of gases from Lavoisier's theory	Dalton's experiments with gasses	Dalton's atomic theory that matter is made of tiny indivisible particles
Galvani's work with effect of static electricity on frogs	Volta's Turning of frog experiment into a voltaic cell	Davy's invention of the first battery
Dalton's atomic theory	Discovery of closeness of atomic mass of elements	Mendeleev's periodic table

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