Chapter one
INTRODUCTION

1.0 INTRODUCTION

Humans are innately curious creatures. This curiosity has driven them since time immemorial to explore the world around them (NCERT, 2013). The inquiring and imaginative human mind has responded to the wonder and awe of nature which resulted in the formation of conceptual models to understand the world (NCERT, 2006). From the ancient world, starting with Aristotle, to the 19th century, *natural philosophy* was the common term for the practice of studying nature. It was in the 19th century that the concept of "science" received its modern shape with emergence of new titles such as "biology" and "biologist", "physics" and "physicist" among other technical fields and titles; institutions and communities were founded; and unprecedented applications to and interactions with other aspects of society and culture occurred (Cahan, 2003). The interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation is viewed as Science by Conant (1951). The word 'science' (Scientia) has the etymological meaning "knowledge". It is the knowledge which is as objective as the prevailing conditions allow it at a particular moment. This knowledge is always open to scrutiny. Fitzpatrick (1960) defines Science as a cumulative and endless series of empirical observations which result in the formation of concepts and theories, with both concepts and theories being subject to modification in the light of further empirical observations. Hence, Science is both the body of knowledge and the process of acquiring knowledge. Scientists believe that all the natural phenomena have some patterns that can be understood through careful and systematic study thus making science a human endeavour (NCERT, 2006). In this way, science has created a body of knowledge which is, time and again, deconstructed and reconstructed. According to Lederman (1983), science is a dynamic, ongoing activity, rather than a static accumulation of information. Science is the approach to the gathering of knowledge rather than a field or subject matter (Best & Kahn, 2009). As a way of thinking, reasoning and finding solutions for diverse kinds of problems related to life and natural phenomenon, Science helps us in developing a notion that nature can be understood. Therefore, Science is both a human activity and an attitude to understand and unfold mysteries of nature.

1.1 CHARACTERISTICS AND NATURE OF SCIENCE

There are certain unique characteristics of science which make it a distinguished discipline from others. The simplest understanding about science is "What scientists do" (Sharma, 2013). However, immediately, the question arises "then what do the scientists do?". The scientists and their efforts are driven by the curiosity of understanding the natural world. While some scientists are interested to solve the puzzles of the nature, others are intensely working towards solving some social problem to utilize science for a better life. The common characteristics of scientists are perseverance, creativity and collaboration (Clough, 2015). Since scientists and scientific thinking have contributed immensely to the development of science as a discipline, the characteristics of science can be drawn from those of scientists. They are explained below:

- Science is a particular way of looking at nature: When an ordinary person looks at any problem or a natural event in an ordinary or routine way, a scientist tries to understand the underlying causes of it and investigates to find its solutions or its consequential effects.
- Science is a rapidly expanding body of knowledge: As the newer disciplines are discovered and established, not only the body of knowledge gets more and more voluminous but also the older disciplines are getting replaced by the newer ones.
- Science is an interdisciplinary area of learning: Though the knowledge was compartmentalized into different disciplines such as physics, chemistry and biology for the convenience of handling the substantial volume of knowledge, no any natural phenomenon falls completely into any one discipline. The study of such phenomenon or any problems requires multiple perspective for more than one discipline.
- Science is a truly international enterprise: The progress of science and its application require participation from all across the globe. It is because no any single country can spend the required human and financial resources for a huge project.
- Science is always tentative: The advancements in the experimental observations or the theoretical developments can lead to revision, improvement or abandonment of well-founded theories.
- Science promotes skepticism; scientists are highly skeptic people: Every new theory is accepted only after verification by experimental observations. Everything is looked upon with suspicion by the scientists.

- Science demands perseverance from its practitioners: Scientists have to be persistent with their ideas until they arrive at some logical conclusions. Science demands tenacity and perseverance.
- Science as an approach to investigation and as a process of constructing knowledge: Humankind shows vast curiosity in finding the solution of any problem. Observation, experimentation, cause and effect relationship are a few examples of the approaches followed by the scientists. This has given rise to the scientific method which is also known as a step by step method and is objective in nature.

In a nutshell, Science demands a multitude of approaches that require ingenuity, creativity, reason and perseverance. What results is knowledge about the natural world, but that knowledge is the product of science, not science itself. Furthermore, that knowledge, no matter how well established, can change as scientists continue their work and come to better understand the natural world. (Clough, 2015).

These characteristics elucidate the dual nature of science. It has a process aspect that strives to understand the nature as well as a product aspect- the knowledge generated as a result of the attempts made under the process. Both the aspects are interconnected with and interdependent on each other. The product aspect of science acknowledges science as an accumulated and systematized body of knowledge whereas the process aspect of science comprises of scientific method of inquiry and scientific attitudes. Therefore, the process aspect always remains in search of truth by adopting the scientific methods which are known as reliable, valid, objective, unbiased and verifiable. There is nothing wrong in saying that science is an overall product of human activity in the form of a systematic and organized body of knowledge. It is the product of all facts, connected with our information, concepts, generalizations, laws and theories framed on the basis of vast fund of accumulated knowledge.

1.3 PLACE OF SCIENCE IN CURRICULUM

Addressing the then National Institute of Sciences (now Indian National Science Academy), Nehru stated, "*Who indeed can afford to ignore science today? At every turn, we have to seek its aid and the whole fabric of the world is of its making"* (Singh, 1988). Considering the crucial role played by science in development of an individual as well as the entire nation science is given leading prominence in the school curriculum. The rich nature and vast applicability of science offers students the ability to access a wealth of knowledge which will contribute to an overall understanding of how and why things work like they do. Post-independence, some remarkable steps were taken to include science as an inseparable part of school curriculum. The chronological order of the national documents referred in this chapter is University Education Commission (1948-49); Secondary Education Commission (1952-53); Education Commission (1964-66); Curriculum for Ten Year School: A Framework (1975); National Policy on Education (1986); Curriculum for Elementary and Secondary Education: A Framework (1988); National Curriculum Framework for School Education (2000); National Curriculum Framework (2005); and National Education Policy (2020). Going through these documents, it can be seen that science and science education has been viewed from several perspectives. However, there are many points which are common in all these documents. First is inclusion of science in the curriculum. It is conspicuous that none of the referred documents underrated the importance of science and hence they all proposed to include it upto different levels of education - upto undergraduate university work (University Education Commission, 1948-49); first ten years of schooling (Education Commission, 1964-66); upto class X (Curriculum for Ten Year School: A Framework, 1975); and include science from the very first class of primary level (National Curriculum Framework for School Education (2000). National Education Policy (2020) suggested to include teaching of science form gradually introducing the general groundwork at preparatory stage to more abstract concept at middle stage to building greater depth across all the subjects at secondary stage.

Second is scientific method. It was aspired from the science education that it should enable the learners to understand and use scientific method (University Education Commission, 1948-49) by which facts can be discovered, relationships established, and sound conclusions can be reached (Secondary Education Commission, 1952-53). For teaching scientific method of inquiry to the learners, it was also pointed out to upgrade teaching of science and renew the science curriculum (Curriculum for Ten Year School: A Framework, 1975). Learners should be able to understand, interpret and deal with various things and phenomena in a more scientific way (Curriculum for Elementary and Secondary Education: A Framework, 1988). Science education should develop children’s ability to inquire scientifically (National Curriculum Framework, 2005).

Third is developmental tasks. Science education should help learners to have an active and intelligent interest in the whole of the physical and biological world (University Education

Commission, 1948-49); pupils should be encouraged to explore every opportunity to develop the attitude of critical inquiry (Secondary Education Commission, 1952-53); science teaching should be able to make scientific outlook a part of life and culture so that the learners can develop deep understanding of basic principles; develop problem-solving and analytical skills and the ability to apply them to the problems of the material environment and social living, and promote the spirit of enquiry and experimentation (Education Commission, 1964-66); a rational outlook leading to better utilization of science and technology (Curriculum for Ten Year School: A Framework, 1975); education in science should aim at developing well-defined abilities in cognitive, affective and psychomotor domains (Curriculum for Elementary and Secondary Education: A Framework, 1988) so as to develop in the child well-defined values and abilities such as the spirit of inquiry, creativity, objectivity, the courage to question and an aesthetic sensibility (National Policy on Education, 1986; Curriculum for Elementary and Secondary Education: A Framework, 1988) and abilities of knowing, doing and being with a focused emphasis on processes (National Curriculum Framework, 2000); to enable the learners to acquire problem solving and decision making skills and to discover the relationship of science with other aspects of daily life (National Policy on Education, 1986, 1986); inquiry skills should be supported and strengthened (National Curriculum Framework, 2005). National Education Policy (2020) also talked about heavily incorporating scientific temper along with other important skills in the curricula and pedagogy. However, the document accentuates annihilation of hard separation of arts and science. Instead a "liberal education" model is proposed.

It is important to notice that the recommendations about science education have undergone major shifts. Initially it was only the science which was expected to develop certain abilities and skills in the learners. Over the period of time the teaching of science and its utilities were perceived in a broader way. This lead to deeper and stronger understanding of science as well as its association with other subjects. Today science is recommended not to be viewed as an isolated subject. Instead, it is considered an important part of the whole curriculum and hence a holistic approach in the name of *liberal education* is proposed.

All in all, these documents considered science an inseparable part of school curriculum and greatly stressed on science education for development of analytical thinking, critical thinking, rational outlook, creative thinking, problem solving ability, scientific attitude, decision making skills, appreciation for scientific methods of inquiry and relationship between science and environment around. Teaching of science is considered here as a strong tool for development of one's inner resources. Hence, science education cannot be underestimated. In this way, science claims an honorable place in the school curriculum. The Following part discusses how science curriculum should be structured.

1.3.1 Guiding principles for Science Curriculum

Guiding principles are the visionary statements for preparing an effective Science Education programme. They can help educators, administrators and curriculum designers to design a curriculum framework that can support student engagement, curiosity, analytical thinking and joyful learning. Following are the guiding principles for an effective science and technology/engineering education given in the Science and Technology/ Engineering Massachusetts Curriculum Framework by Massachusetts Department of Elementary and Secondary Education (2016):

Principle 1 (Relevance): An effective science and technology/engineering program develops students' ability to apply their knowledge and skills to analyze and explain the world around them.

Principle 2 (Relevance): An effective science and technology/engineering program addresses students' prior knowledge and preconceptions.

Principle 3 (Rigor): Investigation, experimentation, design, and analytical problem solving are central to an effective science and technology/engineering program.

Principle 4 (Rigor): An effective science and technology/engineering program provides opportunities for students to collaborate in scientific and technological endeavors and communicate their ideas.

Principle 5 (Rigor): An effective science and technology/engineering program conveys high academic expectations for all students.

Principle 6 (Coherence): An effective science and technology/engineering program integrates STE learning with mathematics and disciplinary literacy.

Principle 7 (Coherence): An effective science and technology/engineering program uses regular assessment to inform student learning, guide instruction, and evaluate student progress.

Principle 8 (Coherence): An effective science and technology/engineering program engages all students, preK through grade 12.

Principle 9 (Coherence): An effective science and technology/engineering program requires coherent districtwide planning and ongoing support for implementation.

National Academics Press (2012) has addressed "Three dimensional learning" in the framework for K-12 Science education for Next Generation Science Standards (NGSS). The framework describes a vision of what it means to be proficient in science. It presents three dimensions that are combined (often referred to as pillars) to form each standard. The term "Three dimensional learning" is now referred to as the "performance expectations". The dimensions fundamentally attempt to shift the focus of science education.

Dimension 1: "Scientific and engineering practices": The term Practice is deliberately used here instead of "Skills" to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems.

Dimension 2: "Crosscutting concepts": Crosscutting concepts have application across all domains of science. As such, they are a way of linking the different domains of science. They include: Patterns, similarity, and diversity; Cause and effect; Scale, proportion and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change. The Framework emphasizes that these concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically-based view of the world.

Dimension 3: "Disciplinary core ideas": Disciplinary core ideas have the power to focus K–12 science curriculum, instruction and assessments on the most important aspects of science. To be considered core, the ideas should meet at least two of the following criteria and ideally all four:

- Have **broad importance** across multiple sciences or engineering disciplines or be a **key organizing concept** of a single discipline;
- Provide a **key tool** for understanding or investigating more complex ideas and solving problems;

- Relate to the **interests and life experiences of students** or be connected to **societal or personal concerns** that require scientific or technological knowledge;
- Be **teachable** and **learnable** over multiple grades at increasing levels of depth and sophistication.

Disciplinary ideas are grouped in four domains: the physical sciences; the life sciences; the earth and space sciences; and engineering, technology and applications of science.

1.3.2 Criteria for ideal science curriculum

National Curriculum Framework - 2005 (2005) discusses ample opportunities for the wholistic development of learners through science education. The document uses the term "good science education" by which it is meant that science education ought to be true to the child, true to the life and true to the science. Moreover, the document includes the basic criteria for a science curriculum to be considered a valid curriculum. These criteria are given in NCF – 2005 by National Council of Educational Research and Training (2005):

Cognitive validity requires that the content, process, language and pedagogical practices of the curriculum are age appropriate, and within the cognitive reach of the learner.

Content validity requires that the curriculum must convey significant and correct scientific and correct information. Simplification of content, which is necessary for adapting the curriculum to the cognitive level of the learner, must not be so trivialised as to convey something basically flawed and/or meaningless.

Process validity requires that the curriculum should engage learners in acquiring the methods and processes that lead to the generation and validation of scientific knowledge and nurture the natural curiosity and creativity of the learner in science. Process validity is an important criterion since it helps the learner in 'leaning to learn' science.

Historical validity requires that the science curriculum be informed by a historical perspective, enabling the learner to appreciate how the concepts of science evolve over time. It also helps the learner to view science as a social enterprise and to understand how social factors influence the development of science.

Environmental validity requires that science be placed in the wider context of the learners environment, local and global, enabling him/her to appreciate, the issues at the interface of science, technology and society, and equipping him/her with the requisite knowledge and skills to enter the world of work.

Ethical validity requires that the curriculum promote the values of honesty, Science in School Curriculum objectivity, cooperation, and freedom from fear and prejudice, and inculcate in the learner a concern for life and preservation of the environment.

1.3.3 Aims and Objectives of science education

Scientific literacy is one of the foremost goals of science education (AAAS, 1993). The development of children's ability to inquire scientifically is the main goal of science education (NCF - 2005). UNESCO (2014) strongly believes that science plays a key education role. The critical thinking that comes with science education is vital in training the mind, understanding the world, making choices and solving problems. Science literacy supplies the basis for solutions to everyday problems in uncontroversial ways, reducing the likelihood of misunderstandings and furthering common understanding. Science literacy and capacity building should be particularly promoted in low and middle income countries, where both the appreciation of the benefits of science as well as the resources for science are lacking.

According to National Focus Group on Teaching of Science (2006) published by NCERT, science education should enable the learners to:

- know the facts and principles of science and its applications, consistent with the stage of cognitive development,
- acquire the skills and understand the methods and processes that lead to generation and validation of scientific knowledge,
- develop a historical and developmental perspective of science and to enable her to view science as a social enterprise,
- relate to the environment (natural environment, artifacts and people), local as well as global, and appreciate the issues at the interface of science, technology and society,
- acquire the requisite theoretical knowledge and practical technological skills to enter the world of work,
- nurture the natural curiosity, aesthetic sense and creativity in science and technology,
- imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment, and

- cultivate ‘scientific temper’-objectivity, critical thinking and freedom from fear and prejudice.

1.3.4 Aims and Objectives of science education at upper primary stage (class VI to VIII) (NCF 2005)

At the upper primary stage, the child should be engaged in learning the principles of science through familiar experiences, working with hands to design simple technological units and modules and continuing to learn more about the environment and health, including reproductive and sexual health, through activities and surveys. Scientific concepts are to be arrived at mainly from activities and experiments. Science content at this stage is not to be regarded as a diluted version of secondary school science. Group activities, discussions with peers and teachers, surveys, organization of data and their display through exhibitions, etc. in schools and the neighbourhood should be important components of pedagogy. There should be continuous as well as periodic assessment (unit tests, term-end tests). The system of 'direct' grades should be adopted. There should be no detention. Every child who attends eight years of school should be eligible to enter Class IX.

1.3.5 Local Perspective: Aims of Science Education by GCERT

At state level, the name of science textbook has been replace by textbook of Science and Technology by Gujarat State Board of School Textbook (NCERT, 2011). Additionally, Gujarat Council of Educational Research and Training (GCERT), a pivotal body responsible for the enhancement of qualitative education at primary and secondary schools, has prescribed aims of science education that science education should enable the learners to (GCERT, 2021):

understand natural phenomena; know cause and effect relationship; understand environment around; understand the importance of science in daily life; develop scientific attitude; make observations; collect and analyze the information (data); try to solve the problem; undertake experiment and verify the results; develop inquisitiveness, curiosity, reasoning ability and decision making and; appreciate the new invention and their inventors.

These aims of science education are supposed to be reflected while designing science curriculum. They also indicate that the outcome of school science education programme should be that students leaving the school system will have developed the knowledge, skills, attitudes and values of science. It is important for science educators to have a clear understanding of above mentioned aims of science education. Moreover, the science curriculum should be transacted in such a way that develops and enriches one's inner resources. Various theoretical foundations can help educators to design tangible education objectives. Taxonomies have been proven to be of great help to the curriculum designers and educators.

1.4 ROLE OF TAXONOMIES IN EDUCATIONAL OBJECTIVES

Educational objectives are the goals of the education system. They are the expected learning outcomes of the learning processes. In the words of Bloom (1956) " By educational objectives we mean explicit formulations of the ways in which students are expected to be changed by educative process, that is, the ways in which they will change in their actions". Educational objectives often reflect what is aspired from the learners. Hence, thorough discussions and deliberations are out to take place for arriving at the statements of educational objectives. Taxonomies can help uniformize the process of education in a way that teachers, educators and policy makers can precisely deal with it.

The term "Taxonomy" is especially used in Botany and Zoology for classifying plants and animals as the superiors and subordinates in a hierarchical fashion. Living and extinct organisms are classified into nested groups such as family, order, class, phyla, kingdom and domain. In the context of education, taxonomies are the classification systems having an order of organization. The taxonomy having carefully defined terms, organized from simple to complex and from concrete to abstract, provides a framework of categories for classifying educational goals. Such systems can (State University, 2021):

- Provide a common language about educational goals that can bridge subject matter and grade levels
- Serve as a touchstone for specifying the meaning of broad educational goals for the classroom
- Help to determine the congruence of goals, classroom activities and assessments
- Provide a panorama of the range of possible educational goals against which the limited breadth and depth of any particular educational curriculum may be contrasted.

Through the reference to the taxonomy as a set of standard classifications, teachers should be able to define nebulous terms such as "really understand", "internalize knowledge" or "grasp the core or essence".

1.4.1 Bloom's Taxonomy (1956) - A Foundational and Pioneer framework

It was in 1940s when the dire need of developing a standard classification system for educational objectives was realized by Benjamin Bloom - an American Educational Psychologist. Beginning in 1948, a group of educators undertook the task of classifying educational goals and objectives with an intention to help teachers, administrators, professional specialists and researchers who deal with curricular and evaluation processes.

The intent was to develop a classification system for three major parts: the cognitive, the affective, and the psychomotor domains. The cognitive domain includes those objectives which deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. Second part of the taxonomy, the affective domain, includes objectives which describe changes in interest, attitudes, and values, and the development of appreciations and adequate adjustment. Third domain, Psychomotor domain, is the manipulative or motor-skill area. The organizational principle followed while framing the taxonomy was "Educational-logical-psychological" classification system. The terms in this order express the emphasis placed on the different principles by which the taxonomy could be developed. Thus, first importance was to be given to educational considerations. Insofar as possible, the boundaries between categories should be closely related to the distinctions teachers make in planning curricula or in choosing learning situations. It is possible that teachers make distinctions which psychologists would not make in classifying or studying human behaviour. However, if one of the major values of the taxonomy is in the improvement of communication among educators, then educational distinctions should be given major consideration. Second, the taxonomy should be a logical classification in that every effort should be made to define terms as precisely as possible and to use them consistently. Finally, the taxonomy should be consistent with relevant and accepted psychological principles and theories. The major phenomena with which the taxonomy is concerned is the changes produced in the individuals as a result of educational experiences. The taxonomy attempts to classify the *Intended behaviour* of the students- the ways in which individuals are to act, think, or feel as the result of participating in some unit of instruction. However, the *actual behaviour* of the students after they have completed the instruction may differ from the intended behaviour. To describe more about the foundation of the taxonomy, there are four guiding principles of the taxonomy. First, since the taxonomy is to be used in regard to existing educational units and programs, we are of the opinion that the major distinctions between classes should reflect, in large part, the distinctions teachers make among student behaviours. Second principle is that the taxonomy should be logically developed and internally consistent. Thus, each term should be defined and used in a consistent way throughout the taxonomy. Third principle is that the taxonomy should be consistent with our present understanding of psychological phenomena. Fourth principle is that the classification should be a purely descriptive scheme in which every type of educational goal can be represented in a relatively neutral fashion.

1.4.2. Structure of Bloom's taxonomy for cognitive domain

The following figure shows each level of cognitive domain as classified by Bloom. The hierarchy proceeds from ***concrete to abstract*** levels. "Knowledge" is the lowest level of cognitive domain whereas "Evaluation" is the highest level as described by Bloom each of which is organized as a series of levels. Each level is the pre-requisite for the next level. Therefore, it is suggested that one cannot effectively or ought not try to address higher levels until those below them have been covered. It is thus effectively serial in structure.

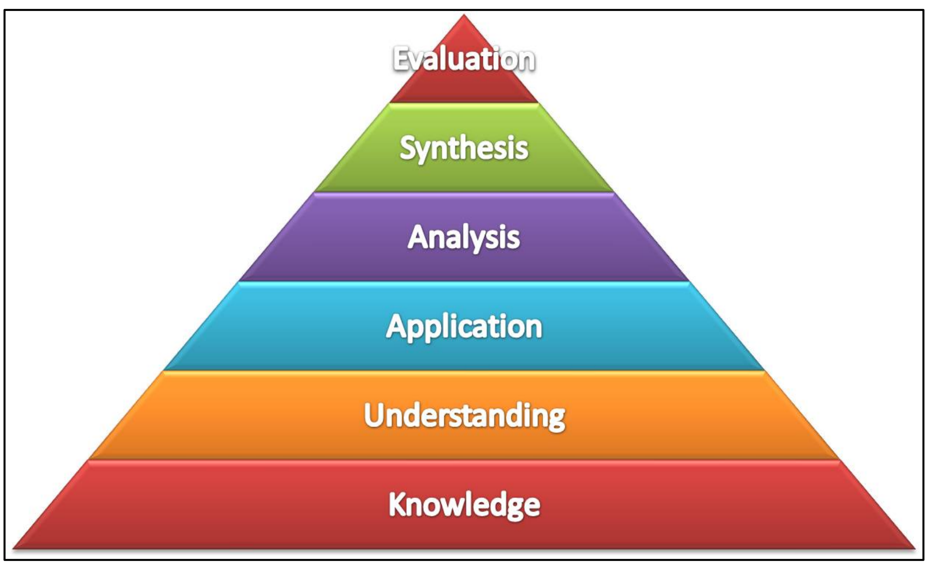

Image Source: McHugh (2013)

Figure 1.1 Bloom's Original Taxonomy

1. Knowledge

Knowledge represents the first and the lowest level in the cognitive domain. The definition of knowledge for this level is remembering of ideas, material or phenomena. The requirement is simply to ***recall***. The range of information may vary from simple facts to complex theories, but all that is required is to remember the information. It can be noted here that though knowledge is involved in all the next categories of the taxonomy, in the very first category remembering is the major psychological process involved whereas in the rest of the categories the remembering is a part of much more other complex processes. The knowledge category is divided into subcategories as follows:

Knowledge of specifics: This refers primarily to the hard core of facts or information in each field of knowledge.

- Knowledge of terminology: knowledge of the referents for specific verbal and non-verbal symbols which include the most generally accepted symbol referents.
- Knowledge of specific facts: knowledge of dates, events, persons, places and sources of information

Knowledge of ways and means of dealing with specifics: This includes the methods of inquiry, the chronological sequences, and the standards of judgement within a field as well as the patterns of organization through the areas of the fields themselves are determined and internally organized.

- Knowledge of conventions: knowledge of characteristics ways of treating and presenting ideas and phenomena.
- Knowledge of trends and sequences: knowledge of processes, directions, and movements of phenomena with respect to time.
- Knowledge of classifications and categories: knowledge of classes, sets, divisions, ans arrangements which are regarded as fundamental or useful for a given subject field, puropse, argument, or problem.
- Knowledge of criteria: knowledge fo the criteria by which facts, principles, opinions and conduct are tested or judged.
- Knowledge of methodology: knowledge of the methods of inquiry, techniques, and procedures employed in a particular subject field as well as those employed in investigating particular problems and phenomena.

Knowledge of the universals and abstractions in the field: this include major ideas, schemes, and patterns by which phenomena and ideas are organized.

- Knowledge of principles and generalizations: Knowledge of particular abstractions which summarize observations of phenomena.
- Knowledge of theories and structures: knowledge of the body of principles and generalizations together with their interrelations which present a clear, rounded, and systematic view of a complex phenomenon, problem, or field.

2. Comprehension

Comprehension is the first step beyond simple recall. It is the first level, demonstrating and understanding the information. It is the ability to ***apprehend***, ***grasp***, and ***interpret*** the meaning of material.

Translation: It means that an individual can put a communication into other language, into other terms, or into another form of communication. It will usually involve the giving of meaning to the various parts of a communication, taken in isolation, although such meanings may in part be determined by the context in which the ideas appear.

Interpretation: It involves dealing with a communication as a configuration of ideas whose comprehension may require a reordering of the ideas into a new configuration in the mind of the individual. This also includes thinking about the relative importance of the ideas, their interrelationships, and their relevance of generalizations implied or described in the original communication.

Extrapolation: It includes the making of estimates or predictions based on understanding of the trends, tendencies, or conditions described in the communication. It may also involve the making of inferences with respect to implications, consequences, corollaries and effects which are in accordance with the conditions described in the communication.

3. Application

Application is the ability to show the pertinence of principles to different situations. At this level, student may ***apply concepts or methods to actual concrete problems***. This thinking skill tells you that a student can transfer selected information to a life problem or a new task with a minimum of direction.

4. Analysis

Analysis requires more than knowledge, comprehension, and application. It also requires an understanding of the underlying structure of the material. Analysis is the ability to break down material to its functional elements for better understanding of the organization. Analysis may include identifying parts and clarifying relationships among parts. This thinking skill tells you that ***a student can examine, take apart, classify, predict, and draw conclusions.***

5. Synthesis

Synthesis requires the formulation of new understandings. If analysis stresses the parts, synthesis stresses the whole. Components of concepts may be reorganized into new patterns and new wholes. ***A student can originate, combine, and integrate parts of prior knowledge into a product, plan, or proposal that is new***.

6. Evaluation

Evaluation is the highest level in the hierarchy. It includes all the other levels plus the ***ability to make judgments, assess, or critique based on evidence and clearly defined criteria.***

1.4.3 Revision of Bloom's Taxonomy for Cognitive Domain

In 2001, the taxonomy given by Bloom was revised by his students (Anderson et al. 2001). Following changes were made in the revised taxonomy.

Terminology Changes

Bloom's six major categories were changed from noun to verb forms. Additionally, the lowest level of the original taxonomy, knowledge was renamed and became remembering. Finally, comprehension and synthesis were retitled to understanding and creating. All these changes are shown in the following figure:

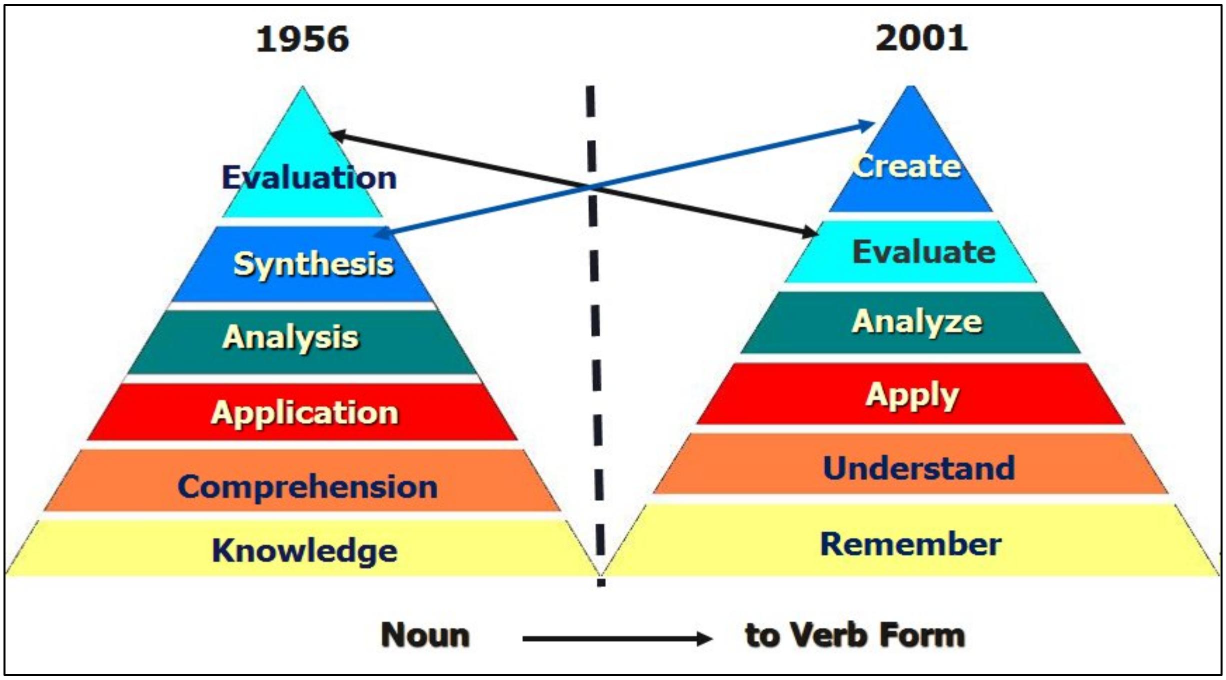

Image Source: McHugh (2013)

Figure 1.2 Bloom's Revised Taxonomy

Structural changes

Bloom's original cognitive taxonomy was a one-dimensional form. With the addition of products, the Revised Bloom's Taxonomy takes the form of a two-dimensional table. One of the dimensions identifies The Knowledge Dimension (the kind of knowledge to be learned) while the second identifies The Cognitive Process Dimension (or the process used to learn). As represented on the grid below, the intersection of the knowledge and cognitive process categories form twenty-four separate cells as represented on the "Taxonomy Table" below.

The Knowledge Dimension on the left side is composed of four levels that are defined as Factual, Conceptual, Procedural, and Meta-Cognitive. The Cognitive Process Dimension across the top of the grid consists of six levels that are defined as Remember, Understand, Apply, Analyze, Evaluate, and Create.

Following Taxonomy Table (or two-dimensional matrix) shows both the knowledge and the cognitive process dimensions along with some action verbs. It also indicated there are different ***levels of knowledge*** associated with each level in the Bloom's taxonomy. On the other side, each level of knowledge is associated with all the levels of the hierarchy.

Table 1.1 Taxonomy Table (Two-Dimensional Matrix)

The Knowledge Domain	**The Cognitive Process Domain**					
	Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual Knowledge	List	Summarize	Classify	Order	Rank	Combine
Conceptual Knowledge	Describe	Interpret	Experiment	Explain	Assess	Plan
Procedural Knowledge	Tabulate	Predict	Calculate	Differentiate	Conclude	Compose
Meta-cognitive Knowledge	Appropriate use	Execute	Construct	Achieve	Action	Actualize

The levels of knowledge under the knowledge dimension are explained in brief as follows:

- **Factual knowledge** is the basic elements students must know to be acquainted with a discipline or solve problems.
- **Conceptual knowledge** indicates the interrelationships among the basic elements within a larger structure that enable them to function together.
- **Procedural knowledge** deals with how to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.
- **Metacognitive knowledge** is knowledge of cognition in general, as well as awareness and knowledge of one's own cognition.

1.5 TAXONOMY FOR COGNITIVE DOMAIN: A TOOL FOR WIDE-RANGE ASSESSMENT IN SCIENCE

Assessment is viewed as a necessary part of the education process since it serves various purposes: (i) it helps improve the teaching-learning process and materials and hence review the objectives; (ii) it gauges the developed capabilities of the learners; (iii) it provides feedback to the learners and sets standards for them to strive towards; and (iv) it certifies completion of a course of study with information related to quality and extent of learning (NCF - 2005: NCERT, 2005). The assessment process is an effective tool for communicating the expectations of the science education system to all concerned with science education. Assessment and learning are two sides of the same coin (National Academy Press, 1996) As a matter of fact, science instruction and science assessment are closely interrelated with each other (Rustaman, 2017). Central Board of Secondary Education (2010) has recommended that the assessment, in a view of getting a complete picture of child's learning, should focus on learner's ability to: retain what is learned over a period of time; acquire a level of achievement; develop child's individual skills, interests, attitudes and motivation; be sensitive to social and environmental issues; apply what is learned; analyze and evaluate. Moreover, assessing conceptual understanding of students -"dig holes, don't cut grass" (The Science Teacher, 2021) is an important principle of assessment design. Since, the present curriculum is overloaded with information and promotes rote learning and memorization, the theoretical paper for science examination should contain questions that are based on some experiments / technology and test students' critical understanding and problem solving ability (NCERT, 2006). Therefore, it is desirable that the assessment questions are of both lower as well as higher order thinking abilities since the level of question do affect development of students' cognitive abilities (Lombardi, 2019). In fact, assessing learners' abilities from all aspects is viewed as a reformation in the Indian education system (Prajapati & Kothari, 2020). It is also suggested to use Multiple Choice Questions (MCQs) along with open ended question to assess students in science (NCERT, 2006; The Science Teacher, 2021). Though designing MCQs is not an easy task as their fairness relies upon proper standard setting, psychometric adequacy, consequential validity and proper construction (McCoubrie, 2004), MCQs can test students higher knowledge and can be used on larger groups (Ehsan, 2017). Considering everything, it can be concluded that assessment in science is a matter of great concern as it mirrors the effectiveness of the learning process.

1.6 RATIONALE

Science is not only a school subject for which students are supposed to secure prescribed minimum marks. Science as a discipline is of great importance for development of the students, the society and the nation. Science helps develop the inner resources of the learners and makes them productive citizens of the nations. Therefore, all the efforts must begin in the early grades when students are naturally curious about the world around them and eager to explore (National Science

Teachers Association, 2002). The effectiveness of the science curriculum and science instruction ought to be investigated time and again so that necessary actions can be taken for improvement of the same. Assessment has been serving as a potent tool to communicate the effectiveness of the science education process to the policy makers, teachers, students and parents. Assessment can measure the extent of fulfilment of the learning outcomes of the science education to great efficiency. For assessing a larger group of pupils, Multiple Choice Questions (MCQs) can serve the purpose due to ease of administration and objectivity of scoring. Though designing effective question can be a challenging task, adopting a standard procedure for construction of the MCQs can reduce the limitations of MCQs to a greater extent. MCQs contain a stem (question or item statement), a key (the correct answer) and distractors (wrong answers). An effective MCQ should have distractors which are as convincing as the key (Professional Testing Inc., 2021). The content and the level of the stems need to be aligned to the stated educational objectives. Students should be given thought provoking questions to respond. The questions must be constructed with respect to a framework (or a taxonomy) to cover the entire spectrum of the difficulty. Thus, carefully framed and validated questionnaire can assess students lower as well as higher abilities. Programme for Students Assessment (PISA) and National Achievement Survey (NAS) are examples of the assessment on a larger population. They attempted to assess students' knowledge of Mathematics, Science and Reading (for PISA) and Language, Mathematics, Science and Social Science (for NAS). They also study learners' ability to apply knowledge of various subject in a new situation that is both lower and higher order abilities. However, India's performance in PISA 2009 was quite dissatisfactory as it ranked 72nd out of 73 schools (OECD, 2010). After that, India did not participate in PISA till now. At national level, NCERT attempted to conduct a National Achievement Survey for grade III, V and VIII in the year 2017. The test report for Gujarat state class VIII science subject are as follows: Average achievement was 52%. For gender wise performance, girls were at 51% and boys 52%. By school location, rural schools achieved 52% whereas urban schools 49% and by school management, 52% for government schools and 46% government aided schools. It can be noticed here that scores are barely crossing 50% or less than that. These statistics make assessment in science a matter of great concern. Researcher concluded here that there was a dire need of conducting a more comprehensive and compact assessment in science for grade IX students as they had successfully completed their primary education and opted for continuing secondary education.

In the light of review of related literature, the reviewed studies corroborated feasibility of test administration by using MCQs. A prominent finding of the studies was that gender did have an impact on the achievements/performance of students. Location wise, either urban area or central parts of the states were the places where the reviewed studies were conducted. Therefore, more attention needed to be paid to remote locations as they were still unexplored. As a result, Kachchh district was selected for conduction of the present research considering feasibility and accessibility aspects for the researcher. The district had more number of Gujarati medium schools than English medium ones (DEO Bhuj, 2019 data) and therefore, medium of instruction became an essential variable for the present study. Another important point to be noted form the review of related studies was that the last study conducted on test construction and standardization was by Ghosh (1985). No any similar studies were conducted in recent times. With regard to test construction, almost all the studies tried to determine students' performance at lower levels of cognition. Therefore, there was a dire need of constructing and standardizing a test which covers lower as well as higher levels of cognition.

1.7 STATEMENT OF THE PROBLEM

A study of cognitive abilities of class IX students in science and technology in Kachchh district

1.8 OBJECTIVES OF THE STUDY

1. To study the cognitive abilities of class IX students in science and technology.

2. To study the cognitive abilities of class IX students in science and technology with respect to gender.

3. To study the cognitive abilities of class IX students in science and technology with respect to medium of instruction.

4. To study the cognitive abilities of class IX students in science and technology with respect to types of school.

5. To study the relationship between cognitive abilities in science and technology and academic achievement in science and technology of class IX students.

1.9 HYPOTHESES

$H_0 1$: There will be no significant difference in the mean achievement scores in CATS of class IX students with respect to gender.

$H_0$2: There will be no significant difference in the mean achievement scores in CATS of class IX students with respect to medium of instruction.

$H_0$3: There will be no significant difference in the mean achievement scores in CATS of class IX students with respect to types of schools.

$H_0$4: There will be no significant interaction between mean achievement scores in CATS of class IX students with respect to gender and medium of instruction.

$H_0$5: There will be no significant interaction between mean achievement scores in CATS of class IX students with respect to gender and types of schools.

$H_0$6: There will be no significant difference in the mean achievement scores in Chemistry of class IX students with respect to gender.

$H_0$7: There will be no significant difference in the mean achievement scores in Chemistry of class IX students with respect to medium of instruction.

$H_0$8: There will be no significant difference in the mean achievement scores in Chemistry of class IX students with respect to types of schools.

$H_0$9: There will be no significant interaction between mean achievement scores in Chemistry of class IX students with respect to gender and medium of instruction.

$H_0$10: There will be no significant interaction between mean achievement scores in Chemistry of class IX students with respect to gender and types of schools.

$H_0$11:There will be no significant difference in the mean achievement scores in Physics of class IX students with respect to gender.

$H_0$12: There will be no significant difference in the mean achievement scores in Physics of class IX students with respect to medium of instruction.

$H_0$13: There will be no significant difference in the mean achievement scores in Physics of class IX students with respect to types of schools.

$H_0$14: There will be no significant interaction between mean achievement scores in Physics of class IX students with respect to gender and medium of instruction.

$H_0$15: There will be no significant interaction between mean achievement scores in Physics of class IX students with respect to gender and types of schools.

$H_0$16:There will be no significant difference in the mean achievement scores in Biology of class IX students with respect to gender.

$H_0$17: There will be no significant difference in the mean achievement scores in Biology of class IX students with respect to medium of instruction.

$H_0$18: There will be no significant difference in the mean achievement scores in Biology of class IX students with respect to types of schools.

$H_0$19: There will be no significant interaction between mean achievement scores in Biology of class IX students with respect to gender and medium of instruction.

$H_0$20: There will be no significant interaction between mean achievement scores in Biology of class IX students with respect to gender and types of schools.

$H_0$21: There will be no significant difference in the mean achievement scores for Remember level of CATS of class IX students with respect to gender.

$H_0$22: There will be no significant difference in the mean achievement scores for Remember level of CATS of class IX students with respect to medium of instruction.

$H_0$23: There will be no significant difference in the mean achievement scores for Remember level of CATS of class IX students with respect to type of school.

$H_0$24: There will be no significant difference in the mean achievement scores for Understand level of CATS of class IX students with respect to gender.

$H_0$25: There will be no significant difference in the mean achievement scores for Understand level of CATS of class IX students with respect to medium of instruction.

$H_0$26: There will be no significant difference in the mean achievement scores for Understand level of CATS of class IX students with respect to type of school.

$H_0$27: There will be no significant difference in the mean achievement scores for Apply level of CATS of class IX students with respect to gender.

$H_0$28: There will be no significant difference in the mean achievement scores for Apply level of CATS of class IX students with respect to medium of instruction.

$H_0$29: There will be no significant difference in the mean achievement scores for Apply level of CATS of class IX students with respect to type of school.

$H_0$30: There will be no significant difference in the mean achievement scores for Analyze level of CATS of class IX students with respect to gender.

$H_0$31: There will be no significant difference in the mean achievement scores for Analyze level of CATS of class IX students with respect to medium of instruction.

$H_0$32: There will be no significant difference in the mean achievement scores for Analyze level of CATS of class IX students with respect to type of school.

$H_0$33: There will be no significant difference in the mean achievement scores for Evaluate level of CATS of class IX students with respect to gender.

$H_0$34: There will be no significant difference in the mean achievement scores for Evaluate level of CATS of class IX students with respect to medium of instruction.

$H_0$35: There will be no significant difference in the mean achievement scores for Evaluate level of CATS of class IX students with respect to type of school.

$H_0$36: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students.

$H_0$37: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX male students.

$H_0$38: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX female students.

$H_0$39: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students of English medium.

$H_0$40: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students of Gujarati medium.

$H_0$41: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students of Government schools.

$H_0$42: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students of grant-in-aid schools.

$H_0$43: There will be no significant correlation between achievement scores in CATS and academic achievement in science of class IX students of private schools.

1.10 OPERATIONALIZATION OF THE TERMS

Cognitive abilities: Researcher took into consideration all the levels of cognitive domain given by Anderson et. al. (2001). Students' performance in terms of their achievement scores in the Cognitive Ability Test for Science (CATS) containing Multiple Choice Questions (MCQ) constructed and standardized by the researcher based on first five levels; and in the Creativity Test for Science (CTS) containing test items focused on top most level of cognitive domain given by Anderson et. al. (2001); were considered as their cognitive abilities for the present study.

Academic achievement in science: Students' scores in science and technology subject of class IX in the academic year 2018-19 were considered as their academic achievement in science.

1.11 EXPLANATION OF THE TERMS

Types of schools: Government schools, grant-in-aid schools and private schools were selected for the present study. The category of government schools included government funded schools; schools under the scheme Rashtriya Madhyamik Shiksha Abhiyan (RMSA), Border Area Develop Project (BADP) and Model schools.

1.12 DELIMITATION OF THE STUDY

The study was delimited to the schools managed by Gujarat Board of Secondary Education (GSEB) in Kachchh district during the academic year 2018-19. The study was also delimited to the content of Science and Technology subject from class six to class eight.

The variables and the methodology were decided based on the review of related studies conducted for the present study. Chapter two contains detailed review of related studies and the implications drawn for the present study.