CHAPTER 5
SUMMARY, DISCUSSION, IMPLICATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 INTRODUCTION

Science occupies a prestigious status in the overall school curriculum in India as in all other nations across the globe. Its status is justified on several grounds, including the significance of preparing scientifically literate individuals in the contemporary science and technology-dominated society. Simultaneously, science pedagogy has witnessed unprecedented levels of research-based innovations, specifically through the prestigious curriculum reforms in the 60s and again in the 90s, and it continues even in the 21st century. All the major shifts in science pedagogy have evolved in the developed countries, with the developing countries following suit and mostly lagging behind.

Contemporary science pedagogy embeds in a constructivist paradigm of learning with an emphasis on hands-on experiences for the students and an advocacy for a process approach to science. The National Curriculum Framework, 2005 vehemently argues for a constructivist approach to learning in schools, and the literature is rife with a plethora of studies concluding the effectiveness of the constructivist approach to science learning in terms of students' achievement of learning goals.

The ground reality is, however, quite different. Even a superficial observation of the pedagogical processes in our classroom reveals that the lecture method is still the most predominant approach in educational situations across the nation (National Curriculum Framework for School Education, 2023; Shelat, 2012; PROBE, 2012) and even in several of the best public schools. Such a scenario is not at all surprising. The different models for teaching that have evolved in the recent past under the umbrella term constructivism are mostly those that have been imported into the country with a criticism of the traditional method of teaching and outright rejection of the same. Further, the innovations that are suggested through experimentation rarely take into consideration the diverse context of school education in India and seldom is any action research carried out with the aim to develop some native model for learning based on the existing practices that suit the Indian context. The top-down approach adopted with reference to science pedagogy needs to be reversed, and a bottom-up approach is needed to make pedagogical innovations have contextual validity.

The lecture method is criticized for being passive with respect to students. Ausubel's learning theory (1963) had clearly established that even lectures can be used to make students active learners, and it can certainly be molded to help them construct their own learning. We need to take into consideration the large teacher-student ratio in our classrooms on the one hand and the limited resources available at the disposal of the schools and teachers on the other hand. The lecture method is the save bacon for teachers and schools. The researcher, with a sense of conviction, holds the assumption that the lecture method can be fashioned in a certain way to suit the active involvement of the students and achieve the purposes of the constructivist classroom.

Further, any method of teaching needs to take into consideration the cognitive load of the students. Cognitive load is the load concerned with the understanding of the topic, presentation of the topic, and processing of the topic for a particular concept (Sweller, 2003). Both cognitive as well as constructivist theories highlight the importance of acquiring learning strategies or methods used to aid knowledge acquisition rather than acquiring mere information and favour the acquisition of procedural, declarative, conceptual, and decision-making skills (Walcutt et al., 2010).

5.1 HISTORICAL PERSPECTIVE OF SCIENCE AND SCIENCE EDUCATION

5.1.1 PRE-INDEPENDENCE

5.1.1.1 Science Education During the Ancient and Medieval Periods

Up until 600 A.D., India saw enormous advancements in astronomy, mathematics, medicine, architecture, and agriculture. According to Kumar (2018), medicine-related knowledge was adapted from religious literature like Rig-Veda (assumed to be written about 4000 years back), Vaisheskia (one of the Upanishads) discusses the atom and the formation of the world, Sankhya philosophy resembles Darwinism, and the Upa-Vedas discuss various sciences, Charaka and Sushruta Samhitas, provide evidence of sophisticated medical knowledge (Naik, 2017). In the past, it was conventional for the best disciples to receive wisdom from the guru. As part of the endeavour to institutionalize education, the two renowned old universities like Taxila and Vikramshila arose. But in India, science education did not advance much during the Middle Ages. Ancient Indian scientific knowledge, methods, and techniques did not contribute to the advancement of science education. Buddhism, which flourished from 750 to 1000 AD, impeded the advancement of the biological sciences. Scholars and knowledgeable individuals left India during the Middle Ages and were welcomed into the royal courts of West and Central Asia. As a result, brain drain occurred. The material, methods, procedures, and concepts used by these experts were adapted, systematized, and promoted as new ideas of the medieval Arabic and Persian scientific traditions of West Asia and Central Asia, while they actually originated in India. Roman and Greek literature on metals, Kanada's (Indian) conception of the atom and atomic physics, Aryabhatta's masterpiece "Aryabhattiyam," and others are only a few examples.

5.1.1.2 Science Education during the Colonial Period

Due to various reasons, science in pre-independence India did not advance significantly during the British era (Amin, 2011). Before that, modern science in India had already undergone a significant shift from the medieval and ancient periods; new scientific fields had emerged, and testing had become a method of gathering data. Scientific institutions had been established, technology had achieved a significant advancement, and the language of science had taken on a distinct form. In comparison to Western nations, India lagged far behind in scientific and technological advancements since these fields were neglected during the pre-independence era.

Oxford University, which has schools in several nations, including India, conducted a thorough analysis of the state of science instruction in secondary schools and published the results in a report known as the Devonshire Commission Report (1895). It has made it possible for science to be taught in classrooms. It was suggested that (a) a significant amount of time be set aside for studying natural sciences in all public schools, with an average of at least six hours per week being dedicated to this purpose; and (b) school laboratories be built to provide space for both chemistry and physics practical work. The report's release signalled the start of the broad integration of botany into the curriculum for girls' schools and physics and chemistry into the curriculum for boys' schools. But it took a while for this to get to India.

In 1916, Thomson established a committee to investigate the role of natural science in the educational system. The committee's findings, titled Natural Science in Education, was published as the Thomson report (1916). Following this, many schools added a large number of advanced science courses. Early in the century, the Association of Women Science Teachers and the Association of Science Masters were established.

Periodicals and school science reviews have a positive impact on both the public and instructors.

Education should support (a) health, (d) command of basic processes, (c) worthy home membership, (d) vocation, (e) citizenship, (f) worthy use of leisure, and (g) ethical character, according to the "cardinal principles of secondary education" report of the Commission on the Reorganisation of Secondary Education (1920). The group recommended in its 1920 bulletin, "Reorganisation of Science in Secondary Schools," that the sciences be taught and structured to support the seven cardinal principles, with the exception of fundamental processes. The project method, which was at the height of its popularity at the time, was one of several approaches that were proposed to influence this.

In its 1938 publication, "Science in General Education," the Commission on Secondary School Curriculum of the Progressive Education Association (SSCPE) criticized the methods used in science instruction at the time and offered recommendations for how secondary school science curricula should be modified to meet the needs of teenagers. Personal living, immediate personal-social interactions, social-civic relationships, economic relationships, and reflective thinking are the following demands. Under the direction of Sir Cyril Norwood, a committee of the Secondary School Examination Council was established, and a report was released. The Norwood Report (1943) had a whole chapter devoted to science instruction.

All of the aforementioned factors combined to cause the Education Act of 1944 to take effect in April of 1945, increasing the quantity of science taught, albeit not to the fullest extent possible.

India's science and education advanced in the ancient and medieval eras, but because of British occupation and the educational system, there was a pause in the seventeenth and eighteenth centuries. A few international initiatives, such as the Devonshire Committee Report (1895), the Thomson Report (1916), and the Norwood Report (1943) at the national level, sparked a push in India before independence for science to be taught in secondary schools.

Noteworthy figures like J.C. Bose, P.C. Ray, M.N. Saha, and C. V. Raman emerged, contributing significantly to global scientific knowledge. However, the overall development of science education was hampered by resource constraints, cultural barriers, and a lack of infrastructure. Science taught was largely theoretical, with minimal practical experimentation or research orientation (Sangwan, 1990).

5.1.2 POST-INDEPENDENCE

After India gained independence in 1947, there was a strong push to rebuild its educational system to serve its own needs and aspirations. The history of science education in India has been shaped by various commissions and policies, each contributing to its evolution. In 1948, the education system began to rebuild based on the Indian education system, leading to the introduction of general science at the secondary level based on the University Education Commission's recommendations. By 1953, the Secondary Education Commission advocated for science to become a compulsory subject in middle and high schools, emphasizing the need for diversification at the higher secondary level. The process continued in 1956 when the difficulties of incorporating science into senior secondary school were discussed at the All-India Seminar on the Teaching of Science in Tara Devi (Simla Hills). A standard method of teaching science, including the use of science clubs and museums, was recommended to enhance learning. The Science Policy Resolution of 1958, which was passed two years later, sought to promote and maintain the advancement of science and scientific research in all of its facets. The 1960s marked a significant period with the establishment of the National Council of Educational Research and Training (NCERT) in 1961, tasked with strengthening school education, developing textbooks, and providing teacher training workshops and conferences to in-service and pre-service teachers to enhance their capability. Central Science Workshop was started under NCERT to develop low-cost kits for primary and middle schools. The same year saw the enactment of the Institutes of Technology Act, creating the Indian Institutes of Technology as autonomous entities. In the same year, Pandit Jawaharlal Nehru established the Indian Parliamentary and Scientific Committee under the chairmanship of Shree Lal Bahadur Shastri ji for the improvement of science teaching in India. This committee aims to foster and sustain scientific research in the country, to make the country advance in the world of science and technology, and to ensure the progress and welfare of the country through planned growth in science and technology. The visit of UNESCO Planning Mission experts in 1963 further recommended enhancements in Science and Math Education, leading to the development of new educational materials. Significant steps were made with the Indian Education Commission (1964-66), which focused on improving textbooks, teaching materials, and the curriculum, suggesting science and mathematics should be integral parts of education during the first ten years of schooling and recommended that:

- "Science and Mathematics to be made compulsory subjects during first ten years of schooling."
- In rural areas, teaching will focus on agriculture, and in urban areas, technology.
- Science should be taught in lower grades by making connections to the surrounding environment.
- Science corners in lower classes and lab/lecture rooms in upper classes should be established.
- Discipline approaches should be used in higher courses. Investigatory methods of instruction are encouraged.

The commission's recommendations laid the groundwork for a more structured and practical approach to science education, emphasizing the need for a disciplinary strategy and the development of cognitive skills in science learning. The adoption of the National Policy on Education (NEP) in 1968 was a monumental step post-independence, integrating science and technology into the curriculum as compulsory subjects and fostering a connection between education and everyday life. The 1976 constitutional amendment indicates that the federal and state governments share responsibility for education by placing it on the concurrent list, which includes science and technology education. The Ministry of Human Resource Development was founded by the Indian government to serve as an administrative ministry. In 1977, a committee was made to review the textbook under the chairmanship of Ishwarbhai Patel because textbooks were previously criticized because it has less learning by doing experiences and this committee considered science as a tool for productive process. The National Curriculum Framework (1975) was created using the Education Policy (1968) as a guide. After that, the National Curriculum Framework (1988) was created based on recommendations of Education Policy (1986), and it was later updated to create National Curriculum Framework (2000). Subsequent policies, including the Technology Policy Statement (1983) and the Science and Technology Policy (2003), emphasized technological competence, innovation, and the role of science and technology in national development with the objective of "integrate programmes of socio-economic sectors with the national Research and development (R&D) system and the creation of a national innovation system”. In 1993, the Yashpal committee published a report titled “Learning without Burden” which said that life-oriented science is more important than abstract concept-based science and recommended that the integration of real life-oriented science in curriculum and science instruction in lower elementary grades has to be child centered. In more recent years, the National Curriculum Framework (2005) and the Science, Technology, and Innovation Policy (STIP) in 2013 introduced modern educational strategies such as the Constructivist Approach for Learning, focusing on learner-centered syllabi and pedagogical shifts and advocated the development of creativity, critical thinking, and scientific inquiry among students.

In order to better meet the demands of the twenty-first century and highlight each student's individual potential, the National Education Policy (2020) seeks to modernize the Indian educational system and make it more comprehensive, adaptable, and multidisciplinary. It places a strong emphasis on understanding and developing critical thinking and scientific temper among students. Based on recommendations made by this policy, the National Curriculum Framework for School Education (2023), framed by the National Council for Educational Research and Training, focuses on creating curricular and pedagogical structures that enable a scientific temper, critical thinking, and a creative understanding of the world. For attaining these objectives, the science framework suggested adopting inquiry-based, discovery learning, virtual learning, integration of technology in pedagogy, and Panchaadi (resemblance with the constructivist approach).

The fundamental tenets of the National Education Policy (2020) are decentralisation, evidence-based decision-making, bottom-up, expert-driven, and inclusivity. Through its collaborative, decentralised, and bottom-up design process, STIP 2020 seeks to refocus research and technology development methodologies, sectoral focus, and priorities for greater socioeconomic benefit.

On January 29, 2024, the Young Scientists Induction Training Program was introduced at the Indian Institute of Management, Visakhapatnam (IIM-V) by the Capacity Building Commission (CBC) in partnership with the Office of the Principal Scientific Adviser (Office of PSA) to the Government of India. This is a first-of-its-kind training programme that envisages honing the capacities of young scientists and science administrators in managing S&T programmes, projects, products, and people; promoting cross-fertilization of ideas among participants; providing practical exposure to new-age research and technology concepts and enhancing functional, behavioral and domain skills. This unique training program aims to improve the abilities of young scientists and science administrators in overseeing S&T programs, projects, products, and personnel; encourage idea sharing among participants; give them hands-on experience with cutting-edge research and technology concepts; and improve their functional, behavioural, and domain skills.

Principal Scientific Advisor to the Government of India Prof Ajay Kumar Sood launched the "Science for Women-A Technology & Innovation (SWATI)" Portal, aimed at creating a single online portal representing Indian Women and Girls in STEMM (Science, Technology, Engineering, Mathematics & Medicine). These policies have aimed to bring science education in India to the forefront, ensuring it contributes to the nation's progress and innovation.

5.2 IMPORTANCE OF SCIENCE

Science, an enduring pursuit for understanding the natural world, stands at the heart of human intellectual inquiry and progress. Its significance transcends the mere accumulation of knowledge, fostering critical thinking, problem-solving skills, and an informed citizenry capable of making decisions based on evidence. In this context, the role of science in education becomes paramount, shaping not only future scientists but also contributing to the holistic development of individuals in a rapidly evolving world. The National Council for Educational Research and Training (2006) stated the importance of science as follows:

- Understand scientific facts, principles, and applications according to the cognitive development and cognitive stage of the learner.
- Learn the techniques and gain an understanding of science.
- Adopt a developmental and historical viewpoint and consider science to be a social endeavour.
- Learn both theoretical and practical skills for your job.
- Concern with local, global, and environmental challenges at the nexus of science and technology.
- Encourage students' innate creativity, aesthetic sense, and interest for science and technology.
- Adopt the principles of science.
- Encourage students to adopt a scientific attitude.
- Imbibe the values of science.

- Fostering Critical Thinking and Inquiry: Science education is pivotal in developing critical thinking skills. Through the scientific method, students learn to question assumptions, analyze data, and draw evidence-based conclusions (Duschl, 2008). This approach encourages skepticism and curiosity, fundamental traits for navigating and understanding an increasingly complex world. The engagement with scientific inquiry thus equips students with a framework for tackling problems, a skill that is transferable beyond the science classroom into daily life and decision-making processes.
- Understanding and Interacting with the World: An understanding of scientific principles is crucial for individuals to interact effectively with their environment. The knowledge gained through science education helps individuals make informed decisions about health, nutrition, and environmental issues (Lee et al., 2013). For example, understanding the basic principles of vaccination and disease transmission has become indispensable in the context of global health crises such as the COVID-19 pandemic. Moreover, science literacy empowers communities to engage with and address environmental challenges, from climate change to conservation efforts.
- Economic Implications and Workforce Development: In the knowledge-based economy, scientific literacy is increasingly linked to economic competitiveness. Learners acquire skills through science education, such as analytical thinking and problem-solving, are demand of the contemporary job market, spanning a range of industries beyond the traditional science and technology sectors (National Science Board, 2006). Furthermore, fostering a strong foundation in science contributes to a nation's capacity to innovate and maintain a competitive edge in the global economy. As this way, science plays a significant role in economic development and workforce preparation.
- To develop a Societal and Ethical sense among learners: Science education plays a crucial role in shaping ethical and responsible citizens. It prompts students to consider the societal and ethical implications of scientific advancements. During the experimentation, science promotes ethical and honest practice for the success of experimentation and promotes honest reporting. In this way, science inculcates values of honesty and ethical practice among the learners.

But, after some time, the National Curriculum Framework for School Education (2023), also advocated science education with its importance because:

1. Science education provides adequate time and space for students to develop critical scientific inquiry skills, such as formulating questions, observations, hypotheses, experiments, arguments, predictions, and data analysis.
2. The development of scientific inquiry skills and a conceptual grasp of scientific ideas, rules, and principles are equally prioritized in science education. Students are supposed to get a scientific understanding of the workings of the physical natural world through these abilities and concepts.
3. Science education provides the scope for the child's cognitive development at the Foundational Stage. At this point, making sense of the world through observation and reasoning is a crucial curriculum objective.
4. In the Preparatory Stage, students study science as a school subject, The World Around Us in order to gain an interdisciplinary grasp of the physical world. At this stage science encourage to learn the fundamentals of the scientific method by posing questions, observing, experimenting, drawing connections, analyzing, and explaining occurrences in their local social and physical environments.
5. The scientific investigation of students' real-world experiences is the main focus of science education in the middle stage. They start describing and analyzing things using schematic and mathematical representations. Students get an appreciation for the nature of scientific knowledge and scientific inquiry techniques by studying the development of scientific hypotheses. Additionally, students learn how to successfully convey what they have learnt.
6. With growing methodological competence, more abstract scientific theories and conceptual structures are introduced in Grades 9 and 10 of the Secondary Stage in the fields of biology, chemistry, physics, and earth science, as well as their relationships with other topics and with one another. As this way, science provides a capability to learners to analyze the relationship between the concepts of two disciplines and develop a sense of interdisciplinary perspectives.
7. At grade 11 and 12 levels, science provides more scope to engage with theories, laws, principles, concepts, and methods of inquiry specific to the disciplines and also helps in developing an understanding on the process and products of the science.

From the above points, we can conclude that the importance of science falls under two domains; one is concerned with the products domain, and another is concerned with the process domain. This process and product of science shows the nature of science.

5.3 NATURE OF SCIENCE

Science is derived from the Latin word Scientia which means "to know". Science is the human enterprise through which we know about the physical and biological phenomena of the surrounding environment. According to the National Science Teachers Association (NSTA, 1982), one of the primary goals of a scientifically literate individual is to comprehend the nature of science. Science has a dual nature. One of the key components of the Nature of Science is its process and products. Products are developed through a process, and the process can be used to verify the products. Product is the structured and interconnected accumulated source of knowledge, while the process is investigatory and dynamic in nature and identified by ongoing activities (Lederman, 1983).

Fitzpatric (1960) defined science as "an ongoing and endless series of empirical observations which results in the formation of concepts and theories, both being subject to modification in the light of future empirical observations." This definition captures the dual nature of science. Science is a body of wisdom as well as the process of learning and improving that knowledge. Barrentine (1986), who defines science as "that human activity which involves the integration of explorative and applicative modes by which one obtains an understanding of and about the world and the universe," offers another perspective on this contradiction about the nature of science. The descriptive and analytical codification of empirically verified eternal facts that result in the synthesis of a structured body of knowledge about our world is known as the explorative mode of science. The prescriptive application of an organized body of information acquired through the explorative mode of science that supports the explorative mode of science and is utilized for societal purposes is known as the applicative mode of science.

From the previous definitions, it is evident that science has two aspects: the process and the end product. Science is made up of two components that are interdependent and connected to one another. Carin and Sund (1970), illustrated how scientific methods and outcomes are interrelated (Figure 1.1). Appropriate utilization of scientific methods to study natural phenomena results in a greater number of proven scientific facts, ideas, principles, generalizations, theories, and laws. The cycle continues indefinitely as a result of these recently obtained products being utilized to expand and intensify scientific research, which includes additional use of processes that result in new, tested scientific products. The figure depicts the interdependence and relationships between the process and the outcome.

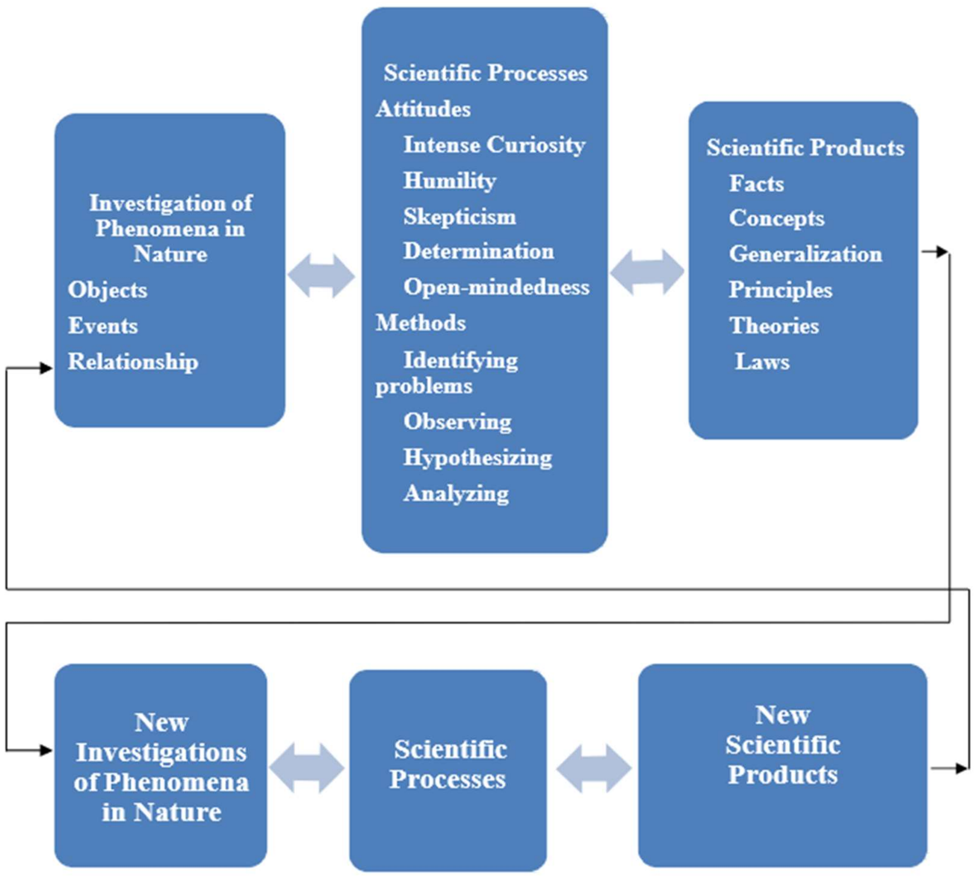

Figure 5.1: Nature of Science (cyclic nature of Process and Product)

Source: Carin & Sund (1970)

Training in scientific procedures and the development of a scientific mindset are essential to the scientific process. The following figure provides a detailed representation of how scientific products are categorized.

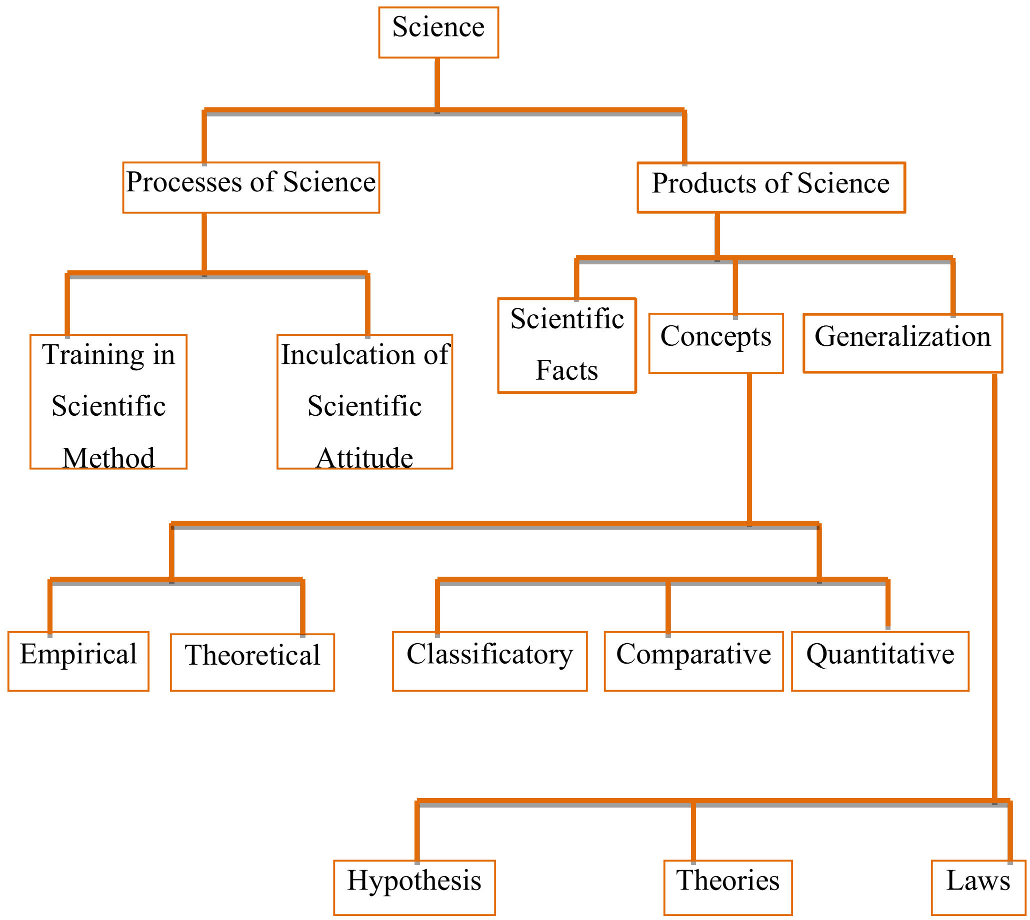

Figure 5.2: Nature of Science

Source: Shelat (2006)

As seen in the above image 1.2, scientific products are divided into three groups. Scientific facts, concepts, and generalizations are the three categories. Singular occurrences seen in nature constitute scientific facts. For instance, the mass of the person remains the same across the universe. Depending on the context, scientific facts can be interpreted in a variety of ways and are inherently tentative. Conceptions are made up of many facts, while generalization is made up of many conceptions. The concepts can be further divided into two categories: empirical and theoretical. The second category is based on whether the notions are quantitative, comparative, or classificatory.

Science is based on observation, experimentation, and logical thinking. These are the process-related things of science. Science is a process; making hypotheses, hypothetico-deductive reasoning, testing hypotheses, experimentation, observation, and drawing inferences take place. Another thing in the nature of science is the product, which comes into existence by the process of science. The product of science is emphasized on theories, facts, concepts, principles, etc.

A substantial corpus of verifiable knowledge has been produced by the facts that scientists have acquired as a result of their studies of nature. The result of scientific research is this structured and methodical topic matter. However, historically, schools have placed more emphasis on the subject matter and the end result of science while downplaying or forgetting the scientific method. Since facts only become legitimate and cumulative after enduring constant scrutiny, an examination of the method used to gather the subject matter indicates the dynamic nature of the scientific process. Therefore, scientific facts are just a byproduct of modern science's larger contribution to the inquiry process, even if they are crucial for any scientific investigation. Science is a process as well as a body of knowledge. Scientific knowledge is the end result of scientific research. Unfortunately, science instruction has mostly been defined by this facet of science. But knowledge is only one aspect of science. Discovering the nature of the universe is a human endeavor that involves mental processes, computational and manipulative abilities, and techniques developed by men. Because it develops as a result of men's activities as they delve into the unknown, this human investigative component of science is dynamic. A scientist exemplifies the inquisitive nature of science by asking questions, doing research, and conducting experiments. Regretfully, science is taught to students as a collection of facts rather than as a method or a component of inquiry (Shelat, 2012), which may lead to the development of misconceptions among students (Priyadarshini, 2024). Teachers have historically placed a strong emphasis on this scientific output, but they have frequently fallen short of one of the most important educational goals of teaching science: helping pupils learn how to solve issues. "Science instruction usually has emphasized the products rather than the process of scientific research," according to Sund (1973), which supports this. Teachers have mistakenly believed that by teaching students about the results of science, they will be able to apply scientific methods. In order to meet the goals of science education, it is important to remember that science education must emphasize both the process and the end product. The learner should be given enough chance to observe, investigate, manipulate, estimate, predict, hypothesize, and measure before concluding why certain events occur the way they do. Through the current study, the researcher attempted to address the nature of science. Taking into consideration both aspects, the researcher created a constructivist teaching method for ninth-grade students.

Based on the above discussion some key points are listed below:

1. Science gives ideas or ways to think and observe things rationally. It gives a vision to learners.
2. Science is dynamic, which means it gets enlarged with time. The previously accumulated body of knowledge acts as the base of new investigations, and after that, again, the body of knowledge comes into existence in the form of theories, facts, and concepts. These are the products of science. A cycle is always going on between process and product.
3. Science gives tentative solutions for any problem which means it never gives the universal truth. With the advancement of Technology, solutions become refined and changed.
4. Scientific knowledge is based on logical reasoning and observation.
5. Science provides a vision to see a phenomenon.
6. Science always gives suspended judgment.

5.4 OBJECTIVES OF SCIENCE TEACHING AT THE SECONDARY LEVEL

The objective of science teaching is to be determined by keeping in mind what should be and, after the whole procedure of teaching-learning, what we gain as an end result. Secondary School is the stage of learning that acts as the foundation of all higher learning. When we talk about science learning, the first things that come to mind are creative thinking, critical thinking, rational thinking, hypothetico-deductive reasoning, and, after all, scientific literacy and scientific temperament or attitudes. According to Piaget, at this stage, learners attain the formal operational stage, and then they start rational thinking, hypothetico-deductive reasoning, and abstract thinking. At this stage, teaching should be such that it develops these competencies in the learner.

According to the NCFSE (2023), the objectives of science are to develop:

1. Scientific understanding of the natural and physical world.
2. Capacities for scientific inquiry.
3. An understanding of how scientific knowledge evolves.
4. Interdisciplinary understanding between science and other curricular areas.
5. An understanding of the relationship between science, technology, and society
6. Scientific attitude

7. Creativity among learners.

In a nutshell, from the above objectives, it can be observed that more emphasis was given to the process of science. To achieve these objectives, from time to time, various committees and policies recommended that science teaching should be practiced in the form of activity centered approach and inquiry method and provide the space for the child to construct knowledge in their own way, i.e. a constructivist approach (NCF, 2005), and through discovery learning, project learning (National Education Policy, 2020). Now we see the present status of science in the light of these recommendations, and to what extent of these recommendations we have achieved.

5.5 STATUS OF SCIENCE TEACHING IN INDIA

The problems and difficulties with science education in schools today are mostly related to curricular materials, assessment systems, laboratory and equipment facilities, and teaching strategies. Among the aforementioned problems and difficulties, the teaching approach is crucial to science education at all levels. The majority of science instruction is delivered through lectures, with the odd lab or classroom demonstration. The process elements were not emphasized in science education. Teachers strictly adhered to the experiments and investigations; facts, concepts, principles, and generalizations dominated science instruction. The Kothari Commission (1966) suggested that educational practices need to be drastically changed. According to Secondary Schools Science Teaching Projects (1969), which were carried out by NCERT in partnership with UNESCO, science education is not appropriately viewed as a whole from the perspectives of attitude development, skill acquisition, and knowledge acquisition. Additionally, the subjects studied and the methods used are not adequately related to children's natural interests, traditional attitudes towards learning science found in Indian schools, the discouragement of investigatory methods, and the prevalence of rote learning at all levels. Low school enrolment and dropout rates at the elementary level, which may be caused by inadequate infrastructure and inexperienced instructors, are among the reasons why countries are having difficulty achieving universal elementary education (UNESCO, 1984). According to a survey report published in the Indian Journal of Public Administration in 1986, the majority of schools lack the fundamental amenities for the teaching-learning process. 41.5% of middle schools lacked blackboards, and 70% lacked laboratory facilities (as cited in Ramesh, 2014).

The current curriculum is narrowly planned, learning has become a somewhat mechanical process of acquiring abilities, and teaching has mostly been a process of tutoring for exams and assessing memory, according to the National Policy on Education (1986). The current curriculum places a greater emphasis on information retention and memorization, with little to no progress made in preparing students for the practical applications of science. The "Herbartian" plan, lecture, lecture cum demonstration approach, and essay-style examination were the characteristics of science teaching, according to Veerappa et al. (1991) (Fifth Educational Survey, 1988-92). In most classrooms, the teaching-learning process is characterised by the exchange of knowledge rather than experimentation, inquiry, or observation, according to the National Advisory Committee on Learning without Burden's report (1992–93). pupils are taught to memorise the material mindlessly without really comprehending the principles; teaching is overly mechanical, and pupils actively participate in the learning process very little or not at all. According to the Public Report on Basic Education (1996), many classrooms are not conducive to learning, in addition to low enrolment, insufficient teachers, lecture-dominated instruction, rote learning, and a lack of facilities like a blackboard, playground, drinking water, library, and teaching aid.

According to research findings by Umasree (1999) and Malhotra (1998), students primarily observe the teacher rather than actively engaging in class, and professors frequently offer lectures while rarely giving them the chance to take initiative or do things on their own. "The dismal picture of science teaching is nothing new; it is mainly emphasis on textbook based rote learning, no scope for experimentation, exploration," according to the thirty-year Hoshangabad Science Teaching Programme (1972-2002). Teachers inspire a love of science in their students in addition to imparting scientific knowledge. Involving pupils in scientific endeavours through science instruction is a difficult challenge for science teachers. Insufficient time to finish the curriculum, a lack of scientific equipment, poor physical infrastructure, and a shortage of qualified teachers are the main causes of students' poor science learning, according to the India Science Report (2004). As people grew older, their interest in science and their level of satisfaction with the quality of science instruction decreased; these factors may not adequately convey enthusiasm for science education. "It is regrettable that the majority of schools throughout the nation teach science in a dull and mechanical style, leaving little room for original thinking and investigation," said

Aravind Kumar, director of the Homi Bhabha Centre for Science Education. Students frequently waste time looking for the right answers, which is a misconception about science instruction. According to HBCSE (2004), science is all about learning by doing from mistakes.

The aforementioned findings demonstrate that science instructors in the majority of institutions use subpar transactional approaches. The only topic with greater opportunity for experiments, investigations, demonstrations, activities, discovery, and so on is science; however, teaching and assessment practices are sadly lacking in creativity. Instructors are not giving their students the chance to engage in hands-on, experiential learning. The development of scientific abilities, interests, attitudes, creative thinking, and problem-solving skills was completely neglected while teaching took place in the classroom most of the time. The constructivist approach to science education places a strong emphasis on the idea that students are the main focus of the learning process, that they have the autonomy to acquire knowledge and skills, and that their active participation is the main goal. Teachers do not dictate the information; rather, students are the ones who construct knowledge and skills (NCF, 2000 and NCF 2005). Policies and commissions have been recommending ways to improve scientific instruction since 1966, yet the current state of science education remains inadequate. When PROBE was re-examined in 2006 in the same northern states, the survey found that the PROBE states had made significant strides in terms of enrolment rates and educational facilities. However, there are also underlying issues, such as the fact that not all enrolled children attend school and that attendance alone does not ensure learning; many students who do attend are in courses with minimal instructional activity. When there is no teaching activity, it frequently results in mindless rote learning; low levels of teaching activity are still a major concern. From a global standpoint, India's educational situation is still dire. There are a lot of obstacles to overcome in upper primary school. Low levels of educational activity are noted in the 2006 survey, physical infrastructure is far from acceptable, and many teachers are inadequate. According to the National Knowledge Commission (2008) and the Indian Institute of Science Bangalore, most schools do not teach science through experiments. They are not improved, even in cases where a laboratory is available. The lack of science resources hurts the pupils, and the chalk-and-talk teaching style, crowded classrooms, and deteriorating laboratory equipment are all contributing factors.

The quality of science instruction must be improved, and rote memorisation must be less prioritised. Students should actively participate, and originality and invention should be encouraged. A paradigm change from "listening science" to "doing science" is required. The 96th Indian Science Congress also recommended that science instruction be greatly improved, assisting students in learning how to gather information and analyse it. Students should be provided the chance to do research and experimentation. Students should be encouraged to develop process skills. The National Curriculum Framework (2000, 2005) promoted the idea that a concentrated emphasis on scientific processes should be a defining feature of science education. Since scientific concepts are mostly derived from experiments and activities, an alternate textbook that incorporates observational activities and experimentation is required. All schoolchildren should be encouraged to participate in certain hands-on, practical activities, according to the National Knowledge Commission's 2006–09 recommendation. Science teachers shouldn't solely rely on textbooks and teach their students to memorise ideas while neglecting process skills. Teaching science is not about transmitting content. Although the fundamentals of science are vital, they should be learnt by scientific inquiry. Science is more about the method than the final output. Formulating scientific concepts, rediscovering new information, cultivating scientific attitudes, encouraging rational and creative thinking, and fostering curiosity all depend on process skills.

In light of these reports, it is very difficult to attain the objectives of science teaching at the secondary level. When we see the status of science teaching, in 60% of classrooms, science is taught in reading mode (Tu Padh Method), 30% of classrooms are taught in lecture mode in only 10% of classrooms of science demonstration and use of realia media are adopted by teachers. Teachers expect pin-drop silence in the classroom, and after questioning, they want a quick response from students. They don't wait for students' responses and rarely have discussions reported in the classroom (Shelat, 2012). This was found that the lecture method is predominantly used in the classrooms.

5.6 LECTURE METHOD

The lecture is an organized verbal presentation of subject matter often augmented by visual aids. According to Bligh (1972), a lecture is a period of more or less uninterrupted talk from a teacher, after that, Percival and Ellington (1988) state that a lecture is 'a didactic instructional method, involving one-way communication from the active presenter to the more or less passive audience'. Perhaps unkindly we should also include the student who described a lecture as 'an occasion to sleep whilst someone talks'.

5.6.1 HISTORY AND BACKGROUND

The lecture's history dates back to the 5th century BC, when the Greeks were big fans of it. It is still the most popular teaching strategy in higher education today, having been widely used at the early Christian and Muslim universities throughout the Middle Ages when books were in short supply. The word "lecture" is derived from the Latin "lectare," which means to read aloud, designating it as an explanatory or "telling" technique.

Although the majority of the lecture is one-way communication from the instructor, this does not preclude debate or interaction between the instructor and the students. Although many competent lecturers can make their lectures more interactive and thought-provoking to allow for deeper learning, such two-way contact is sometimes restricted to the teacher asking questions to demonstrate that the material has been retained (The lecture method, 2014, p.387).

5.6.2 WHY TEACHERS USE THE LECTURE METHOD

In the light of the PROBE report as well as other reports, we saw that Indian schools are suffering from the scarcity of resources and functional labs (Amin and Patel, put year) therefore the use of the lecture method in the classroom is compulsion.

1. The lecture method is the most economical method of providing a large amount of information across a large classroom in a short duration.
2. This method is useful in efficiently imparting factual information.
3. A good lecture can motivate, inspire, and instigate a student towards creative thinking.
4. Lecture helps to channel the thinking of students in a given direction.
5. It is a time-saving method in the classroom.
6. It is easy for students to listen to what the teacher says without taking pains of experimentation and observation.

Despite these advantages, the lecture method cannot achieve the objectives of science teaching because the lecture method has several disadvantages as stated by Kapoor (put year) are as follows:

1. One of the major disadvantages of this method is that it provides less scope for the

activity of the students.

2. It is against the principle of learning by doing. In the lecture method, the principle of learning by doing is not recognized. Normally, when the instructors are delivering lectures, they are making use of various types of teaching and learning materials. When the instructors are teaching, the students are primarily required to pay attention and take notes. They are not encouraged to participate in tasks and activities where they learn by doing. Hence, this is regarded as one of the major disadvantages of the lecture method, as in order to learn well and achieve academic goals, it is necessary to learn by doing.
3. It does not take into consideration individual differences among students. The students are different from each other based on various factors, i.e. intelligence, caste, creed, race, religion, ethnicity, age, gender, skills, abilities, personality traits, and socio-economic background. The lecture method does not take into consideration these factors.
4. Lectures are not suited for teaching higher orders of thinking such as application, analysis, and evaluation. Furthermore, they will not be regarded as worthwhile for imparting motor skills and influencing attitudes and values.
5. In educational institutions, students have different learning styles. They put into operation different learning styles to understand the subjects and concepts. The lecture method emphasizes listening skills.
6. It does not provide for inculcating the scientific attitude and training in the scientific method which are the main aims of teaching science.

After these advantages and disadvantages, the lecture method is the most commonly used method for teaching science in the classroom (Joshi et al., 2016; Singh & Yaduvanshi, 2015; Shelat, 2012). This method is used only for transferring knowledge from the head of the teacher to the head of students. These all things keep in mind that the NCF 2005 recommends that there is an urgent need to shift in science teaching towards the constructivist approach because it gives the chance to learner to construct knowledge in their own way by developing an understanding of concepts and nurturing creative thinking, divergent thinking, etc. National Education Policy 2020 also recommended the adaptation of activity-based, inquiry, and discovery-based pedagogy in science teaching.

For the attainment of the objective of science, many methods evolved during the development of instructional processes in the learning of science. For greater learning outcomes, the involvement of students in the classroom is a very necessary component. To attain this goal, the name of constructivism is a preceding approach. In this approach, learning involves the learning procedure, exploring the situation, and constructing knowledge by own way.

5.7 CONSTRUCTIVISM

Constructivism is the philosophy of the construction of knowledge. It is an umbrella term that contains a vast majority of thoughts. It gives scope to the learner for the construction of knowledge in their own way based on previous experiences that the learner encountered. Learning is a process that goes on with the teaching in the classroom, not in a segregated manner in the classroom. The students are living intellectual people of society. He/she observes and participates in the many activities in society, from where he/she accumulates the majority of experience and schemas. Based on these, he/she actively constructs his/her new knowledge. This knowledge, which is also founded on recognized models within a certain field, is the main component of constructivism. The teacher provides scaffolding for this. The role of the teacher is never denied by constructivism. It disregards the teacher's function as a source of information. This is the study's foundation. Constructivists hold that the learner is not accused of having the novel concept. The student is actively reorganising his information based on his experiences from the past and present. Constructivism places a strong emphasis on students' active participation; knowledge is then ingrained in their memory. Our wisdom cannot be poured into students who are empty vessels. Students must create their own knowledge. Teachers can only help pupils reach a desired objective. The duty of teachers is to facilitate learning. Students should build their knowledge in their minds. Numerous elements influence how knowledge is constructed. Because constructivist teaching incorporates experiential learning, group projects, questioning and solving, peer learning, learning new approaches and techniques, empowering students to create their own learning patterns, comparing and contrasting approaches, case study methods, and more, it increases the significance and durability of students' learning.

5.7.1 PHILOSOPHY OF CONSTRUCTIVISM

Discontent with conventional Western models of knowledge led to the development of constructivism as a philosophical approach (Bhushan, 2020). As such, it contrasts sharply with objectivist epistemology and positivism (Glasersfeld 1995). In contrast to the objectivist notion of objective truth and meaning inherent in objects, independent of any consciousness, constructivism postulates that knowledge cannot exist outside our minds; truth is not absolute; and knowledge is not discovered but constructed by individuals based on experiences (Crotty, 1998, p 42). Constructivism replaces the traditional conception of truth as the correct representation of an external world with the concept of viability, meaning that descriptions of states or events of the world are relative to the observer (Glasersfeld 1995, p.8). The constructivist perspective, therefore, posits that knowledge is not passively received from the world or authoritative sources but constructed by individuals or groups making sense of their experiential worlds (Maclellan and Soden 2004). Constructivism advances meaning-making and knowledge construction as its foremost principles (Crotty, 1998). It views knowledge as temporary, nonobjective, internally constructed, developmental, and socially and culturally mediated (Fosnot 1996). Individuals are assumed to construct their own meanings and understandings, and this process is believed to involve an interplay between existing knowledge and beliefs and new knowledge and experiences (Schunk 2004). This view of meaning-making through previously constructed knowledge implies that:

1. Social constructivists believe that all knowledge is constructed by social interaction ie. society, peer group, etc.
2. All learners construct their knowledge based on prior experiences.
3. Interaction with society as well as novel situations gives the higher-order mental process for the construction of new knowledge.
4. Knowledge is not inherent and not imposable; it is only generated by self-effort.

As an educational constructivist, constructivism is a trend, conversation, and theory that emerged and disseminated during the period between 1980 and 1990 (Welsch, 1998). This term tells that the information is constructed by the student. That is to say, the individual does not adopt the information as it is, he restructures his information. He adopts the information he is provided in combination with his information under his conditions (Ozden 1999). Constructivism describes the structuring of the reader the mental presentation in an active manner by combining textual information with new information (Spivey, 1987).

The philosopher Vico defended the idea that "the one who knows something also explains" in the eighteenth century. The same concept was expanded upon by Emmanuel Kant, who claimed that humans actively create information, receive knowledge, and establish relationships with prior information. In the sense of influencing the construction, scientists such as Vygotsky, Piaget, and John Dewey contributed to structuralism (Özden, 1999). Idealist philosophers are strongly related to constructivist philosophers. Constructivists contend that our knowledge reflects our beliefs (Shukla, 2016). Furthermore, they argue that it is impossible to tell if the observers are keeping an eye on the same things. This view is also argued by the NCF 2005, and this document recommends an urgent shift in the epistemology (way of acquiring knowledge) of current scientific knowledge. At the root of Constructivism, philosophy as well as psychology are present. Piaget's work and his desire to give a scientific basis to his work is the first steps of the origin of constructivism (Glasersfeld, 1995). This is today known as trivial constructivism or cognitive constructivism.

5.7.2 DEFINITIONS OF CONSTRUCTIVISM

Bruner (1966) defined constructivism as a learning theory in which learning is seen as an active process in which learners construct new ideas or concepts based on their current and past knowledge. Vygotsky (1978) defines constructivism as the process whereby learners socially construct knowledge linguistically through interacting with signs and symbols with the help of a knowledgeable learner or adult. (As cited in Bhushan, 2020).

There are two main paradigms that constructivist approaches fall under:

First, the Cognitive constructivist approach is supported by the view of Piaget (1975), and second, the social constructivist approach is supported by the views of Vygotsky (1962). The first paradigm states that learners construct knowledge by transformation, organization, reorganization, and assimilation of new knowledge and information, while another believes that learners construct knowledge through social interactions with their society and peers. A conceptual shift happens when one moves from the first paradigm to the second one, from individual development to collaboration and social interaction (Rogoff, 1998).

5.7.3 COMMON METHODS AND STRATEGIES USED IN THE CONSTRUCTIVIST APPROACH

Based on reviews (Dobbs, 2008; Vaca, 2010; Kalyani and Rajasekaran, 2018), different types of constructivist strategies as listed here:

Brainstorming: The process of brainstorming is used to generate original solutions to issues. The process of brainstorming involves concentrating on an issue, then purposefully generating as many solutions as you can and advancing the concepts as far as you can. The fact that the brainstormers refine other people's ideas in addition to coming up with fresh ones during a session is one of the reasons it works so well.

Scaffolding: Without the help and direction of the teacher, scaffolding enables pupils to do tasks that would typically be just a little bit above their capabilities. Students can operate at the forefront of their own growth with the right kind of teacher support. As a result, scaffolding is a crucial component of constructivist education.

Project-Based Learning: Teaching method that pushes students to use real-world research to find the answers to their problems. These opportunities for in-depth learning inspire pupils and incorporate a variety of curriculum goals.

Questioning: A fundamental component of each of constructivism's building blocks is the question. Questions fall into the following categories: integrating, clarifying, anticipating, and directing. Through questions, the learner and teacher can clarify their misconceptions about the concept.

Simulations: The process involves actors role-playing within a relatively complex symbolic model that represents a real or hypothetical social process. This approach often incorporates gaming elements and can be carried out entirely by people, by a combination of people and computers, or solely by computers.

Team Teaching: Team teaching is an instructional approach where teaching responsibilities are shared among multiple educators rather than being carried out by a single instructor. This collaborative method allows students to engage more actively in the learning process, as they benefit from the diverse expertise and perspectives of a teaching team.

Cooperative Learning: Cooperative or group learning is a pedagogical strategy that involves organizing students into small groups, enabling them to work collaboratively. The aim is for students to support one another in achieving academic success, thereby enhancing both individual and group learning outcomes.

Class Discussion: In this technique, the instructor depends on students to contribute their ideas, experiences, opinions, and knowledge. This method can be effectively used during regular classroom sessions, as well as in preflight and post-flight briefings, particularly after students have gained some level of knowledge or practical experience on the topic.

Present New Material in Small Steps: This method involves breaking down the learning content into smaller, manageable segments for presentation. Doing so supports deeper conceptual understanding, as our working memory has a limited capacity and can only process a small amount of information at a time. Presenting too much information at once can overwhelm students and cause confusion, since their working memory may not be able to accommodate it all (Rosenshine, 2012).

Mind Map: Mind mapping is a visual learning strategy that helps to present large volumes of conceptual and hierarchical information in a clear and structured manner. By converting traditional outlines into colourful, spatial representations, mind maps allow learners to simultaneously grasp both the overall structure ("the forest") and the detailed components ("the trees") of the subject matter (Cunningham, 2006).

Hands-on Activities: This approach encourages learners to actively interact with their surroundings or specific learning tools. Teachers create opportunities for students to explore and engage directly with materials through tactile, experiential activities. Student performance in such tasks can be assessed using checklists and observational methods to evaluate their interaction with the given materials.

5.8 PRESENT STATUS OF USE OF CONSTRUCTIVISM IN CLASS

Tradition method of teaching like the lecture method is the most usable method at all levels in the classrooms (Cuban, 1984) but after the recommendation of NCF 2005 whole education system gradually shifted towards the constructivist approach significantly affecting the whole education system and achievement of learner and this approach also help the teacher in fostering the teaching environment in the classrooms. Bhushan (2016) conducted a study and reported that according to students 25.30 % of teachers showed a low level of usage of constructivist teaching practices, 50.60% of teachers showed a moderate level of usage of constructivist teaching practices, and 24.09% of the teachers shown a high level of usage of constructivist teaching and according to Chandi (2020), 27.71 % teachers shown a low level of usage of constructivist teaching practices while 49.39 % teachers shown a moderate level of usage of constructivist teaching practices and 22.89 % teachers show a high level of usage of constructivist teaching practices by upper primary science teachers. Another study by Guha and Paul (2014) reported that teachers have a moderate level of attitude toward the usage of the constructivist approach in secondary classrooms.

As it is well established that the constructivist approach provides ample opportunity for many methodologies to be adopted for the attainment of a student-centered learning atmosphere, therefore, the researcher wants to see the effect of constructivist strategies in the lecture or student-centered classroom, which is advocated by constructivist philosophy. In this regard, it has been observed that the lecture method, conjoined with various other teaching activities, will help in attaining the goals of constructivist philosophy. On the one hand, the thorough examination of school subjects reveals science as the most befitting subject (other subjects also have adequate scope) to achieve the desired goal. On the other hand, if the students act as passive listeners in the classroom and are always exposed to poor instruction, then students face the difficulty of rote memorization, and their memory faces the strain for processing that information, which is known as cognitive load.

5.9 COGNITIVE LOAD

Our working memory has a limited capacity to hold and process information. When we give more information to working memory for processing, then our working memory undergoes overloading, which is called as cognitive load. Cognitive Load Theory (CLT), developed by John Sweller (2003), is an instructional design framework that focuses on understanding how the brain processes and retains information, emphasizing the limitation of working memory and the importance of managing cognitive load to optimize learning. Cognitive Load Theory (CLT) divides the cognitive load into three domains: **Intrinsic, Extraneous, and Germane.**

Intrinsic Cognitive Load (ICL): This refers to the inherent complexity of the material being learned, which is difficult to reduce. The complexity of the topic cannot be altered, so intrinsic cognition is constant for a particular topic. The complexity of the content, which is based on the quantity of interactive information elements needing to be processed simultaneously, also determines the intrinsic cognitive load.

Extraneous Cognitive Load (ECL): This load arises from poor instructional design or irrelevant information that distracts learners and puts unnecessary strain on working memory.

Germane Cognitive Load (GCL): This is the cognitive effort that contributes to the construction of meaningful knowledge and long-term retention.

The organization of the information being analyzed and the knowledge stored in the individual's long-term memory, or prior knowledge, can be taken into account simultaneously to determine element interactivity (Chen, 2023; Sweller, 2010). The presentation of instructional materials might lead to extraneous cognitive load (ECL), which increases element interactivity and causes cognitive activities that are not related to learning (Sweller, 2011; Sweller, 2019). As a result, element interactivity rises, further putting additional strain on the working memory resources (Sweller, 2019; Chandeler, 1991; Sweller, 2010; Merriënboer, 2005). As both extraneous and intrinsic loads are cumulative, lowering the extraneous cognitive load becomes essential when the intrinsic cognitive load is high (Sweller, 2011).

Everybody has a Schema in their mind, and that schema is the permanent and long-lasting impression of the object in the mind of the person. When a person encounters a new concept in the process of formation of a schema, three things are important first is the complexity of the concept, second is the representation of the concept associated with the instructional procedure, and third is the total effort done by the person to internalize the concept as "Schema" in working memory. These three things are called as **Intrinsic Cognitive Load (ICL), Extrinsic Cognitive Load (ECL), and German Cognitive Load (GCL)** respectively. The cognitive load theory plays a significant role in designing instructional strategies and learning (Sweller, 2019). Cognitive load plays a crucial role in learning therefore; the assessment of cognitive load also plays an essential role in learning. This cognitive load is measured on two dimensions suggested by Pass (1999), i.e. **mental load and mental effort**. The **mental load** was enforced by instructional design, and **mental effort** alludes to the sum of mental energy that's apportioned to instructional loads.

An optimum level of cognitive load is necessary for learning, but too much cognitive load hampers learning and diminishes the learner's achievement in a particular subject, and it may even cause the learner to drop out of that subject. Based on the above discussion, we can say that the whole cognitive load is mainly exerted by the working memory of the learner therefore, the understanding of working memory and its working process is essential.

5.10 WORKING MEMORY

Working memory (WM) is a key idea in cognitive psychology (Baddeley and Hitch, 1974). "It alludes to the "central" systems and procedures that enable human thought processes by temporarily preserving, storing, and manipulating information" (Pezzulo, 2007). This working memory is the conspicuous component of the general memory (Demir, 2021). This is a system with limited capacity that allows you to operate on and retain "active" a small quantity of data for a short time. The "working memory concept reflects fundamentally a form of memory, but it is more than memory, as it is memory at work, in the service of complex cognition," (Conway et al., 2007, p. 3). Likewise, working memory was defined as "storing and processing information while performing higher-order cognitive tasks such as comprehension, learning, and reasoning" by Baddeley and Logie (1999, p. 15). The working memory has a distinct way of processing the information that is perceived from the environment. The Atkinson-Shiffrin Multi-Store Model of Memory (1968) is the most accepted model of memory for explaining the workings of memory.

1.10.1 MODEL OF MEMORY

The Atkinson-Shiffrin Multi-Store Model of Memory (1968), which was an extension of Broadbent's (1958) information processing model, was the first memory model in the modern era. It was followed by the Levels of Processing Model of Memory (Craig & Lockhart, 1972) and, lastly, the Working Memory Model (Baddeley & Hitch, 1974).

There are three main parts to the human memory model:

- **Memory** stores include working memory, long-term memory, and sensory memory. These are storage that store information, sometimes for a very short time and sometimes for a very long time.
- **Cognitive processes**, including perception, rehearsal, encoding, retrieval, and attention. These mental operations transfer data between memory stores.
- The cognitive process by which we keep an eye on and control how information is stored and transferred across stores is known as **meta-cognition**.

Working memory is smaller than both sensory memory and long-term memory, according to this model. This serves as a reminder that it has a smaller capacity than the other two components of memory. Additionally, there are more arrows to the left of the attention than to the right in **Figure 1.3**. This indicates that we do not pay attention to every stimulus we come across; our attention functions as a screen, and we are not going to notice many of the stimuli until they are brought to our attention by someone or something. As shown in Figure 1.3, the memory stores, cognitive processes, and meta-cognition are all interrelated, which shows that each component of the memory is working synchronously not separately. In this model, the sensory memory grasps the information from the environment and transfers it to the working memory after the processing. Working memory has limited capacity and can hold only 5 to 7 units of information at a time. Here the sensory memory holds the information until the working memory processes the information; in this way, the sensory memory helps the working memory to process the information. After that, the working memory transfers the processed information into the long-term memory where information can be stored for a long duration (Eggen and Kauchak, 2016).

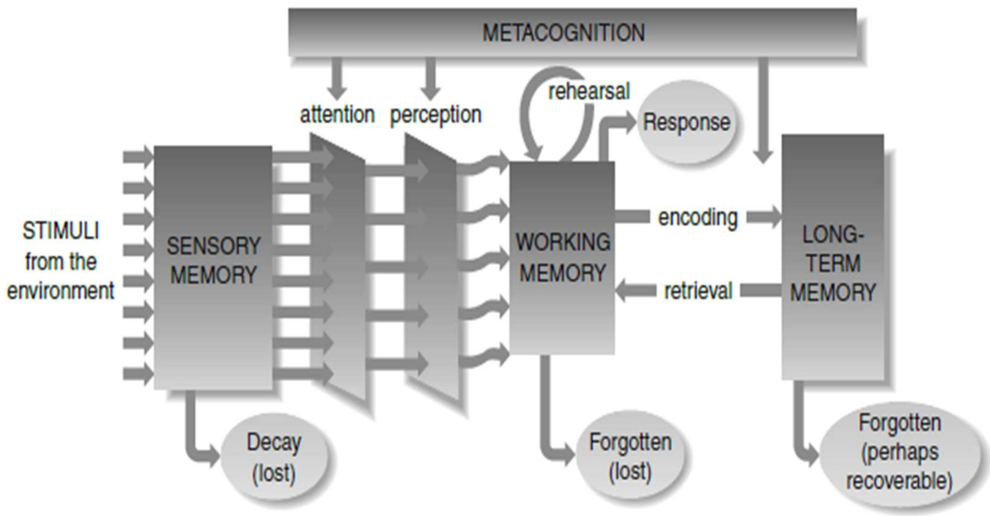

Figure 5.3 Atkinson-Shiffrin Multi-Store Model of Memory

Source: Eggen and Kauchak (2016, p 289)

Baddeley and Hitch (1974) gave a model to explain the Atkinson-Shiffrin Multi-Store Model of Memory (1968). According to this model, the working memory consists of one central system known as the central executive and three sub-systems namely the **phonological loop,** and **visual-spatial sketch pad,** and the **episodic buffer** (Pezzulo, 2007; Demir, 2021).

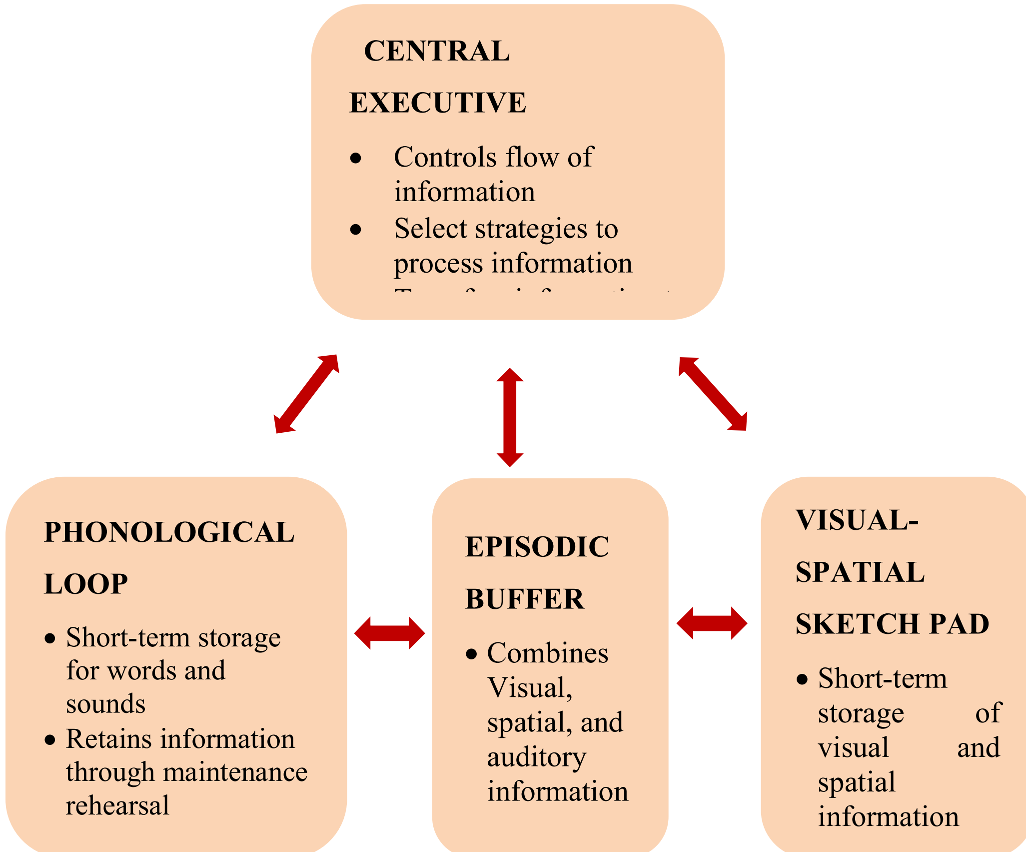

Figure 5.4 Model of Working Memory

Source: Adapted from Eggen and Kauchak (2016)

According to Pezzulo (2007), the central executive is the primary element that was introduced in 1974 by Baddeley and Hitch as the component of the storage and computational processing of information (Demir, 2021). It is a flexible workplace, but it is limited in capacity. It has the control of managing executive functions, such as actions; focusing attention on pertinent information while suppressing irrelevant information and undesirable behaviors; controlling information integration; coordinating the execution of several cognitive processes in parallel; and coordinating the working memory subsystems (Pezzulo, 2007).

A rehearsal mechanism that protects auditory information from rapidly deteriorating is made possible by the phonological loop. A (brief) list of words or numbers, for instance, can be retained in memory if you repeat them to yourself regularly. Maintaining and modifying visual and spatial information is made possible by the visual-spatial sketchpad. The visual-spatial sketch pad processes, stores and manipulates the visual and spatial information held in long-term memory. For instance, the learners can generate and rotate mental images, make and traverse mental maps, and more. Two subsystems make up this system; the first is dedicated to visual information, and the second to spatial information. Visual-spatial sketch pad helps in learning (Baddeley, 2003), and it also helps in the movement of eyes on the lines and recognition and encoding of the words and letters of the book (Dehn, 2008).

In a unitary, episodic representation, the episodic buffer momentarily combines auditory, spatial data, and visual information data with potentially additional types of information (such as musical or semantic information). In this sense, it serves as a bridge between the WM subsystems and the segment of long-term memory dedicated to episodic memory (EM) (Tulving, 1972), which is the recall of particular events that incorporate time, location, and emotions.

After examining the concept of working memory from different scientists, the researcher can conclude that working memory helps in the processing of information from the environment and avenue for storing and manipulating the information. It also plays an intermediate role between sensory memory and long-term memory. Inspite of these, the working memory has limited space and capacity to process the information; therefore, if working memory is exposed to overloaded information and unorganized modalities, then it faces the problem in processing it in a stipulated time and feels overloaded. This overloading is directly correlated with the increased cognitive load. Some factors identified which are responsible for overloading the working memory are as follows.

5.11 FACTORS AFFECTING COGNITIVE LOAD

Quality of instruction: When the quality of instruction is poor, then cognitive load increases. Cognitive load increases when the instruction fails to establish a relationship between the previous body of knowledge and new information in working memory, then. In this continuum, if the instruction modality contains many ways to deliver the same content or in other words, the same information presented in various media, then it causes overload in the working memory, which is called as redundancy effect (Sweller et al., 2011; Albers et al., 2023).

Overloaded information: According to Miller (1956), an adult's working memory can only store seven pieces of information at once for ten to twenty seconds. (Children have considerably limited working memories.) We "are probably only able to deal with two or three items of information simultaneously when required to process rather than merely holding information", since choosing and organizing information also consumes working memory space (Sweller et al., 1998, p. 252). Working memory is depicted in this manner to remind us of its restricted capacity since, as we can see in Figure 1.3, it is smaller than either sensory memory or long-term memory. When our working memory is exposed to overloaded information or instruction, it feels difficult to process it, and cognitive load increases.

Unorganized information: When we give unorganized information, the cognitive load increases. When an instruction contains too much information in a haphazard manner, then working memory resources are used to organize the information. For instance, sometimes teachers in the classroom use too many teaching aids or they use aids in an unorganized manner then it creates a greater cognitive load among learners.

Coherence Effect: According to Mayer (1999), instruction that contains information that is not meaningful or relevant to the learner or when unnecessary explanation added to the concept (Renninger, 1992) then it increases the cognitive load because due to the irrelevant information the workspace of working memory is occupied and processing of relevant information in working memory gets hampered.

The above-mentioned factors affect the cognitive load in the learners. The cognitive load is one of the causes that hamper learning among learners. But some of the techniques that can be considered to reduce the cognitive load are as follows:

5.12 HOW TO REDUCE COGNITIVE LOAD

Through the adaptation of various techniques, learners and teachers can reduce the cognitive load.

Chunking: The process of cognitively rearranging separate objects into bigger, more significant pieces is known as "chunking" (Miller, 1956). For instance, some numbers 1 2 5 7 9 7 6 3 2 5 are written separately, then it is complex to remember. Now that 125-797-6325 has been "chunked" into three larger pieces as it is generally written, it is easier to comprehend and remember, which lessens cognitive strain.

Automaticity- “The capacity to carry out mental processes with minimal awareness or conscious effort is known as automaticity” (Feldon, 2007), and it is crucial for learning as well as daily life. For example, we can dedicate all of our finite working memory space to producing high-quality written work after our keyboarding and grammatical skills become automatic, meaning we can write and apply proper syntax, punctuation, and spelling, effectively "without thinking about it." Similar to this, calling on our learners will become almost automatic if we have defined learning objectives, apply good examples when instructing, and practice teaching. This will allow us to allocate our working memory space to engaging with our students in a productive manner. Another example of automaticity is those teachers who have been teaching the same subject in the class for a long time, after a few days they do not have to work hard to teach that subject.

Distributed processing- In our working memory, there are two parts available i.e. visual-spatial sketchpad and the phonological loop function independently, allowing each to carry out mental tasks without consuming the resources of the other. By doing this, the processing load is "distributed" between the two parts; the visual processor enhances the verbal processor, and the verbal processor enhances the visual processor. This implies that wherever feasible, we ought to incorporate visual aids into our spoken explanations. Lessons that give verbal and visual information together rather than separately facilitate the integration of words and visuals (Clark & Mayer, 2003, p. 38). For instance in the classroom when teachers use only the lecture during the transaction of the topic before the learners the learners feel bored and attainment of learning objectives decreases because only one unit of working memory engaged in the whole task on the other hand when teachers use some audio-visual aid or PowerPoint presentation along with the lecture then learners take interest in the classroom and attainment of objective increases this is because both the units of working memory is engaged in the processing of information and provide a support to each other in processing the information.

Organization- Organization means processing information; the organization of information also decreases the cognitive load. As we saw the working memory has a limited capacity to process the information then if we provide unorganized information or instruction with unnecessary information we exert unnecessary strain on the working memory to process the whole information and due to the limited workspace in the working memory it is occupied and become overloaded on the other hand if we provide a piece of organized information or instruction then working memory encounter with only relevant information and processes easily as a result the cognitive load decreases.

Segmenting Principle: This principle refers to the intrinsic cognitive load is basically concerned with the complexity of the content of a particular topic. If we break down the whole content into parts, then it can be easily grasped by the learners. For instance: in the classroom, the teacher breaks down the whole chapter into parts and then delivers before the learners, as a result, the learners easily grasp the concept underlined in the chapter (Mayer, 2021).

Scaffolded Learning: According to Vygotsky (1978) the learners construct knowledge with the help of social interaction. Every learner possesses the capacity to solve problems without any support called as actual development level of the learner. On the other hand, they can solve problems with the help of someone more proficient than the learner, that level is called as potential development of the learner. This support is called scaffolding; scaffolding helps in the reduction of the complexity of the task as a result the working memory easily processes the information and cognitive load decreases.

By adopting these techniques during the designing of the instruction one can reduce the cognitive load and enhance the learning outcomes. The proposed research is thus embedded in the theoretical premises of the cognitive load that is a necessary component for fostering the learning of the science subject (and other subjects also) and the constructivist approach that has a great scope to achieve the objectives of the science teaching. Science is an essential component of the modern curriculum; it helps foster students' critical thinking and creative thinking. Due to this character of science after independence, the Kothari Commission advocated for science and mathematics teaching in school as a compulsory subject up to the secondary level. The objectives of science are to develop the scientific attitude and temperament in the learners and to promote rational thinking and logical thinking among learners. For the attainment of these objectives, various commissions and committees suggested for the adoption of activity-based and inquiry-based pedagogy for the teaching of science at the school level. Recently, the National Education Policy (2020) and the National Curriculum Framework for School Education (2023) also recommended the adoption of inquiry-based and experiential learning in science teaching to attain the objective of science teaching. Mishra and Yadav (2013) also suggested that activity-based teaching is more effective than the traditional method of teaching the science subject but reports like PROBE (2012) and the findings of Umashri (1999); Shalat (2012); Ramesh (2014), showed the ground reality is quite different the teaching of science is suffering due to main challenges like lack of well-equipped laboratory infrastructure in the school (Patel and Amin, year) in many schools infrastructure present but materials are not present. (Priyadsrshini, 2024) found that in the majority of the government schools of the Ranchi district of Jharkhand State, there is a lack of laboratories to conduct even simple basic scientific experiments. Science is a practical subject, and practical is the backbone of science education and it helps in inculcating a sense of inquiry among students. In rural and semi-urban areas, science teaching is practiced in the form of book reading, and as a result, students become dependent only on the rote memorization of concepts of science and textbook reading. Another challenge in the classroom is that the teachers are not well-trained in the pedagogy. According to a report by NIEPA (2016), at secondary-level schools, only 44% of teachers have a post-graduate degree, and 15% of teachers do not even have a graduate degree. Only 3.3% of government schools meet the RMSA norm of 5 teachers. In the words of the NEP 2020 "According to the Justice J. S. Verma Commission (2012) constituted by the Supreme Court, a majority of stand-alone Teacher Education Institutions (TEIs) - over 10,000 in number are not even attempting serious teacher education but are essentially selling degrees for a price" this indicates a pathetic condition of the teacher training in the country due to this the untrained teacher in pedagogy are practicing the teaching of science. According to the findings of Dhimmer (2024), the internship practices are also compromised in the teacher training institution due to these reasons untrained teachers come into the schools for science teaching. According to the finding of Shelat (2012), science teachers are rarely practicing activity-based pedagogy in the classroom. In this continuum the scarcity of teachers in the school is also a challenge to effective teaching of science. It is also seen that there is an irregular recruitment of the teachers in the school as a result the student-teacher ratio in the classroom is exponentially increased which ultimately reduces the teacher's attention to the students. All these factors hinder the science teaching and learning in the classroom. The combined effect of these challenges makes a compulsion to the student to rely only on the content of the textbook and memorize the content during the examination. These challenges also lead towards adoption of lecture method in the classroom which badly affects the quality of instructions. At the school level, the lecture method is not a sufficient method for the teaching of science. The poor quality of instruction increases the extraneous cognitive load in the learners' memory. In the science subject, many abstract things are present and when learners are exposed to poor-quality instruction then it occupies the larger space in the learners' brain and reduces the space for Germane cognitive load which helps in processing the concept in the form of schema due to this reason learner feel disengaged from the content and thinks that science is a very complex subject. To address these issues in the classroom, the constructivist approach-based pedagogical intervention programme is essential. Constructivism advocates the construction of knowledge by the learners based on his/her previous experiences. The cognitive constructivism given by Piaget advocates for the construction of knowledge by learners themselves, while the social constructivism given by Vygotsky advocates that the construction of knowledge is the product of the interaction between the learner, peers as well as society. When we incorporate the constructivist principle in teaching-learning, then it gives more scope to the learner for learning by doing. In constructivism, many strategies are found, like brainstorming, problem-solving, mind mapping, and discussion, which provide ample scope for the learners to construct knowledge in the classroom.

5.13 RATIONALE OF THE STUDY

Science is a practical subject and ensures rational thinking in the minds of the learners. In the light of PROBE (2012), we saw that a large number of Indian schools has lack of resources and infrastructural facilities, as a result, the lecture is the most dominating method of teaching in the Indian classrooms (Shelat, 2012). In the report of the "Programme for International Student Assessment (2018)," it is found that the lecture method is dominant in the science classroom in most of the countries of the world. In this condition, the use of physical objects is very limited. When we talk about the Indian context, a greater part of India suffers from the unavailability of resources such as well-equipped labs (Patel and Amin, n.a.) as well as smart classes. Due to this, the lecture method acts as a save bacon. In this condition, opportunities to encounter physical objects are too limited. On the other hand, the National Curriculum Framework (2005), National Education Policy (2020), and National Curriculum Framework for School Education (2023) suggested that science teaching should be in an activity-based method. These documents also recommended an urgent need to shift education towards the constructivist approach and activity-centered method. Through the reviews of the previous work done by the researchers it was found that constructivism is a valuable method for the teaching-learning of science because it ensures greater learning as well as learning for a long duration. After all, it gives more scope to the learner to apply their knowledge in real situations and construct knowledge in their own way, but in teachers' opinion, activity-centered or constructivism-based teaching consumes much time, and the syllabus cannot be completed in the stipulated time (Shelat, 2012). In the report of PISA (2015) it is stated that no single method is sufficient for better learning therefore researcher tried to take advantage of both methods and want to develop a pedagogical intervention by incorporating the constructivist strategies in the lecture method that can be implemented in larger classrooms as well as with a minimum of resources without compromising on the quality of instruction.

In this regard, the secondary level is very crucial in students' life as it lays a strong foundation for senior secondary as well as for higher studies. According to Piaget, at secondary level, the students are in the formal operational stage, and their abstract thinking capacities start developing; therefore, it is necessary to expose the student to conditions that promotes rational thinking, abstract thinking, and reflective thinking among them. The constructivist approach has a variety of teaching strategies which promote these capabilities in the students (Chandi, 2020).

According to Pangat (2017) and Chandi (2020), the constructivist approach helps students in improving their reflection and also helps in enhancing their achievement in the subject. According to Shukla (2016), the constructivist approach plays a very significant role in science achievement separately in Physics, Chemistry and Biology and students also report that this approach is a very effective approach for learning (Puacharearn & fisher, 2004; Kumar, 2016) and teaching (Moore, 2005). Furthermore, every topic has its own complexity and the teaching of all topics through the uniform method in the classroom is too difficult. When the topic or content becomes out of reach of the mind of the student then the processing of the topic in the form of "schema" is the very difficult as a result the cognitive load of the student increases. As it is known that the intrinsic cognitive load is associated with the complexity of the topic that cannot be altered while as extraneous cognitive load is associated with the instruction method and germane cognitive load is associated with the processing of concept in the form of schema in the working memory. The intrinsic cognitive load is constant for a particular topic, but when we decrease the extraneous cognitive load with quality instruction, then in working memory, more space is offered for the germane cognitive load. On the other hand, if we provide poor-quality instruction, then learners face difficulty in processing the concept or information. As a result, learners don't focus in the classroom, which means the engagement in the classroom becomes diminished, but NEP-2020 and NCFSE-2023 advocated shifting the whole education toward the constructivist paradigm. However, after reviewing the literature, the researcher felt that there is lack of sufficient literature on the effectiveness of the constructivist approach on the cognitive load and the effect of this approach on learning outcomes. Therefore, the researcher intended to conduct the present study with following research questions.

5.14 RESEARCH QUESTION

1. To what extent does the integration of the constructivist strategies with the lecture method help in achieving the objectives of science teaching?
2. How far does the developed constructivist pedagogical intervention contribute to the attainment of learning outcomes of science teaching?
3. How far does the developed constructivist pedagogical intervention contribute to reducing cognitive load among students?

5.15 STATEMENT OF THE PROBLEM

Situating Constructivist Strategies in Lecture: An Exploration in Pedagogy of Science at Secondary Level

5.16 OBJECTIVES

1. To identify the content of science textbooks that can be taught through the constructivist approach.
2. To identify the strategies of the constructivist approach for situating during the lecture method.
3. To develop a constructivist pedagogical intervention for teaching science at the secondary level.
4. To implement the developed constructivist pedagogical intervention in teaching science at the secondary level.
5. To study academic achievement in science among secondary students.
6. To study cognitive load in science among secondary students.
7. To examine the effectiveness of the developed constructivist pedagogical intervention in terms of the enhancement of academic achievement in science among secondary students.
8. To examine the effectiveness of the developed constructivist pedagogical intervention in terms of reducing cognitive load in science among secondary students.

9. To study the relationship between academic achievement and cognitive load in science among secondary students.
10. To examine the reaction of students toward the developed constructivist pedagogical intervention.

5.17 HYPOTHESES

H_{01}: There is no significant difference between the mean gain score of the post-test on achievement between the experimental and control groups at the 0.05 level of significance.

H_{02}: There is no significant difference between the mean gain score of the post-test on cognitive load between the experimental and control groups at the 0.05 level of significance.

5.18 EXPLANATION OF THE TERM:

Constructivist Pedagogical Intervention Programme: The intervention programme is based on the lecture method, in which strategies of the constructivist approach are incorporated as per the need of the particular content. In this intervention programme, brainstorming, problem-solving, mind mapping, questioning and discussion were incorporated as appropriate content.

5.19 OPERATIONAL DEFINITIONS

Academic Achievement- Academic achievement is the extent to which the student achieves a pre-decided goal or objective. It is the score after and on a valid and reliable test in a particular subject. In this study, the achievement of students is the score obtained by students on achievement tests developed by the researcher. In this test, there are two sections. The first section consists of objective questions of knowledge, understanding, and application level. The second section consists of descriptive questions.

Cognitive load: Cognitive load is referred to as the sum of Intrinsic (complexity of content), Extraneous (complexity of instructional process), and Germane (total effort to process a concept in the form of schema) cognitive load. In this study, cognitive load is the score obtained by students on the scale of cognitive load developed by Hwang and colleagues (2013). There are eight items total: three for "mental effort" and five for "mental load." With a Cronbach's alpha of 0.784 for mental effort and 0.817 for mental load.

Effectiveness of Pedagogical Intervention: This is the score difference between the post-test of the control group and the experimental group on the academic achievement test and the cognitive load scale.

5.20 DELIMITATION

The present study is delimited to the Gujarat Secondary and Higher Secondary board-affiliated English medium school in Vadodara city. In the present study, the Secondary School is delimited to standard IX only.

5.21 REVIEW OF RELATED LITERATURE

The review of related literature gives a clear idea to the researcher for carrying out her investigation. The researcher has reviewed a total of ninety-one studies for the present study. A researcher reviewed studies from the Shodhganga, Survey of Research in Education (CASE) Library, Elsevier Science, Education Resources Information Centre (ERIC), Taylor and Francis, and Doctoral Theses. For the review on cognitive load, the researcher has analyzed the SCOPUS database to find out the research gap in the field of cognitive load.

The reviewed studies are categorized as follows: 1) Studies related to Strategies developed on constructivism. 2) Studies related to cognitive load. 3) Studies related to innovation in lecture method.

5.22 METHODOLOGY

A quantitative approach was used in the present study. The methodology included the design of the study, variables of the study, population, sample, tools of data collection, procedures of data collection, and data analysis.

5.22.1 DESIGN OF THE STUDY

This study was quasi-experimental in nature. The pre-test and post-test non-equivalent group design (Cresswell, 2008) was used in the proposed study. Best and Kahn (1996) described, “This design is often used in classroom experiments when experimental and control groups are such naturally assembled groups as intact classes, which may be similar.” The design of the proposed study is presented as follows.

Table 5.1: Design of the Study

Pre-test Post-test Non-Equivalent Control Group Design	
Experimental Group	O_1 X O_2
Control Group	O_3 C O_4
O_1 and O_3 = Pre-test O_2 and O_4 = Post-test	
X = Treatment C = Control (No Treatment)	

5.22.2 VARIABLES OF STUDY

In the present study, the independent variable was the developed intervention program based on the constructivist approach. The dependent variables were the achievement of students in science and the cognitive load of students in the science subject.

Table 5.2: Variables of the Study

Independent Variable	Dependent Variable
Intervention Programme Based on Constructivist Strategies	Achievement
	Cognitive Load

5.22.3 POPULATION

All the standard IX students studying in English Medium Schools that were affiliated with Gujarat Secondary and Higher Secondary Education Board of session 2023-24 were considered as the population of the study.

5.22.4 SAMPLE

Two English medium schools affiliated with the Gujarat Secondary and Higher Secondary Education Board were selected purposively from Vadodara city to get the schools for the experimentation of one semester. Out of these two schools, i.e. University Experimental School and Vidyut Board Vidyalaya, the University Experimental School was selected for the control group, and Vidyut Board Vidyalaya was selected for the experimental group. In the University Experimental School, there was one section in which a total of 61 students were enrolled. At the same time, in Vidyut Board Vidyalaya, there were two sections, i.e. A and B, in which 61 and 63 students were enrolled, respectively. All the students of standard IX of the selected schools constituted the sample of the proposed study. Both experimental and control groups were made equal based on their scores on Raven's Progressive Matrices. For this purpose, the one-by-one matching technique was applied. A total of 85 students were excluded from the final sample. After exclusion, only 100 students remained in the final sample. The mean of both experimental and control groups was 39.82.

Table 5.3: Number of Participants

Sr. No.	Groups	Number of students	Mean
1	Control Group	50	39.82
2	Experimental Group	50	39.82

5.22.5 TOOLS OF DATA COLLECTION

The following tools were prepared by the researcher and used for data collection.

5.22.5.1 Ravens Progressive Matrices: John C. Raven created this tool in 1936. In this tool, there are five sections with increasing difficulty levels. It was designed to evaluate logical thinking as well as intellectual growth. It helped the researcher to measure adults' IQ from 14 to 65 years old, regardless of their nationality, religion, or other characteristics. The goal is to identify the desired figure both in the answer gap and among the offered choices, forming a pattern that links all the figures together. The Raven Test gets more complex as it goes on, requiring more mental capacity to interpret and assess the questions.

5.22.5.2 Cognitive load scale: The cognitive load scale was designed to measure students' cognitive burden during the lab equipment learning exercise. The three types of cognitive load measurement are practiced in educational scenarios, i.e. Self-reported assessment, Dual-task measurement, and Physiological measurement. This scale is based on self-reported measurement techniques. This scale is a direct-subjective technique that allows students to report their stress and difficulty levels during the learning process. The survey was modified from the Hwang, Yang, and Wang (2013) survey scale. The parameters given by Sweller, Van Merrienboer, and Paas (1998) and Paas (1992) served as the main focus of the survey. It consists of three items for "mental effort" and five items for "mental load." It includes statements like "I had to put a lot of effort into answering the questions in this learning activity," "The learning content in this learning activity was difficult for me," and "I need to put a lot of effort into completing the learning tasks or achieving the learning objectives in this learning activity." This is a five-point Likert scale which provide scope to rate their experience from strongly disagree to strongly agree. In the study by Hwang, Yang, and Wang (2013), the Cronbach's alpha values for mental load and mental effort were 0.86 and 0.85, respectively. Chang and Hwang (2018) employed the scale to assess cognitive strain with success.

5.22.5.3 Reaction Scale: The reaction scale was prepared to collect data on objective 9 from the students. This reaction scale is a 5-point Likert scale to know the students' opinions on the effectiveness of the developed intervention program. This scale was prepared based on dimensions such as interest, scope for activities, active participation, joyful learning, and attainment of concept. This reaction scale consisted of 23 questions that were answered from strongly agree to strongly disagree. All items were positive statements; therefore, five marks were assigned to strongly agree, and in this decreasing continuum, one mark was assigned to strongly disagree.

5.22.5.4 Science Achievement Test: The researcher has prepared an Achievement Test, which served as the tool for data collection. The researcher prepared this test to evaluate the performance of experimental and control groups of students on their Knowledge, Understanding and Applying levels based on Bloom's Taxonomy. The lowest level of Bloom's Taxonomy is knowledge, which is defined as the ability to recall basic terms, definitions, concepts, and other information from previously learned material (memory level or knowledge level). The next level is comprehension, characterized by organizing, comparing, translating, interpreting, providing a description, and outlining the essential ideas to show that one understands the facts and concepts. The ability to apply learned facts, strategies, and principles in novel or creative ways to solve problems in novel contexts is the focus of Bloom's level III Applying, which comes after Understanding (Yaduvanshi, 2016).

For test construction, the researcher thoroughly studied the whole content of the syllabus of the class IX science textbook that was covered in the first semester prescribed by GSHSEB. The purpose of the test was to assess the candidates' performance in relation to knowledge, comprehension, and application levels of the cognitive domain.

The Gujarat Secondary and Higher Secondary Board (GSHSEB) suggested the seven chapters for the first semester from the class ninth science syllabus, which served as the basis for this achievement test. These lesson plans covered the chapters of the Class IX NCERT (National Council of Education Research and Training) science textbook titled Matters in our Surroundings, Is matter around us pure? The Fundamental Unit of Life, Motion, Force and Laws of Motion, Gravitation, and the Improvement of food resources. In this test, a total of 100 items are present; every correct response to the question is assigned one mark, and a wrong response to the question is assigned zero marks.

5.23 PROCEDURE OF DATA COLLECTION

The aforementioned four instruments were used to gather data between June 2023 and November 2023 of the academic year 2023-2024. The researcher conducted experiments and collected data in person for one semester during this academic session of 2023-24. At that time the control group was taught by the conventional method of science teaching.

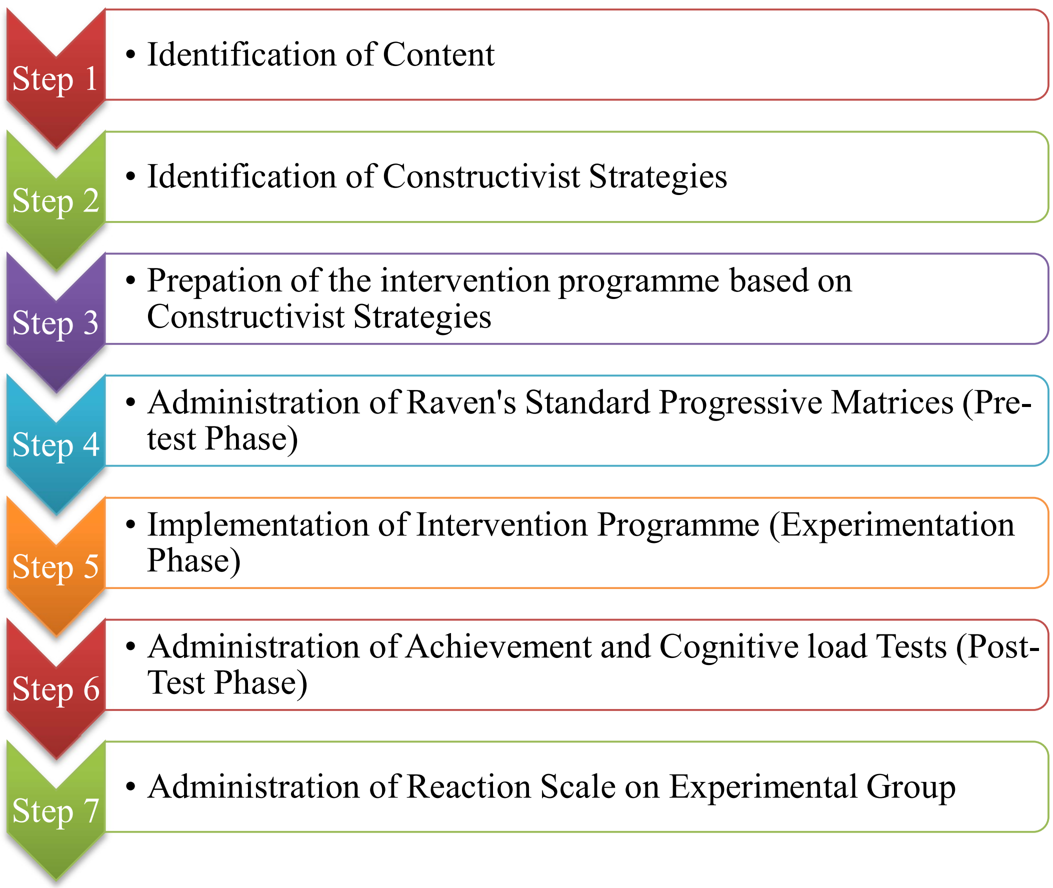

Figure 5.5: Steps of the Study

Phase 1. Identification of Content- The researcher thoroughly analyzed the textbook for the selection of content that can be taught through the constructivist approach.

Phase 2. Identification of Constructivist Strategies

For the selection of the constructivist strategies, the researcher reviewed studies as well as took the opinion of the expert from the science pedagogy and science subject who were working in the schools and university departments.

Phase 3. Preparation of Intervention Programme based on Constructivist Strategies- The researcher took the whole syllabus of the first semester of class 9^{th} for the intervention purpose. In the science book of class 9^{th}, a total of 6 chapters were prescribed by NCERT.

Phase 4. Administration of Raven's Standard Progressive Matrices- Phase IV was carried out at the starting of the academic year in June 2023. One standardized instrument was the Raven's Standard Progressive Matrices (SPM) test. First of all, the researcher took permission from the principals of the two schools chosen to administer the intelligence test. In this phase, the experimental and control groups took the Raven's Standard Progressive Matrices (SPM) test during the first week of the academic year 2023-2024. The time duration specified in the standardized tool was one hour. The students received the booklet and the OMR sheet to record their responses. Within the allotted time, every student in the experimental and control groups finished the Raven's Standard Progressive Matrices (SPM) test.

Phase 5. Implementation of Intervention Programme: The pedagogical intervention program was implemented in the experimental group. The experiment continued for a whole semester. The researcher took utmost care that the teaching-learning process of students did not get hampered during the implementation of the intervention programme. At the same time, the control group was taught in the regular teaching process.

Phase 6. Administration of Achievement Test and Cognitive Load Scale: All the data was personally collected by the researcher throughout the study. Before implementing the pedagogical intervention, a pre-test was administered to the students of both experimental and control groups to measure their achievement and cognitive load. After implementing the strategies, a post-test on both groups was administered at the end of the session. For cognitive load, the researcher assessed it after the completion of the intervention programme.

Phase 7. Administration of Reaction Scale:

The researcher implemented the developed intervention programme, for duration of one semester, on the students for teaching science. After that the researcher administered reaction scale on the student to know their reaction about developed pedagogical intervention programme.

5.24 DATA ANALYSIS

The collected data was analyzed using quantitative statistics techniques- Mean, Mean rank, Mann-Whitney tests, and Intensity Analysis. The Mann-Whitney-U test is most suitable test for analysing the collected data because in the present study sampling technique was purposive sampling and data were not following the assumptions of normality.

5.25 MAJOR FINDINGS

1. There is a significant difference between the experimental and control groups concerning their achievement scores at the 0.05 level of significance. The experimental group secured a higher mean (59.08) than the control group (36.26), which was significantly higher than the control group.
2. For the achievement effect size was .834, which depicted a higher level of effectiveness of the intervention programme on the experimental group for enhancement of achievement scores.
3. There is a significant difference between the experimental and control groups concerning their cognitive load at the 0.05 level of significance. The control group secured a higher mean (21.66) than the experimental group (19.58), which was significantly higher than the Experimental group.
4. For the cognitive load, the effect size was .234, which depicted a moderate level of effectiveness of the intervention programme on the experimental group for reducing the cognitive load.
5. The total average intensity score was 3.65, which indicated an overall positive reaction of the students towards the intervention programme. The data indicated a generally positive perception towards the intervention programme, with high agreement on its effectiveness in engaging students, promoting rational and creative thinking, healthy interaction with peers and teachers, and improving self-confidence. The intervention programme also gave the scope for the students to

identify strengths and weaknesses in the subject. The lowest scores still indicate a positive impact, showing overall satisfaction with the method.

5.26 DISCUSSION

The effectiveness of the developed constructivist pedagogical intervention programme is seen on the academic achievement and cognitive load of the secondary students. The discussion has been done on the effectiveness of developed constructivist pedagogical intervention programme on:

1. Academic Achievement
2. Cognitive Load
3. Scatter Plot

5.26.1 DISCUSSION ON ACHIEVEMENT

The study aimed to examine the effectiveness of a developed pedagogy incorporating constructivist strategies, such as brainstorming, problem-solving, questioning, discussion, and mind mapping, in enhancing science achievement among secondary students. The findings, as evidenced by the results of the Mann-Whitney U Test, strongly suggest the superiority of the intervention programme over traditional lecture methods.

The Mann-Whitney U Test revealed a significant difference in achievement scores between the experimental and control groups, with the experimental group showing a much higher mean rank (71.35) compared to the control group (29.65). This statistical significance, with a U-value of 207.500 and a z-value of -7.189, confirmed at the 0.01 level, and a p-value of .001, led to the rejection of the null hypothesis. The effect size of .834 further underscored the substantial impact of the experimental intervention on student's achievement in science.

These findings are consistent with previous studies that have explored the efficacy of constructivist approaches in education. For instance, a study by Chandi (2020) highlighted that constructivist teaching methods, which emphasize student-centered learning and active engagement, significantly improve student motivation and performance across various educational contexts. Similarly, Ginga and Zakariya (2020) found that a social constructivist instructional strategy significantly enhanced students' performance in algebra compared to conventional teaching methods. These results resonate with the present study's outcome, demonstrating that the constructivist strategies foster a deeper understanding and greater achievement in scientific subjects.

Moreover, the use of constructivist approaches in science education has been shown to enhance critical thinking and social maturity among students. Sheela (2018) conducted research indicating that social constructivist teaching strategies not only improve science achievement but also enhance students' critical thinking skills and social maturity. These findings suggest that constructivist pedagogy contributes to a holistic educational experience, equipping students with essential skills beyond academic achievement.

The present study's findings align with those of Alaagib et al. (2019), who compared lecture-based problem learning with traditional lectures in teaching physiology. They found that students exposed to problem-based learning showed better attention, a more active role, and a higher enjoyment of the learning process, which in turn improved their understanding of physiological concepts. This mirrors the increased engagement and higher achievement observed in the experimental group of the current study.

The experimental group's higher achievement scores and greater variability suggest that constructivist strategies do not only improve average performance but also cater to a broader range of learning styles and abilities. This is supported by the study of Bawaneh (2019), who found that mind maps significantly enhanced students' immediate grasp and retention of concepts related to electric energy compared to traditional teaching methods. This approach aligns with the principles of constructivism, where students actively construct knowledge through meaningful learning experiences.

Furthermore, the significant impact of constructivist strategies on rural students' achievement in biology, as reported by another study, indicates that these methods can help bridge the achievement gap between rural and urban students. This is particularly relevant in diverse educational settings where traditional methods may not effectively address the unique challenges faced by students from different backgrounds.

In summary, the study's findings strongly support the effectiveness of constructivist pedagogical strategies in enhancing science achievement among secondary students. The statistical evidence, combined with the substantial effect size, highlights the significant impact of these strategies on student learning outcomes. By fostering an interactive, student-centered learning environment, constructivist approaches not only improve academic performance but also develop critical thinking, problem-solving, and social skills. These findings are in line with a growing body of research that advocates for the adoption of constructivist methods in education to create more engaging and effective learning experiences.

5.26.2 DISCUSSION ON COGNITIVE LOAD

The findings of this study reveal significant insights into the effectiveness of the developed pedagogy in reducing cognitive load among secondary students in science. The Mann-Whitney U test results indicate a significant difference between the cognitive load scores of the experimental and control groups at the 0.05 level of significance. Specifically, the control group exhibited a higher mean rank compared to the experimental group, indicating that students in the control group experienced more cognitive load than those in the experimental group.

This outcome suggests that the intervention program implemented in the experimental group was effective in reducing cognitive load. The Z-value of -2.020, which lies within the critical range of ±1.96 to ±2.56, confirms the significance of this difference. The effect size of .234 further supports this finding, indicating a moderate effect of the intervention on reducing cognitive load.

These results align with previous studies on cognitive load theory and educational interventions. For instance, Amadieu et al. (2009) found that learners with lower prior knowledge benefited more from hierarchical concept maps, which reduced their cognitive load. Similarly, Liang and Lai (2013) demonstrated that 3D courseware significantly improved learning outcomes while reducing cognitive load. These findings reinforce the idea that well-designed educational interventions can effectively manage cognitive load and enhance learning outcomes.

Furthermore, the study by Turan and Goktas (2016) supports the present study findings, showing that the flipped classroom model resulted in higher academic achievement and lower cognitive load compared to traditional teaching methods. This consistency across studies highlights the importance of innovative pedagogical approaches in reducing cognitive load and improving student learning experiences.

In addition, the study by Seufert (2019) emphasizes the role of pre-training in reducing cognitive load, particularly for learners with higher prior knowledge. This finding underscores the necessity of tailoring instructional strategies to meet the diverse needs of learners, ensuring that cognitive load is managed effectively to optimize learning outcomes.

The violin plots presented in the study visually reinforce the statistical findings, showing a clear distinction in the distribution of cognitive load scores between the experimental and control groups. This graphical representation further validates the effectiveness of the intervention program in reducing cognitive load.

In conclusion, the study provides robust evidence that the developed pedagogy significantly reduces cognitive load among secondary students in science. The moderate effect size and significant difference between the experimental and control groups underscore the efficacy of the intervention program. These findings contribute to the growing body of literature on cognitive load theory and highlight the potential of targeted educational interventions to enhance student learning outcomes. Future research could further explore the long-term impacts of such interventions and investigate their applicability across different subjects and educational contexts.

5.26.3 DISCUSSION ON RELATIONSHIP BETWEEN ACADEMIC ACHIEVEMENT AND COGNITIVE LOAD

The scatter plot with density marginals revealed differing trends between the control and experimental groups regarding the correlation between cognitive load and achievement. In the control group, a slight positive correlation was observed, suggesting that higher cognitive load may be associated with slightly better achievement. This could be indicative of students exerting more effort to cope with the cognitive demands, leading to marginally better performance. This aligns with Hadie and Zul (2018), who found that cognitive engagement could be enhanced through well-structured instructional methods, even if it does not significantly reduce cognitive load.

Conversely, in the experimental group, a significant negative correlation was identified, where increased cognitive load was associated with lower achievement. This suggests that the intervention was effective in reducing cognitive load, thereby enabling students to achieve better results with less cognitive strain. This finding corroborates the results of studies by Andrade et al. (2015) and Josephsen (2018), which emphasized the importance of managing intrinsic and extraneous cognitive loads to enhance learning outcomes.

5.27 IMPLICATIONS OF THE STUDY

The findings from this study have several important implications for society, particularly in the context of educational practices, policy-making, and overall student well-being. By demonstrating the effectiveness of a pedagogical intervention in reducing cognitive load and improving achievement, the study offers insights that can inform various stakeholders, including educators, policymakers, parents, and students themselves.

1. Effective for Large Classrooms

This pedagogical intervention is helpful for a larger classroom in which the number of students is larger. It is also helpful in overcoming the drawbacks of constructivism, like lengthy activities that are hurdles in syllabus completion and the lecture method, like the monotonous classroom, because this intervention programme is the amalgamation of constructivist strategies and lecture method.

2. Effective in Resource-Constrained Classroom

This pedagogical intervention programme will help to teach in a larger classroom where insufficient resources are available. This programme provides scope for learners learning by doing through various teaching-learning strategies.

3. **Enhanced Educational Outcomes**

One of the primary societal implications of this study is the potential for improved educational outcomes. By adopting instructional strategies that effectively reduce cognitive load, schools and educational institutions can enhance student learning and achievement. This, in turn, can lead to better educational attainment and prepare students more effectively for higher education and the workforce. Improved academic performance can also contribute to closing achievement gaps, thereby promoting equity in education.

4. Informed Educational Policy

The results of this study can guide policymakers in making informed decisions regarding curriculum design and instructional methods. Policymakers can promote the implementation of evidence-based pedagogical interventions that have been shown to improve learning outcomes. By supporting teacher training programs that focus on cognitive load management and effective instructional design, educational authorities can ensure that teachers are well-equipped to create optimal learning environments for their students.

5. **Teacher Professional Development**

For educators, the study underscores the importance of professional development in modern teaching methodologies. Training programs that focused on cognitive load theory and its practical applications can empower teachers to design and deliver instruction that minimizes cognitive overload and maximizes student engagement and achievement. This professional development can also foster a culture of continuous improvement and innovation in teaching practices.

6. **Student Well-being**

Reducing cognitive load not only enhances academic performance but also positively impacts students' overall well-being. Excessive cognitive load can lead to stress, burnout, and disengagement from learning. By implementing strategies that reduce cognitive strain, educators can help create a more supportive and nurturing learning environment. This can improve students' mental health, increase their motivation, and foster a positive attitude towards learning.

7. **Parental Involvement**

The study highlights the role of parents in supporting their children's education. Understanding the impact of cognitive load on learning can help parents provide better support at home. They can collaborate with teachers to create a conducive learning environment, recognize signs of cognitive overload, and help their children develop effective study habits that align with the principles of cognitive load theory.

8. **Societal Equity and Inclusion**

By demonstrating that targeted pedagogical interventions can reduce cognitive load and enhance achievement across diverse student populations, the study supports efforts to promote equity and inclusion in education. Ensuring that all students have access to effective instructional strategies can help bridge gaps in educational achievement and provide equal opportunities for success, regardless of socioeconomic background or learning challenges.

5.28 SUGGESTIONS FOR FURTHER RESEARCH

1. This study investigated the effectiveness of the intervention programme (made by the amalgamation of lecture method and constructivist strategies like brainstorming, problem-solving, mind map, discussion, and questioning) on achievement and cognitive load. It is suggested that in the future, other researchers should design some unique intervention programmes which can decrease the cognitive load on students, hence increasing their achievement scores and overall mental well-being.

2. This study explored the effectiveness of the intervention programme only at 9th standard students. In the future, similar studies can be replicated at elementary and senior secondary levels.
3. This intervention programme was delimited to the subject of science, but for better exploration of its effectiveness, it can be applied to other subjects also.
4. In this study, the intervention programme includes multiple constructivist strategies; future research should conduct component analysis to determine the individual and combined effects of these strategies. This would involve isolating specific elements like brainstorming, problem-solving, and mind mapping to understand their unique contributions to reducing cognitive load and improving achievement.

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