SITUATING CONSTRUCTIVIST STRATEGIES IN LECTURE: AN EXPLORATION IN PEDAGOGY OF SCIENCE AT SECONDARY LEVEL

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1.0 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).

1.2 IMPORTANCE OF SCIENCE

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.

1.3 OBJECTIVES OF SCIENCE TEACHING AT THE SECONDARY LEVEL

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.

In light of PROBE reports as well as various other reports, Indian schools are suffering from the scarcity of resources and trained teachers; therefore, 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, and in only 10% of classrooms, 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). It was found that the lecture method is predominantly used in the classrooms.

1.4 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'.

1.5 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.

1.6 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).

1.7 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.

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).
and observational methods to evaluate their interaction with the given materials.

1.8 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.

1.9 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.

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.

1.10 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.

1.11 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**.

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,** the **visual-spatial sketch pad,** and the **episodic buffer** (Pezzulo, 2007; Demir, 2021).

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).

1.12 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:

1.13 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. the visual-spatial sketchpad and the phonological loop, which 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 the 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 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.

1.14 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 concepts in the form of a 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 a 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 the following research questions.

1.15 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?

1.16 STATEMENT OF THE PROBLEM

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

1.17 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.

1.18 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.

1.19 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.

1.20 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.

1.21 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.

2.0 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.

2.1 IMPLICATIONS OF REVIEW OF RELATED LITERATURE

The researcher reviewed a total of ninety-one studies. Sixty studies were on Constructivism, twenty studies on cognitive load, and eleven studies on innovation in the lecture method. By reviewing the studies, the researcher found many studies related to constructivism such as Constructivism has been a positively significant method for teaching biology (Mohapatra & Kumari, 2015; Kumar, 2016; Sandhu, 2017), teaching science (Shukla, 2016), teaching science through cooperative learning strategy (Yaduvanshi & Singh, 2018), teaching of science through 7Es model (Adak, 2017), chemistry learning (Huseyin et. al. 2003). Secken and Alsan (2011) found that constructivism was a beneficial approach to teaching and learning the concept of hydrolysis in chemistry. Chawdhury (2016) found that this approach has a significant positive effect on mathematics achievement, and understanding and applicability have been enhanced. Pangat (2017) found that this approach significantly positively affects mathematics achievement and enhances reflective ability. Loyens et al. (2006) suggested constructivism helps in developing problem-solving ability, while Kroesbergen (2004) found the constructivist approach has less impact on mathematics learning than the explicit method.

Science teaching should be through activity-based pedagogy because the attainment of the objectives of science teaching is possible through activity-centred pedagogy. As we saw, the constructivist approach provides scope to the learners for activity and construction of knowledge based on previous experiences; therefore, the National Curriculum Framework (2005), the National Education Policy (2020), the National Curriculum Framework for School Education (2023) advocated for adopting activity-based pedagogy and constructivism for science teaching but through constructivism completion of the subject is not possible therefore teacher have a moderate attitude to adopt constructivism in classroom. On the other hand, the lecture method makes the classroom monotonous. However, previous research showed that interactive lectures and lectures with problem-based pedagogy and mind maps improved learning among the learners. The investigator came across 60 studies done on the constructivist approach, most of which were related to developing strategies based only on the constructivist approach. However, the researcher found few studies that incorporated constructivist strategies in the lecture method, so the researcher wants to develop a pedagogical intervention by incorporating constructivist strategies in the lecture. As a result, the disadvantages of both pedagogies are overcome with the advantages of both types of pedagogy. In this continuum, the researcher finds the study related to examining the effect of constructivism on the teaching of science, biology, chemistry, the education system, motivation, problem-solving, flexibility in thinking, reflective thinking, reasoning skills, and mathematics learning. The researcher also found that mind maps and concept maps, the cognitive load theory-based lecture method, help in reducing the cognitive load among the learners. After analyzing the SCOPUS database and reviewing the literature, the researcher felt a scarcity of research evidence that shows the effect of the constructivist approach on the cognitive load of students. For the present study, the researcher chose class ninth-grade students because these students fall under the age range of 13-16, which is crucial for developing critical thinking and rational thinking. At this stage, abstract thinking is also developing in the students; therefore, for the present study, this age group of students was more appropriate. In this study, the researcher tried to investigate the effect of the intervention programme based on constructivist strategies on the cognitive load of secondary students in the science subject.

3.0 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.

3.1 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.

3.2 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.

3.3 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.

3.4 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.

3.5 TOOLS OF DATA COLLECTION

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

3.5.1 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.

3.5.2 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 that provides 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.

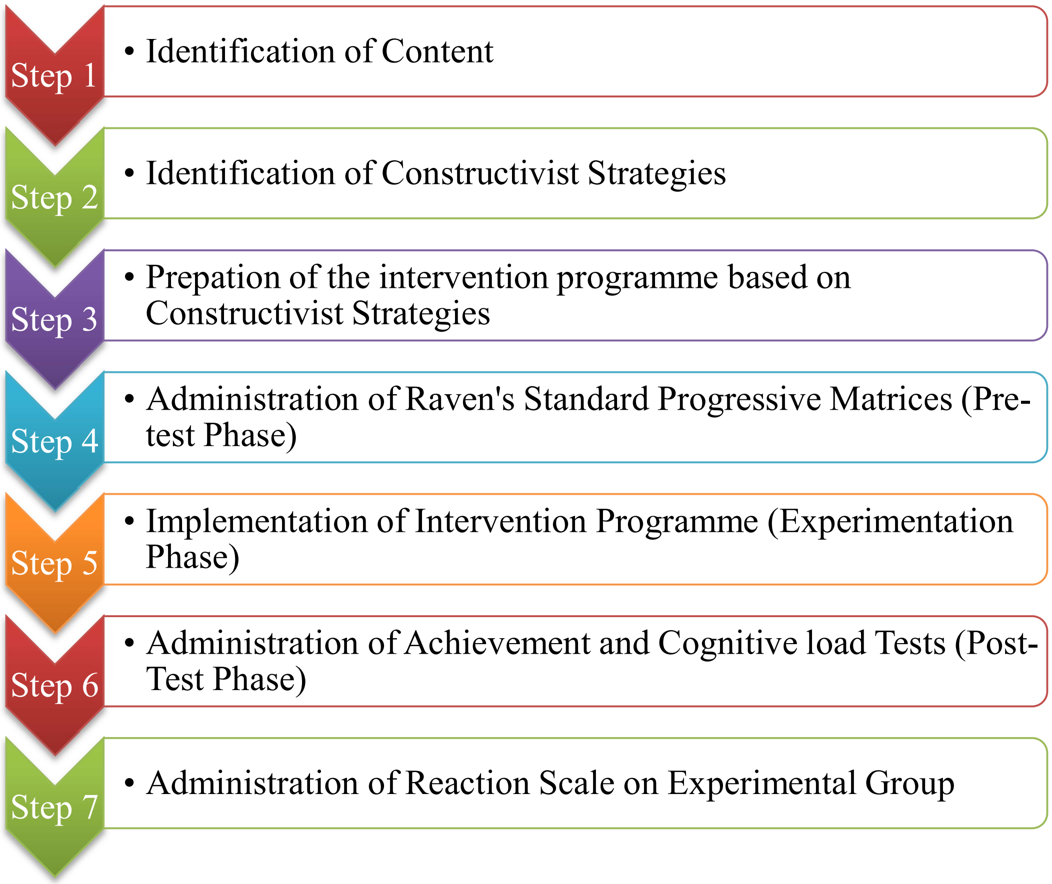
3.5.3 Reaction Scale: The reaction scale was prepared to collect data on objective 9 from the students. This reaction scale is a 5-point Likert scale to know the students' opinions on the effectiveness of the developed intervention program. This scale was prepared based on dimensions such as interest, 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, 5 marks were assigned to strongly agree, and in this decreasing continuum, 1 mark was assigned to strongly disagree.

3.5.4 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 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 six 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.

3.6 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.



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 a reaction scale to the students to know their reaction to the developed pedagogical intervention programme.

4.0 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 the most suitable test for analysing the collected data because in the present study, the sampling technique was purposive sampling, and the data were not following the assumptions of normality.

4.1 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 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.

5.0 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

5.1 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.

5.2 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.

5.3 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.

5.4 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 the 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.

5.5 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 9^{th} 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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