VALIDATION OF THE FACTOR STRUCTURE EQUIVALENCE OF THE SCIENCE ACADEMIC ACHIEVEMENT MODEL ACROSS GENDER AND BATCH GROUPS IN SECONDARY SCHOOL STUDENTS

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2026

DECLARATION

I, hereby declared that the presented work in the thesis entitled "**VALIDATION OF THE FACTOR STRUCTURE EQUIVALENCE OF THE SCIENCE ACADEMIC ACHIEVEMENT MODEL ACROSS GENDER AND BATCH GROUPS IN SECONDARY SCHOOL STUDENTS** "in fulfillment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of Dr. Rajib Chakraborty, working as Associate Professor School of Education in Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigators. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



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CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled "**VALIDATION OF THE FACTOR STRUCTURE EQUIVALENCE OF THE SCIENCE ACADEMIC ACHIEVEMENT MODEL ACROSS GENDER AND BATCH GROUPS IN SECONDARY SCHOOL STUDENTS** " submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in School of Education, is a research work carried out by Syamala Pilla, Registration No. 42100386, is bonafide record of her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



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Date: …….. **Syamala Pilla**

ABSTRACT

Secondary school education is an important juncture in the academic journey of any student (Coestela et al., 2024). It comprises of exhibition of performance of the student in multiple aspects of learning primarily seen through the lens of achievements in the school subjects. One of the most important subjects that decide scientifically lead a joyous life but also a good professional learning prospects in the future is the subject of science. The factors that contribute to the offering of quality science education at school thus become the subject of research interest for the practitioners and administrators alike. More over government if Indian policy documents (NCF, 2005: NEP, 2020) on school education also emphasize the stress to be given to the offering of science education which not only is purposeful and filled with utility value but also contextual in nature.

The present study reviewed the literature thoroughly to identify variables of science education at the secondary level that can play a critical role in improving science academic achievement through their collective promotion these member antecedents of science academic achievement were found to construct a constructivist environment, epistemological beliefs, science self-efficacy and science academic flow. Further review of the literature either revealed stand-alone studies or very scanty works on the relationship existing among these variables. A comprehensive and empirical framework was developed and supposed for validation in this study. The framework was to be subjected to statistical testing to ensure its measurement equivalence with respect to gender and batch of secondary school students.

The population of the study was selected to be secondary school students belonging to the Central Board of Secondary School Education (CBSE). The rationale behind the selection of the mentioned population was the homogeneity existing among the schools belonging to this board with respect to science pedagogy and the numerical supremacy of these schools across the country, aiding in the generalization of the study and implementation of policy implications.

The large geographical area of the state of Andhra Pradesh was considered as the region in which the study was to be conducted. The state has 13 districts consisting of 325 schools affiliated to the CBSE Board as per the source SARAS of

the government of India. In order to address the inherent diversity present in the students belonging to the different demographic levels and to provide equal representation to them, the stratified random sampling technique was considered as the sampling technique of the study.

Using the central limit theorem 10% of the sampling network consisting of the district-wise list of all the 325 schools were considered in the study. The school to finally visit for the data collection was selected from the district-wise sampling frame list of schools using an Excel sheet and its command = RANDBETWEEN(1,20) for instance to generate a random school to visit.

Four tools were used for date collection in the present study. To measure constructivist learning, Constructivist Learning Environment Scale by Tylor and Fraser, (1991) adopted by Nik, Faser and Led (2003) was used. For measuring Epistemological beliefs, the scale developed by Conley (2004) was used. Science self-efficacy was measured using Glynn and Koballa (2006) adapted by Biswal and Chakraborty (2024) in the Indian context. The science flow in secondary school students was measured using the scale developed by Heite (2019) all the instruments were adapted in the Indian context.

Prior permission was taken from the head of all the schools to be visited and permission was obtained from them to gather the data during class room session in the presence of the class teachers instructions on how to fill the questionnaire, assurance of confidentiality of the data and its usage strictly for research purpose and the consent for the voluntary participation in the exercise were taken from the students before data collection. The study was approved by the institutional ethics committee of lovely Professional University bearing registration number EC/NEW/INST/2022/3110.

The obtained data was subjected to Network Psychometric analysis for validation of the four scales of Constructivist learning environment, epistemological beliefs in science, science self-efficacy, science academic flow the poor performing items of each of these scales were deleted to form the final instrument of data collection from secondary school students studying of all the 13 districts of Andhra Pradesh state. The final sample was n= 932, after removing the outliers using Mahalonobis distance, the final sample size reduced to 918. Network psychometrics

based model validation and estimation of the consistence of the network with respect t gender and class of the students was conducted. The Network was found to be not only valid having good stability and accuracy of its nodes and edges, but also constant with respect of its structure across the gender and the cl ass groups. This result means that present empirical model us valid and works equally well in improving the science academic achievement in secondary school student irrespective of their gender or class levels of 9^{th} and 10^{th} standards.

The attenuation index of all the four scales reliability were estimated by finding the difference between Cronbach's alpha and ordinal Cronbach's alpha reliabilities and to show the under estimation of reliability by the well-known by Cronbach's alpha estimate.

The findings of the study are of relevance to range of stake holders involving the students, parents, teachers and school administrators along with researcher in the field of school education, the implications, recommendations limitations and the conclusion are discussed.

Keywords: *Constructivist learning environment, Epistemological Beliefs in Science, Science Self-efficacy, Science Academic Flow, Science Academic Achievements, Secondary school students, Network Approach, Network consistence, Attenuation index.*

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CHAPTER-I

INTRODUCTION

CHAPTER - 1 INTRODUCTION

"Education is not the learning of fact, but the training of the mind to think."

Albert Einstein

1.1 Concept of Education

The present scenario of the education system depicts that there is a tremendous change from the Vedic period to till today. As we are living in an era of technology drastic changes are noticed in the system, earlier the process of teaching learning was teacher centered where teacher use to dominate the system. Later, it was learner centered and now it is learning centered education with the use of technology. This rapid change in the field of education is due to demands of the society. In spite of all these changes, many schools in our nation are lacking the basic facilities like infrastructure, teaching learning resources, human resources and such others. In these schools, the mode of transaction is still teacher dominated.

The progress of the nation depends on the quality of education provided in the schools. Due to modernization and globalization private schools are mushrooming. As the numbers of institutions are increasing, the quality is declining. The decline is because of commercialization of the institution and this leads to lack of zeal among teachers to teach in an innovative way.

Most of the schools are result oriented and school personnel are not motivated. Teachers lack interest in teaching the learners from diverse background. One method of teaching may not be suitable for all categories of children. The school education plays an important role in nation building, developing self-confidence in learners and competencies to face the life. School education is a foundation to the entire life of a child. If the foundation is strong then only we can imagine about building of a nation. In such context, the school education must cater the needs of the present society, teachers are social engineers to be trained with new innovative methods of teaching, and especially the focus must be on construction of knowledge among the learners and not mere passive recipients of knowledge. According to National Curriculum Frame Work (2005), the role of teacher is to facilitate the learner by providing varied experiences to them and learner need to actively construct the new knowledge based

on their prior knowledge. In this aspect, the latest curriculum, which is followed in many states of our nation, is based on constructivism. When we think of the word 'science', we automatically think of chemicals or astronauts or engineers building bridges. These activities are most common for a scientist but science is so much more than this. It is not even restricted to studying fields like biology, chemistry, and physics.

Today, science has its wings spread over a number of fields of study. There are sciences of life, physical sciences, social sciences, food sciences, agricultural sciences, forensic sciences, space sciences etc. This list is endless. Each individual is surrounded by science in everyday life. It finds application in each and every activity of life. Whether you are talking a friend on phone, or sitting comfortably in your air-conditioned office, or taking medication, science is everywhere.

Science is rooted deeply in our everyday lives in thousands of ways. So, we can't even probably imagine its substantial impact on our lives and cultures. There isn't a single aspect of life which is not influenced by science. Due to this deep and constructive contribution of science towards the development of societies and individuals, the subject matter of science has gained huge importance in school education.

Science has provided the basis to a majority of modern technology – the equipment, material, techniques and sources of energy that make our lives and work easier. The inventions and discoveries made by scientists have helped in shaping our views about ourselves and our place in this universe. The meaning of recreation has changed completely for the present child with different kinds of music-playing equipment, computer games, apps, video games, DVDs and the social media.

The immense uses of science in day-to-day life have helped us in solving problems effectively, dealing with health issues logically, preserving food for times of need, constructing houses which save us from natural disasters, providing a wide variety of communication media and numerous time-saving modes of transport. Science has also helped in understanding diseases and check epidemics thereby saving a precious human life. Science has contributed tremendously to making individuals progressive. Without a science-literate population, the outlook for a better world is not promising. (AAS, 1985).This suggests the necessity of delivering high-

quality science education from the very beginning of schooling. Educational institutions must play a significant role in providing quality science education to develop individuals who are globally competitive and capable of handling such a competitive technological environment.

1.1.1 Science Education in India

From preschool to higher education, there is broad agreement in Indian school curricula and policy that scientific education is crucial for all students, regardless of educational level. As a result, scientific instruction is now required at the elementary school level. The system's objective of developing pupils' scientific literacy is supported by high-quality science instruction. A workforce with scientific aptitude and a society with scientific literacy may arise from improving students' views of their scientific aptitude and the importance of science in a future job.

If we want to produce globally competitive and scientifically progressive individuals, we need to have comprehensive planning to implement the science curriculum in schools. The problem of catering to the needs of a huge population is one of the most severe obstacles in achieving the goals of science education in India. It is difficult to identify persons having a sound scientific temper due to the restricted amount of facilities and limited resources concerned with science education.

As a result, many masterminds remain unidentified. Science education aims at providing essential science proficiency, effective methods of acquiring knowledge, drawing inferences from experiments, developing scientific temperament and building a bridge between technology and culture.

Science education also plays a critical role in motivating students to adopt technology based careers which are deemed indispensable in contemporary Indian societies, so that they can easily face scientific development challenges. Science education also aims at creating a skilled labor force which can work innovatively and compete with the developed countries in terms of the innovations they are coming up with. Scientific literacy also helps us in solving problems related to our society creatively and logically. Science education in India seeks to build and maintain a pool of creative workforce which can help our nation to keep pace with our global neighbors. In a developing nation like India, the quality of science education has to be

improved immediately. Widespread access to high-quality science education is desperately needed in order to train tomorrow's scientists. As a result, students' motivation and interest will increase, enabling the best students to pursue professions in science. One of the major challenges facing Indian formal education is raising the bar for scientific success and cultivating a favourable attitude towards science.

The National Curriculum Framework (NCF) 2005, alongside the Rashtriya Madhyamik Shiksha Abhiyan (RMSA) Framework 2009, highlights a critical concern in India's educational landscape: the diminishing emphasis on practical work and hands-on experimentation in science education at the secondary and senior secondary levels. In response, the RMSA Framework advocates for the establishment of integrated science laboratories in schools, aiming to provide students with more opportunities for active learning and experimentation, thus enhancing their practical scientific skills. These resources are specifically designed to support inquiry-based learning, stimulate critical thinking, and foster analytical abilities among students. The goal is to enrich science education across all Indian states and Union Territories, ensuring that students gain a deeper, hands-on understanding of scientific concepts.

Furthermore, the Central Board of Secondary Education (CBSE) has taken significant strides to strengthen science education by introducing skill-based courses at the secondary and senior secondary levels. These courses, which begin in Class IX, are designed to develop core practical skills that are directly applicable to real-world scenarios. The CBSE collaborates with various skill knowledge providers to enhance the effectiveness of these courses, ensuring that students are not only equipped with theoretical knowledge but also gain valuable, employable skills.

In this broader context, science education plays an indispensable role in shaping the educational and professional futures of students in India. The frameworks and initiatives introduced by organizations like RMSA, NCERT, and CBSE are pivotal in transforming the way science is taught and learned, helping to cultivate a scientific mindset, enhance inquiry-based learning, and better prepare students for academic and career opportunities in an increasingly complex and technology-driven

world.

1.1.3 Science Education at the Secondary Level

Science education at the secondary level is crucial in shaping students' understanding of the natural world and equipping them with the skills needed for future academic and career opportunities. In India, secondary education typically covers grades 9 to 12, a period during which students are introduced to more advanced scientific concepts and methodologies.

At the heart of secondary science education in India is the framework set by the National Council of Educational Research and Training (NCERT). NCERT is responsible for developing the national curriculum, ensuring that it is consistent, up-to-date, and relevant to the needs of students across diverse regions and backgrounds. The NCERT curriculum emphasizes a holistic approach to learning, integrating theoretical knowledge with practical applications, and encouraging students to engage with science in a way that enhances both their academic and personal growth.

Through a blend of theoretical instruction and hands-on laboratory experiences, secondary science education in India aims to cultivate curiosity, inquiry, and a deeper understanding of scientific phenomena. This foundation not only prepares students for higher education in science and technology fields but also equips them with the analytical and problem-solving skills necessary to succeed in a rapidly changing world.

The science curriculum for secondary education in India covers a broad range of subjects, including physics, chemistry, biology, and environmental science. These subjects are integrated with an emphasis on practical application and real-world problem-solving. Students engage in a variety of activities that foster curiosity and critical inquiry, with laboratory-based learning being a core component. Through experiments, observations, and data analysis, students develop a deeper understanding of scientific concepts while enhancing their analytical, evaluative, and experimental skills.

In addition to theoretical knowledge, secondary science education in India encourages hands-on learning and inquiry-based methods. Students work with scientific equipment and conduct experiments that mirror real-life applications, promoting a deeper engagement with the subject matter. This approach not only strengthens their grasp of scientific concepts but also cultivates a sense of scientific inquiry and investigation, which is essential for higher education and careers in science, technology, and engineering.

Furthermore, the focus on critical thinking and problem-solving helps students develop important skills such as logical reasoning, teamwork, and communication, all of which are indispensable in today's knowledge-driven world. Overall, science education at the secondary level in India is designed to equip students with the knowledge, skills, and attitudes necessary to thrive in both academic and professional spheres, laying the groundwork for their future endeavors.

Science education at the secondary level focuses on establishing good attitudes towards science in addition to academic knowledge and practical abilities. Students are encouraged to acquire a feeling of wonder and curiosity about the natural world, as well as an appreciation for the role of science and technology in society.

The Indian government has launched a variety of initiatives and programs to boost secondary scientific education. The National Science Talent Search Scheme (NSTSS), for example, is a scholarship program aimed to find and foster outstanding students in the area of science, while the INSPIRE program seeks to stimulate student research and innovation. Despite these attempts, scientific education at the secondary level in India faces several problems. Inadequate infrastructure, a scarcity of trained professors, and a lack of funding for actual experimentation and research are among them.

Furthermore, increased diversity and inclusion in scientific education are required to guarantee that all students have equal opportunity to pursue jobs in science and technology. In conclusion, secondary science education in India is crucial for creating a solid foundation of scientific knowledge, abilities, and attitudes. While

there are obstacles to overcome, initiatives are underway to promote high-quality scientific education and to prepare students for successful employment in science and technology.

1.2 Definitions of Constructivism

Constructivism is a learning theory that emphasizes the active role of learners in constructing their own understanding. According to this perspective, learners build new knowledge by connecting new information to their pre-existing ideas and experiences (Khadar, 2005). The mind synthesizes prior knowledge to form more complex concepts (Lock, 1947). As Brooks and Brooks (1993) explain, "Constructivism is not just a teaching method, but a theory of knowledge and learning," highlighting that knowledge is dynamic, evolving, and shaped by social and cultural contexts, rather than being fixed or objective.

"Knowledge, no matter how it is defined, exists in the minds of individuals, and the thinking subject has no alternative but to construct what they know based on their own experience" (Von Glasersfeld, 1995).

Constructivism is an epistemology and a learning theory that offers an explanation of the nature of knowledge and how humans learn. It maintains that individuals create or construct new understandings or knowledge through the interaction of what they already know and believe with ideas, events, and activities they encounter (Camella and Reiff, 1994; Richardson, 1977).

Constructivism is an approach in which the learner builds an internal representation of knowledge a personal interpretation of experience. It emphasizes the careful study of the processes by which children create and develop their ideas (Simson, 1993).

Learning is an internal process influenced by the learner's personality, prior knowledge, and learning goals. Constructivism describes a learner-centered environment where knowledge and the creation of knowledge are interactive, inductive, and collaborative. In such environments, multiple perspectives are represented, and learners' questions are valued (Brooks and Brooks, 1993).

1.2.1 Concept of Constructivism Learning Environment

The term constructivism refers to the construction of new knowledge by the learner based on their pre-existing knowledge and current experiences. Thus, it is a process of meaningful and authentic learning. In constructivism philosophy, we learn to know how the knowledge construction takes place among the individuals and what they learn. The construction of knowledge may happen individually or in a group. Learners interact with teacher and peers to form knowledge. Constructivism does not mean that it is recreating the knowledge but it understands how it works.

Constructivist Learning Environment

Jonassen (1994) enumerated eight characteristics of the Constructivist Learning Environment (CLE), which include:

1. Providing multiple representations of reality.
2. Ensuring multiple representations avoid oversimplification.
3. Emphasizing knowledge construction rather than knowledge reproduction.
4. Using authentic tasks in meaningful contexts.
5. Avoiding a predetermined sequence of instructions.
6. Encouraging thoughtful reflection on experiences.
7. Enabling context- and content-dependent knowledge construction.

To design a Constructivist Learning Environment, Jonassen (1999) proposed a model that facilitates knowledge construction and outlined essential components, which are as follows:

Focus of the Environment: The problem, question, or project is the central focus of the constructivist learning environment. The design of the problem includes three prime components: problem context, problem representation or simulation, and problem manipulation space.

Related Cases: These represent a set of related experiences that support learning by scaffolding students' memory and providing various themes, interpretations, and contexts. Related cases help reduce the complexity of the problem and enhance cognitive flexibility.

Information Resources: A constructivist learning environment provides resources to help students comprehend and solve problems.

Cognitive Tools: These tools, including computer tools, assist with the visualization, organization, and automation of thinking processes. Different types of cognitive tools serve various functions, such as Static and Dynamic Knowledge Modeling Tools (SDKMT), Problem/Task Representation Tools (PRT), Information Gathering Tools (IGT), and Performance Support Tools (PST).

1.2.2 Characteristics of Constructivism

According to Piaget, Vygotsky, Novak and Posner following are the basic characteristics of constructivism.

- Learning is an active and meaning full process.
- Learners' new learning is based on their prior knowledge.
- Learning is a result of social interaction.
- Authentic learning tasks given to the learner results into meaningful learning.
- Learning stands for reconstruction of prior concepts.

1.3 Constructivist Learning Theories

Various Constructivist Learning Theories have been given by educationists. Tebogo (2014) enumerated some constructivist theories to make understand knowledge construction with the article published on Applicability of Constructivist Theory in Qualitative Educational Research. These theories are;

Personal Constructivism: It is also named as Personal Construct Psychology and states that individuals systematized their experience with development of bipolar

dimensions of personal construct. According to this theory, People learn effectively when their experiences are exposed which affected on them.

Social Constructivism: This theory describes that Knowledge is a human product and is socially and culturally built upon. People create sense through interactions among themselves and with their environment. Knowledge construction is also affected by the inter-subjectivity formed by social and historical factors of the community.

Radical Constructivism Hardy and Taylor (1997) describe this theory as a kind of learning theory and also pedagogical model. It suggests that mental construct structured from prior experience and facilitate to impose order on one's flow of continuing experience.

Psychological Constructivism: Piaget (2001) stated that learning is an interaction between two cognitive activities i.e., assimilation and accommodation. According to the Abdal-Haqq (1998), "this theory is based on the notion that imparting education to the individual child in a manner that supports the child's interests and needs. Subsequently, the child is the subject of study and persons' cognitive growth is the focus".

Contextual Constructivism This theory considers social construction of knowledge and applicability of knowledge. Ranee (2006) highlighted the fact that, "knowledge should purpose to yield calculations, agrees with the problems that the scientific community sensitizes. It should address an alternative paradigm which asserts to solve those problems that are required". These constructivist theories promote different kinds of teaching- learning resources which are necessary to run educational process.

Main Aspects of Constructivist Learning Approach

Construction of knowledge is primary aim of constructivist approach and constructivist classroom facilitate learning in following way;

a) Constructed learning: Students already have knowledge, ideas and understanding when they come in learning conditions. A teacher can't disseminate knowledge directly to the learner. In the constructivist approach, prior knowledge is the raw material for the new knowledge that students create themselves.

b) Active learning: Constructivist learning theory states that when students actively construct knowledge, they learn perfectly. Duffy, Lowyck and Jonassen (1993)

suggested that “knowledge construction can be made possible by solving authentic problems which usually requires collaboration with others”.

c) Reflective learning

In the constructivist approach, students have the opportunity to control their own learning processes by reflecting on their experiences and teachers support the students by creating situations.

d) Collaborative learning

Collaboration contributes learning properly because the students in peer group can easily pick up strategies and methods from one another by reviewing and reflecting on their experiences.

e) Inquiry based learning

Inquiry is a prominent thing in constructivist learning as it leads to construction of knowledge. Students use inquiry methods to ask questions, frame hypotheses, explore a topic and use a variety of resources to find out the solutions and to draw conclusions. These conclusions help to create questions and questions lead to more questions. Inquiry promotes logical thinking and reasoning ability in students.

f) Evolving

This process is needed to evolve the incorrect, invalid and insufficient ideas of students that couldn’t explain experiences and it doesn’t integrate knowledge.

Different Constructivist Strategies

All bases of gaining information provide new ideas about problems. Thus, this theory motivates learners to use active techniques, such as experiments (inquiry) and problem-solving methods, to construct more knowledge. Therefore, learning in a constructivist environment should be collaborative, cooperative, inquiry-based, reflective, problem-based, and evolving. Learners integrate new knowledge with prior knowledge through these practices, which in turn support them in constructing their current conceptions. These constructivist techniques differ from one another in some respects.

Project based learning

This approach primarily focuses on a production model. Students begin by defining the purpose of creating the end product, identifying their audience, researching the topic, designing the product, managing the project, solving problems that arise, and finishing the product, followed by self-evaluation and reflection.

Problem based learning

This method uses an inquiry model. Students start with a given problem, plan how to gather information, pose new questions, and summarize their research by presenting their conclusions.

Inquiry based learning

Inquiry learning encourages students to formulate questions, investigate to find answers, build new understandings and knowledge, and then communicate their findings to others. This knowledge is new to the students and may be used to answer a question, develop a solution, or support a position or point of view. The knowledge is usually presented to others and may lead to some kind of action.

Guided instruction learning

This strategy involves the teacher presenting strategically placed prompts, questions, cues, and direct explanations. The teacher guides students' thinking and facilitates increased responsibility for completing a task.

1.4 Constructivist model used in Science Classroom

The 4-E Learning Cycle, which includes the phases of Exploration, Explanation, Expansion, and Evaluation, is grounded in constructivist learning theory, particularly as articulated by Jean Piaget (as cited by Renner & Marek, 1988). This model encourages students to engage actively with their learning process, allowing them to build on their existing knowledge and create meaningful connections with new information. Constructivism emphasizes that students learn most effectively when they are provided with a variety of learning experiences that allow them to construct their own understanding over time. In this context, teachers play the role of facilitators, guiding students to use their prior knowledge as a foundation to make

sense of new content. By structuring lessons in a way that encourages exploration and reflection, educators can help students connect previously learned concepts to new ones, fostering deeper understanding.

In the Primary Connections approach, each unit is designed around the 4-E cycle to ensure that students have opportunities to engage with content in diverse and dynamic ways:

1. **Explore**: In this phase, students are encouraged to interact with new ideas, concepts, or phenomena. This phase emphasizes hands-on activities or investigations that allow students to generate questions, make observations, and engage in inquiry. It helps them build an initial understanding based on their own experiences.
2. **Explain**: Here, students refine their understanding through teacher guidance, discussions, or explanations. Teachers help students make sense of their explorations, linking their prior knowledge to new concepts and introducing key terminology and scientific principles.
3. **Expand**: In the expansion phase, students extend their knowledge by applying what they have learned in new contexts. This may involve solving more complex problems, conducting further investigations, or making connections between the new information and other areas of study.
4. **Evaluate**: Finally, students reflect on their learning, assess their understanding, and receive feedback. This phase helps students to consolidate their knowledge and think critically about the concepts they have explored. It also provides an opportunity for teachers to assess student progress and identify areas for further development.

The Department of Education, Science, and Training (Australian Government), which oversees the Australian Academy of Science, has adopted a similar approach, aligning with constructivist principles. By organizing learning around the 4-E cycle, educators can create a rich, student-centered learning environment that promotes active engagement and deep understanding.

Common methods and strategies used in Constructivist Approach

The constructivist approach to teaching emphasizes active, student-centered learning, where students build on their prior knowledge through exploration and interaction. Here are several common methods and strategies used in constructivist classrooms:

1. Brainstorming

Brainstorming is a creative problem-solving technique in which students collaboratively generate a wide variety of ideas to address a particular problem or question. The goal is to encourage out-of-the-box thinking and spark new connections by building on each other's contributions. This method fosters a sense of collective creativity, as students refine and expand on the ideas of others.

2. Scaffolding

Scaffolding involves providing temporary support to help students tackle tasks that are just beyond their current capabilities. This support, typically provided by the teacher, can take the form of hints, cues, prompts, or structured tasks that guide students through challenging material. Over time, as students gain confidence and competence, this support is gradually withdrawn, allowing them to perform tasks independently.

3. Project-Based Learning (PBL)

Project-Based Learning is an instructional strategy where students engage in real-world, interdisciplinary projects. Through inquiry, exploration, and collaboration, students develop solutions to complex problems, often involving investigation, design, and the application of skills across various subjects. PBL fosters deeper learning by requiring students to actively construct knowledge and apply it in meaningful ways.

4. Questioning

In a constructivist classroom, questioning is a key tool for promoting critical thinking and guiding learning. Teachers use a variety of question types such as guiding, anticipating, clarifying, and integrating questions to prompt students to think critically, make connections, and explore different perspectives. Effective questioning encourages deeper reflection and engagement with content.

5. Self-Assessment

Self-assessment empowers students to take ownership of their learning by reflecting on their own progress and performance. Through checklists, rubrics, or open-ended questions, students evaluate their strengths and areas for improvement, helping them develop self-regulation and meta cognitive skills. This strategy encourages a growth mindset and a sense of responsibility for their learning journey.

6. Simulations

Simulations are immersive, experiential learning activities that replicate real-world or hypothetical scenarios. These activities, often involving role-play or gaming, allow students to engage in decision-making, problem-solving, and critical thinking within a controlled, yet dynamic, environment. Simulations encourage deeper understanding of complex concepts by allowing students to experiment and learn from consequences.

6. Team Teaching

Team teaching involves collaboration between multiple educators in the classroom. By sharing instructional responsibilities, teachers can draw on diverse expertise and teaching styles, offering students varied perspectives. This approach fosters a dynamic learning environment where students benefit from a broader range of ideas and experiences.

7. Cooperative Learning

Cooperative learning involves organizing students into small groups to work collaboratively toward a common goal. Each student is responsible for their own learning, but success is also dependent on the group's collective effort. This strategy promotes peer-to-peer learning, encourages communication, and builds social and collaborative skills.

8. Class Discussion

Class discussions encourage active participation, critical thinking, and the exchange of ideas. Students are invited to share their thoughts, experiences, and opinions on the topic being studied. This method encourages students to listen to others, form reasoned responses, and develop a deeper understanding of the material through dialogue. It is particularly useful in promoting reflective thinking and synthesizing diverse viewpoints.

9. Present New Material in Small Steps

Constructivist learning often employs a "whole-to-part" approach, where complex material is broken down into manageable chunks. The teacher introduces new concepts gradually, allowing students to process and understand each part before moving on to the next. This scaffolded approach ensures that students build a solid foundation of knowledge before tackling more advanced topics.

10. Hands on Activities

Hands-on activities engage students in direct interaction with materials, tools, or their environment. These activities allow students to manipulate and experiment, providing opportunities for experiential learning. Through physical engagement, students deepen their understanding of concepts and enhance their ability to apply knowledge practically. Observation and checklists can be used to assess their progress and success.

11. Reflection

Reflection is a key component of constructivist learning, encouraging students to look back on their experiences, analyze their learning, and think critically about their process. By engaging in self-reflection, students develop metacognitive skills and gain insights into how they learn best. Reflection helps to solidify learning and encourages continuous improvement.

1.5 Constructivist Approach of Science Teaching

Constructivism in education is rooted in the foundational work of Jean Piaget, whose research in the 1970s emphasized the critical role of active, student-driven learning. Piaget's theory suggests that knowledge construction is a dynamic process where students build their understanding through personal experience and reflection, aided by the teacher's guidance. In this paradigm, learning is seen as a process of assimilation and accommodation, where students integrate new information into their existing mental structures or adjust those structures to accommodate new experiences.

At its core, the constructivist approach challenges traditional education methods by focusing on student-centered learning. Rather than being passive recipients of information, students in constructivist classrooms are active participants in their learning journey. They engage in activities such as creating concept maps, problem-solving tasks, and collaborative discussions, which guide them to discover new concepts and refine their understanding.

This approach also emphasizes the importance of reflection and community discourse. Students regularly assess their understanding of concepts, engage in self-questioning, and discuss their learning with peers, fostering deeper insights. Teachers record students' initial conceptions and track their progression, designing activities that help build new knowledge on these foundational ideas. This ongoing process of evaluation encourages students to be metacognitive, prompting them to ask themselves how they learn and what strategies help them better understand the material. Research by Iofciu, Miron, and Antohe (2010) further reinforces the value of

constructivism in education. They highlight the importance of the teacher's role in supporting learners as they construct their own mental models, arguing that direct instruction can still be a crucial element in guiding students to refine their understanding. By carefully planning activities that allow students to engage with and test their knowledge, teachers help learners build a more robust and nuanced understanding of concepts, preparing them for lifelong learning.

1.6 Role of Teacher to develop Constructivist Classroom

In a constructivist classroom, the role of the teacher undergoes a significant transformation from that of an authoritative figure to that of a facilitator of learning. This shift emphasizes inquiry, collaboration, and critical thinking, with the teacher fostering an environment where students feel empowered to question, explore, and build upon their existing knowledge.

The teacher in this context does not merely deliver content through traditional lectures but instead creates opportunities for students to interact with the material, explore different perspectives, and arrive at conclusions on their own. Through strategic questioning, presenting challenges, and encouraging independent exploration, the teacher helps students recognize and articulate their own thinking processes.

Classroom dynamics in a constructivist setting are far more collaborative and democratic. Rather than adhering to a rigid, teacher-centered structure, students are encouraged to share their ideas, engage in group discussions, and learn from one another. The teacher listens attentively to students' ideas and respects their prior knowledge, using it as a foundation upon which new concepts can be built.

The classroom becomes a space for dialogue, experimentation, and problem-solving, where mistakes are seen as valuable learning opportunities rather than failures. In this environment, the teacher's primary responsibility is to design learning experiences that challenge students' existing understanding and push them to think critically. This may involve posing thought-provoking questions, presenting real-

world problems, facilitating group projects, and providing opportunities for hands-on exploration. The constructivist approach is grounded in the belief that knowledge is not something to be simply transmitted from teacher to student, but something that is actively constructed through interaction with the world and others. In this model, both teacher and student play dynamic roles in the creation of knowledge. The teacher serves as a mentor and guide, while the student takes on the role of a knowledge constructor, actively participating in their own learning process.

Here are ten guiding principles that define constructivist thinking in education:

1. **Learning is an Active Process:** Students actively engage in constructing their understanding, rather than passively receiving information.
2. **Learning to Learn:** Students develop the skills to think critically and learn independently, which are valuable beyond the classroom.
3. **Learning Involves Language:** Language plays a central role in shaping and expressing understanding; it's not just a tool for communication, but for thinking and learning.
4. **Learning is Contextual:** Knowledge is constructed in specific contexts, and understanding is shaped by the experiences and environments in which learning occurs.
5. **Meaning Construction is Mental:** The process of learning happens in the mind, where new information is integrated with prior knowledge to create meaning.
6. **Everyone Needs Knowledge to Learn:** Prior knowledge and experiences form the foundation for new learning; everyone brings something to the table.
7. **Learning Requires Effort:** Learning is not a passive activity—it requires active engagement, effort, and persistence to integrate new ideas.
8. **Motivation Drives Learning:** Intrinsic motivation plays a crucial role in student engagement and deep learning. Learners are more likely to engage when they find the material relevant and meaningful.
9. **Knowledge is Evolving:** Learning is a continuous process of building, revising, and adapting understanding. Knowledge is not static but subject to refinement as

new information and experiences are encountered.

In a constructivist science classroom, these principles guide the teacher in creating a learning environment where students actively construct their scientific understanding, collaborate with peers, and apply critical thinking to real-world problems. This approach nurtures a deeper, more meaningful connection to knowledge, preparing students for lifelong learning.

Palmer (1997) emphasized that effective teaching involves an integration of the teacher's personal self, the subject matter, and the students within the broader context of life. He believes that great teachers teach from a place of authenticity, where their personal identity is closely intertwined with their teaching. By being whole and undivided in their approach, they not only model but also inspire a sense of interconnectedness in their students.

Constructivist theories, applied by many educators and cognitive psychologists, highlight the role of the teacher as a facilitator within the learning environment. The teacher's responsibility is to create opportunities for students to engage actively with each other and the material. This is achieved through thoughtful questioning, adjusting the environment to foster learning, and offering support during challenges. In addition, teachers collaborate in designing and adapting the curriculum to meet students' evolving needs.

1.7 EPISTEMOLOGICAL BELIEFS

Epistemology is a fundamental branch of philosophy that explores the nature, scope, and origins of knowledge. It delves into questions about what knowledge is, how it is acquired, and the limits of human understanding. In classical Greek philosophy, epistemology was central to discussions about the reliability and scope of human cognition, particularly in relation to scientific and empirical knowledge. Philosophers in this tradition sought to understand not only the sources of knowledge

such as perception, reason, and intuition but also the criteria that determine whether a belief can be considered knowledge.

Epistemological Beliefs:

Epistemological beliefs refer to the beliefs individuals hold about what knowledge is and how it can be acquired (Hofer and Pintrich, 1997). These beliefs significantly influence individuals' thoughts, behaviors, and actions. Research on epistemological beliefs emerged in the 20th century, with Perry (1970) leading the way by studying how educational experiences shape individuals' understanding of knowledge. This research resulted in the epistemological development theory (Hofer and Pintrich, 1997). Perry's work also explored how students interpret educational experiences in relation to knowledge acquisition.

Importance in Education:

Epistemological beliefs play a key role in shaping educational strategies for both learners and teachers (Green and Hood, 2013). Educational programs have a significant impact on students' epistemological beliefs, influencing how they perceive knowledge and learning (Walter, 009). Research areas in epistemology include: The nature of knowledge (e.g., source, certainty, organization). How knowledge is acquired (e.g., control, speed of learning). The research suggests that students' epistemological beliefs strongly influence their learning strategies and attitudes toward learning.

Growing Research Focus:

The field of epistemological beliefs is expanding, with ongoing research aimed at understanding individuals' beliefs about the source, certainty, organization, and control of knowledge, as well as the speed at which they believe they can learn. In conclusion, epistemological beliefs are crucial in shaping the ways individuals approach learning and knowledge acquisition. Understanding these beliefs can help improve educational strategies and contribute to more effective learning environments.

Dimensions of Epistemological Beliefs

Schommer (1990) has proposed four dimensions to study epistemological beliefs, i.e., simplicity of knowledge, certainty of knowledge, quick learning, and innate ability. In her study, she characterized these four dimensions from a naive perspective.

(a) Knowledge is simple and not complex (simplicity of knowledge)

(b) Knowledge is certain and not tentative (certainty of knowledge).

(c) Knowledge is innate and not acquired from outside (innate ability).

(d) Learning happens quickly, or it never happens (quick learning).

1.9 Epistemological Beliefs in the Field of Science

Promoting student engagement and achievement in Science, Technology, Engineering, and Mathematics (STEM) has become a key focus in modern educational research and practice (OECD, 2016). It is not enough for students to simply acquire knowledge in STEM disciplines; they must also understand how scientific knowledge is generated and developed. This deeper comprehension of the principles underlying scientific inquiry enables students to participate meaningfully in everyday socio-scientific discussions. Mason and Bromme (2010) describe this understanding as epistemological beliefs, which encompass students' perceptions of the nature of knowledge and the process of knowing. These beliefs play a critical role in students' ability to grasp complex scientific concepts and are essential for effective learning in STEM fields (Elby et al., 2016; Greene et al., 2018).

1.10 CONCEPT AND MEANING OF SELF- EFFICACY

Mahatma Gandhi once stated, *"If I have the belief that I can do it, I shall surely acquire the capacity to do it, even if I may not have it in the beginning."* This reflects the concept of self-efficacy**,** which refers to the belief in one's ability to achieve specific goals or handle challenges. Self-efficacy is a crucial psychological concept that shapes how individuals approach tasks and challenges, influencing their motivation, resilience, and persistence. The definition of self-efficacy can be traced back to Fuller, Wood, Rapaport, and Dornbussch (1982), who described it as the

individual's perceived expectation of achieving desired outcomes through personal effort. Albert Bandura (1986), a key figure in developing the theory, further defined self-efficacy as one's belief in their capacity to organize and execute the necessary actions to manage or influence future situations.

In essence, self-efficacy emphasizes that personal belief in one's abilities plays a pivotal role in overcoming obstacles, achieving success, and navigating life's challenges. It shapes how people approach tasks, their level of determination, and how they handle setbacks, all of which significantly impact their overall performance and outcomes. It was explained that people who possessed self-efficacy utilize these symbolic capabilities to perceive the physical and emotional environment around an them by firm actions, solve problems they may face, think reflectively and communicate appropriately with others around them. When people are able to symbolize their experiences, they are able to enjoy progressive living. It has been observed that such people plan their life well by setting achievable goal and challenges.

It is reported that when an individual sets certain personal standards in life, all their actions thereafter and behavior motivations are affected by the positive and negative outcomes of those personal benchmarks. All individuals tend to engage themselves in activities that provide some form of satisfaction and self worth to them, and tend to avoid actions that devalue their self (Pajares, 2002).

Behavior of an individual can be foreseen through his/her notion of self-efficacies. belief of a person in his/her own capabilities over what an individual actually achieves, as self-efficacy determines what an individual achieves from the knowledge and skills possessed. At times behavior can vary a lot from actual capabilities because of the significance of perceived self-efficacy. Sometimes individuals with huge talent may suffer from acute doubt in self, even though they have the capability to complete the task assigned to them in a very efficient manner, on the contrary some individuals demonstrate very high confidence in their ability to achieve despite of their minimal skills and capabilities.

1.11 Definitions of Self-Efficacy

Fuller, Wood, Rapaport and Dornbusch (1982) defined self-efficacy as, the individual‘s perceived expectancy of obtaining valued outcomes through personal efforts.

Stajkovic and Luthans (1998) defined self-efficacy as an individual‘s conviction about his/her abilities to mobilize cognitive, motivational and behavioral faculties needed to successfully execute a specific task within a given context.

Kolbe (2009) defined self efficacy as, "Belief in innate abilities means valuing one's particular set of conative strengths. It also involves determination and perseverance to overcome obstacles that would interfere with utilizing those innate abilities to achieve goals."

Bandura (1997) stated that people live in psychic world that they have created on their own for themselves. It is often seen that people have the ability to judge themselves, and so this judgment emerges to be a fulfillment of the image an individual creates for himself/herself. Mostly their confidence is weighed by the emotional state they experience as they consciously think about their own actions. In addition to this, when people experience negative thinking and anxiety regarding their own capabilities, those negative thoughts can further lower their awareness of their own capability and activate the stress and nervousness that further leads to deficient performance they are scared of. We can say that the fear that one experiences before a task guides our self-efficacy. An intense emotional reaction to a task, however, provides an awareness regarding the prediction of success or failure of the outcome.

Ormrod (1999) defined self-efficacy as, The extent or strength of one‘s belief in one‘s ability to complete task and reach goals.

Williams and William (2010) noted that Individuals with high levels of self-efficacy approach difficult tasks as challenges to master rather than as threats to be avoided. They do not believe in avoiding difficult situations but they take it as a challenges that they know they will be able to overcome.

According to Bandura (1977) self-efficacy of an individual can be judged by four sources:

- Performance outcomes

- Vicarious experiences or social modeling
- Verbal persuasion
- Physiological feedback.

Out of these performance outcomes or past experiences are the most important source of self- efficacy attainted through mastery experiences. An Individual‘s ability to perform a specific task is influenced by positive and negative experiences. People can develop high or low self-efficacy vicariously by observing how others perform.

Self- efficacy is also affected by how an individual has been encouraged and discouraged with respect to his/her performance or his/her capability to perform. The sensations from their bodies such as anxiety, sweaty palms, and/or a racing heart, have the least influence on the self-efficacy of a person.

Most of the individuals are guided by their beliefs though beliefs and realities rarely match perfectly. Considering all of this, self-efficacy is seen to make predictions regarding accomplishments of a person and has lesser to do with their previous achievements and knowledge. Elevated levels of self-efficacy can neutralize the impact of minimal skills and knowledge. Self-efficacy beliefs affect human beings in diverse ways:

1.12 Effects of Self Efficacy

Life is full of challenges, obstacles, adversities, setbacks and frustrations. Bandura and others have found that an individual’s self efficacy plays a major role in approaching towards goals, tasks and challenges. Generally, people prefer environment in which they feel competent and comfortable and avoid those in which they feel incompetent. Individuals own self evaluations not only influence the goal for which they strives, but also effect the amount of effort they put towards the attainment of a goal. In fact, self efficacy is not concerned with the skill one possesses but the judgment of what one can do with whatever skill one possesses. Students need more than ability and skills in order to perform successfully (Bandura, 1993). Self efficacy is belief in one’s abilities to accomplish a task and not a measure of those abilities. It implies that people’s beliefs in their self efficacy effect

- Choices they make

- Quality of functioning
- Persistence level
- Resilience to adversity
- Level of motivation
- Thought pattern and emotional reactions
- Susceptibility to stress and depression.

Levels of Self Efficacy

According to Bandura (1993) people generally have two levels of self efficacy i.e. high level of self efficacy and low level of self efficacy. People who have high level of self efficacy beliefs may approach difficult tasks as challenges to be mastered rather than seeing on the limitations. This approach may foster deeper interest in the activities in which they participate. They set challenging goals and maintain strong commitment to accomplish them. They quickly recover from setback and disappointments. This ability of resilience greatly impacted self efficacy.

Strong sense of self efficacy enhances human accomplishment and personal wellbeing. People with low level of efficacy in a given domain may withdraw from difficult tasks and believe that these tasks are beyond their capabilities. They have lower aspirations and quickly lose confidence in their personal abilities. They show a weaker commitment to their goals they choose to pursue. They do not concentrate on how to perform well. Instead they spend much of their energy on focusing on personal failings and negative outcomes.

1.13 Causes of Low Self efficacy

Self efficacy is situation specific (Wang & Richards, 1988) and tasks specific. An individual may have high self efficacy at solving math problem but low self efficacy at giving public speeches (Pajares, 1996). There are certain causes which induce low level of self efficacy among children. These are:

Lack of successful experience:

- Learner who generally lags behind in completion of doing a task failed to experience success. It leads to induce low self efficacy. Lack of external

motivation: Generally, we see ourselves from the eyes of others.

- Lack of motivation or reinforcement from others becomes the cause of low self efficacy.

- Learners‟ attribution style: Self efficacy depends on how learner perceives the cause of success. If the learner's attribution styles internal, he perceives that the cause of success is his abilities and efforts. To the contrary, if learner's attribution style is external, he perceives that cause of success is external i.e. luck, chance factor etc. Schunk and Gunn (1985, 1986) also supported that attributions of success to stable factors such as high ability have the greatest impact on increase in subsequent self efficacy.
- Criticism by parents and teacher: Ericson in his theory of psycho-social development explains that child begins to doubt on his abilities when their parents, peers and teachers criticize them. This becomes the cause of low self efficacy.
- Highly competitive environment: High competition and comparison with others creates stress and strain among children and becomes the cause of low self efficacy.

1.14 Sources of Self Efficacy

There are many sources which influence self efficacy. Bandura (1997) identifies four sources which influence self efficacy.
These are:

- Mastery Experiences
- Vicarious experience
- Social persuasion
- Psychological reactions

Mastery Experiences:

The most effective way of developing a strong sense of efficacy is through mastery experiences. Bandura explained performing a task successfully strengthens sense of self efficacy. However, failing to adequately handle a task or challenge can undermine and weaken self efficacy. It means mastery experiences are the most important factor determining a person's self efficacy. Success raises self efficacy, while failure undermine self efficacy.

Vicarious experiences:

According to Bandura, "seeing people similar to oneself succeed by sustained effort raises observer's belief that they too possess the capabilities to master comparable activities to succeed." People think that if they can do it, I can do it as well. When they see something succeeding, their own self efficacy increases; where they see people failing, their self efficacy decreases.

Social persuasion:

Bandura asserted that people could be persuaded to believe that they have the skills and capabilities to succeed. Social persuasion generally manifests as direct encouragement or discouragement from another person. Getting verbal encouragement from others helps people overcome self doubt and instead focus on giving their best effort to the task at hand.

Psychological reactions:

Our own responses and emotional reactions to the situations also play an important role in building self efficacy. How a person feels about their personal abilities in a particular situation depends on his mood, emotional state, physical reaction, and stress level. Bandura (1997) found that physical and social environmental transitions sometimes lead to reduction in the self confidence of adolescents, needed for many challenging tasks. Self-efficacy is positively related to self confidence. The more confident a person is in his abilities, the more likely he is to succeed. It is the duty of teachers and parents to create an environment which is conducive to enhance their confidence level.

1.15 Role of Teacher in developing Self Efficacy

Educators must be aware of the sources of self efficacy. Self efficacy generally corresponds to the level of competences an individual feel and these competences can vary from one situation to another. Self efficacy is multidimensional construct that varies according to domain of demands (Zimmerman, 2000).Bandura (1994) observed that learning environment and teaching methods can improve self efficacy in the classroom. Studies also revealed that educational programs have the possibilities to enhance students‟ self efficacy (Dinthera, Dochy and Segerse, 2010). Similar findings were reported by Fencl and Scheel (2005). Self efficacy is now considered the principal mechanism of behavior change. In the classroom, students with higher self efficacy see complexity as a challenge (Pajares, 2000), see failure as indication that more effort is needed (Bandura, 1986; Collins, 1984; Pajares, 2000) students with lower self efficacy more likely to equate failure to bad luck and poor ability (Pajares, 1995, 2000).

Studies have shown that perceived self efficacy is a significant determinant of performance (Moritz et al., 2000; Haddad and Taled, 2016) that operates partially independent of underlying skills. Self efficacy performs a mediating role which affects outcomes. Multon Brown & Lent, 1991) through a research on 38 studies within the years 1997 to 1988 found the positive relationship between the self efficacy and academic achievement.

Tipton and Worthington (1984) opined that the performance of an individual is affected by both specific self-efficacy and general self-efficacy. General self efficacy refers to our overall belief in our ability to succeed. In psychology intelligence has been acknowledged as most powerful predictor of achievement. But when researchers explored the joint contribution of self-efficacy and intelligence, they found that student's self-efficacy beliefs made a powerful and independent contribution to the prediction of their academic performance.

Self-efficacy develops from experiences of success. Therefore, teachers must set up expectations according to level of the students in that specific task or situation and push them to meet those expectations. After successful completion of tasks by students, teacher can gradually increase the level of expectations held.

Teachers must use constructivists teaching learning methodologies in the classroom which provide them mastery experiences and vicarious experiences and generate confidence in them. Teachers must ensure that the belief of self-worth and confidence must develop within the students and it should be based on their knowledge and success. It should not be based on rewards and positive reinforcement because many extrinsic rewards sometimes undermine their level of self-efficacy.

Self-efficacy beliefs are also affected by attributions that students make for their success and failure. By learning how to minimize stress and elevate mood when facing difficult or challenging tasks, students can improve their sense of self-efficacy.

Benefits of High Self Efficacy

People must, have a higher sense of self-efficacy to sustain the perseverant effort needed to succeed. Students with high self-efficacy beliefs are more effective problem solvers and persist more in difficult situations. Their time management is better and are always more enthusiastic about their work. They set more challenging goals for themselves. They are more open to feedback and put more efforts to improve their performance. High level of self-efficacy assists them to deal effectively with failure and frustration. Such students can cope with academic stress and anxiety in a better way. Students with high level of self-efficacy have the ability to use and apply knowledge and skills in life. Higher self-efficacy leads to higher academic and social self- esteem in students.

1.16 ACADEMIC FLOW

The concept of “flow experience,” characterized by a state of immersive enjoyment and profound engagement, pertains to individuals’ deep involvement in intriguing and pleasant tasks. In the field of study, individuals are in a state of flow when encountering challenging tasks, which matters considerably in completing the tasks. Therefore, learning flow is considered a hotspot in education that may be related to improving academic performance. Nonetheless, there remains contention regarding the extent of learning flow’s impact on academic performance. To this end,

meta-learning was hereby used to provide evidenced on the relationship between them.

"Flow" reflects a state of profound concentration or complete absorption in an activity (Kaya and Ercag, 2023). This concept encompasses nine critical dimensions: challenge-skill balance, immediate and lucid feedback, unequivocal goals, deep concentration, harmonious action, heightened self-awareness, a robust sense of control, altered perception of time, and engagement in the task at hand.

The initial trio serves as the foundational prerequisites for flow, while the subsequent sextet characterizes its intrinsic state. Notably, this phenomenon permeates academic endeavors (Oertig et al., 2014), rendering "learning flow" a descriptor for students' optimal engagement, wherein they relish the learning process, devoid of ennui or angst (Huang and Wang, 2022).

Consequently, learning flow is pivotal in educational engagement, cognitive evolution, self efficacy, and academic performance (Kim and Lee, 2021). For students, academic performance reflects personal past performance results, and also provides key information concerning students' mastery of academic activities and technical skills, mattering considerably in their participating in academic related tasks and achieving success in educational activities (Brown et al., 2016). For children, academic performance is usually assessed by transcripts or standardized national tests (Smith et al., 2023).

According to flow is an optimal condition that includes passion, concentration, and intense interest in doing a task or activity that leads to pleasant feelings without thinking about others, so that the individual can "sink" without thinking about the situation (Csikzentmihalyi, 1990). Environment and individuals who can experience flow will have better performance than individuals who do not share the flow condition.

According to flow is a positive area in psychology that leads to total concentration and comfort in individuals (Bakker, 2005). There is an inner motivation for an individual's activity, where the movement has such a broad scope. Furthermore, according to the academic flow has three aspects: absorption, enjoyment, and intrinsic motivation (Bakker, 2005).

The habit of students when they are bored and recognizes in the classroom will undoubtedly find activities that occur such as with friends, while in progress, or doing other activities outside of academic activities (Alfarabi et al., 2017). And this problem also often occurs in schools that implement a full-day school system and are based on boarding school. Academic flow becomes interesting because every student taking education will undoubtedly have differences in achieving flow conditions when carrying out academic activities. Of course, some students are easy to attain academic flow. Still, on the contrary, some students have difficulty achieving this flow condition due to various factors, namely intrinsic and extrinsic factors (Asakawa, 2004).

Students quickly achieve flow conditions in the academic environment when students desire to involve themselves in academic activities because they learn and develop. Still, they will then enjoy each of these academic activities (Mesurado et al.,2016). It means here that the desire to involve himself in academic activities certainly comes from within, where it is included in the intrinsic factor to achieve and feel the condition of academic flow Novitasari, Hidayati and Setyowati (2020) found that intrinsic factors influence students to achieve flow conditions when doing activities related to academics, compared to extrinsic factors or factors from the environment.

According to Jackson and Marsh (1996), the subjective flow experience is generally characterized by the following features:

- Clear goals
- A high degree of concentration
- Loss of self-consciousness
- Lack of temporal awareness (time seeks to pass faster)
- Intrinsically rewarding experience
- Pleasure and enjoyment
- Autotelic experience
- Academic achievement,

On the other, has remained as the most accepted criterion for measuring to what extent educational goals have been accomplished. However, there is no consensus on how it is best measured but generally cumulative percentage of marks or cumulative grade point average obtained are considered as one's academic achievement at the secondary school level.

As such, a student experiencing flow in academic situations is more likely to perform better than a student not experiencing flow. The reason is clear: a person experiencing flow has clear goals, is intrinsically motivated, finds pleasure in doing the task and experiences a balance between challenge and his skills. Unfortunately, in real school situations, some students find school activities too easy, while for others it might be too difficult. The optimal skill ratio is not achieved for most students. (Shernoff, 2013).

1.17 Relationship between Learning flow and Academic achievement

It is important to examine the relationship between learning flow and academic achievement. The impact of flow experience on school performance was analyzed. A total of 697 eighth grade students with an average age of 13.4years completed a questionnaire that included the measurement of self-control, school performance and learning flow at the beginning and end of the school year.

The study revealed a correlation coefficient of 0.14, demonstrating that learning flow was significantly correlated with academic performance (Kuhnle et al., 2012). To find the moderating effect of learning flow and academic achievement in online learning, a study on 272 nursing students from six universities in two different cities was conducted using self-reported questionnaires to measure learning flow, learning process, digital literacy and academic achievements. The study found that the mediating effect of learning flow on academic performance was 0.42, with a stronger learning flow indicating a stronger academic performance, which was confirmed to further improve academic performance (Ryu et al., 2022).

However, randomized experimental research was designed to explore how to improve students' enthusiasm, flow and academic success through the generated competitions and challenges. A total of 30 college students in the control group and 30 in the experimental group used the educational application for one semester. The study

found no significant difference in the level of flow experience between the control groups (Yeh et al., 2019). To reveal the mindfulness learning experience, learning flow, self-efficacy and mastery experience, another study recruited 83 students from the fifth and sixth grade participating in a six-week game-based creativity learning program.

The researchers found the path model analysis did not support the direct impact of flow experience on mastery experience mindfulness learning and self- efficacy (Adil et al., 2020). To conclude, the influence of learning flow on students' academic achievements is not uniform, indicating an ongoing disparity in viewpoints concerning its potential effects. Therefore, Meta-analysis was hereby used to clarify the relationship between them. This study contributes considerably to students' learning and education, and possesses better clinical significance for improving students' academic performance. Meanwhile, this paper also facilitates to promote flow learning strategy. The purpose of this study is to explore the relationship between learning flow and academic performance. Therefore, the central question of this study is whether there's a relationship between students' learning flow and their academic performance.

1.18 ACADEMIC ACHIEVEMENT

Academic achievement is a broad term that generally indicates pupils' learning outcomes. Achievement of these learning outcomes requires a series of planned and organized experiences; hence, learning is called a process. In this process of achievement of behavior change, one cannot say that all students reach the same level of change during the same period.

Meaning and definitions of Academic Achievement

Academic achievement is the sum of one's academic accomplishments across all subjects. This is computed by averaging the students' final examination results across all topics. **(**1959, Good) "Learned knowledge or competencies established in academic subjects as determined by test results, instructor marks, or both" is how "academic achievement" is defined. Plato coined the phrase "Academic Achievement," which implies "the degree at which a student functions in his or her school work through a regular curriculum in a set location that he dubbed the

academy."

Crow and Crow (1969) defined achievement as the extent to which a learner benefits from teaching in a particular area of learning; in other words, the achievement is measured by the amount of skill and information supplied to him.

Gratis (1988) defined Academic Achievement as the degree or level of proficiency attained in academic work. This is a skill that children have displayed in the subjects they have studied in school. In educational contexts where learning and teaching are anticipated to continue, it directly impacts students' growth and development. Academic achievement is a student's numerical score indicating his or her level of adaptation to coursework and the educational system.

Importance of Academic Achievement

Academic achievement is the outcome of education and the extent to which a student, teacher, or institution has achieved its educational goals. Examinations or continuous assessments commonly measure academic achievement. However, there is no general agreement on how it is best tested or which aspects are most crucial procedural knowledge, such as skills, or declarative knowledge, such as facts. Academic achievement is the accomplishment or proficiency of performance in a given skill or body of knowledge.

Robinson and Horrock (1975) defined achievement as "status level or individual learning and his ability to apply what he has learned." According to this definition, the achievement is initially assumed to include any knowledge or skill. However, a much broader approach includes attitude, interests, and values as aspects of achievement. Achievement is defined as learning attitudes and interests as they are learned, retained, and forgotten, just as knowledge or skill.

According to Crow and Crow (1956), achievement means the extent to which a learner benefits from interaction in a given learning area. In other words, achievement means the extent to which teaching and studying have resulted in mastery. It is the outcome of general and specific learning experiences. Their achievement scores usually judge the student's performance in a class in the examinations, which is often considered their academic achievement.

Academic achievement has been treated as the primary basis for admission and

promotion of a student to their next class. It has also been considered a criterion in selecting individuals for various vocational and professional courses. On the other hand, intelligence is the ability and capacity to learn and carry out abstract thinking to respond appropriately to a new situation.

Intelligence was as closely related to intellect, which includes observing, thinking, understanding, remembering, and all ways of knowing. Achievement refers to the scholastic or academic achievement of the student at the end of an educational program. A good number of variables, such as personality characteristics of the learners, the SES, the school's organizational climate, curriculum planning, etc., influence achievement to different degrees.

These variables are generally referred to as correlates of achievement. The factors which influence on academic achievement of students are many. Students" IQ, health, peer group, experience, attitude towards the school subjects and teachers, emotional care, parents" love and affection, family environment, SES, etc., are some of the factors which affect the academic achievement of students. The Academic Achievement of the student is of significant concern both to the parents as well as to the teachers. Some students demonstrate a discrepancy between expected and actual achievement.

1.19 Factors Affecting Academic Achievement

IQ tests have shown that personality and intelligence differences among pupils with more excellent mental abilities are associated with individual disparities in academic achievement. Higher conscientiousness is linked to effort and accomplishment motivation and is associated with higher academic achievement.

A recent meta-analysis highlights the role of mental curiosity—measured by regular intellectual engagement in fostering academic success, in addition to factors like IQ and conscientiousness. When children enter first grade, their home learning environment often shifts from being semi-organized to more structured, and this transition can have a significant impact on their academic trajectory. Early academic achievements are linked to sustained success in later schooling.

The concept of "parents' academic socialization" refers to the ways in which parents influence their children's academic outcomes by shaping their abilities, behaviors, and attitudes toward school. Parents affect their children's academic development not only through the environment they create at home but also through the conversations and interactions they engage in. The socioeconomic status of parents can also play a role in this dynamic, with higher-education families tending to offer more stimulating and enriched learning environments.

In addition, the quality of the parent-child relationship is a crucial factor. Recent studies indicate that a strong, supportive relationship between parents and children can positively influence the development of academic self-efficacy in adolescence, which, in turn, impacts academic performance.

Early childhood development is vital for building the linguistic and social skills necessary for school readiness. These early abilities help children adapt to academic expectations. Moreover, there is growing evidence suggesting that physical activity contributes to academic success. Exercise has been shown to enhance neuronal activity in the brain, particularly in processes related to working memory and attention, both of which are critical for academic achievement.

Cognitive Aspects

How well a person can learn or think depends on their cognitive talents "'s particular capabilities can affect how well someone learns or succeed academically. Cognitive processes, including attention, memory, and reasoning, are among these variables. Exams are frequently used to measure cognitive abilities; college admissions committees assess applicants using standardized tests like the SAT and ACT. High-achieving undergraduate students exhibit mature learning principles and solid knowledge integration.

Non-Cognitive

The "attitudes, actions, and techniques" that enhance academic and professional success are non-cognitive factors or abilities. Examples include academic self-efficacy, self-control, motivation, anticipation and goal-setting theories, emotional

intelligence, and determination.

Sociologists Bowles and Glints first used the phrase in the 1970s to draw attention to elements other than those evaluated by cognitive test results. The phrase distinguishes cognitive abilities that teachers assess through tests and quizzes. Because they offer a more comprehensive explanation for academic and professional outcomes, non-cognitive skills are becoming increasingly popular.

Motivation

Motivation is a powerful force that drives individuals to engage in certain behaviors, particularly in academic settings. Research indicates that students who exhibit a strong sense of intrinsic motivation the desire to perform well for personal satisfaction rather than external rewards tend to excel academically. These students set meaningful, self-driven goals and are more persistent in their efforts, which help them overcome challenges and achieve success. In contrast, students who focus primarily on extrinsic rewards, like grades or approval, may struggle with motivation, especially when external incentives are removed. In addition, poor lifestyle choices, such as unhealthy eating habits, can negatively impact a student's motivation, leading to decreased energy, focus, and academic performance.

Self-Control

Self-control is a crucial factor in academic success. Defined by Baumeister, Vohs, and Tice as "the ability to adjust one's responses to align with ideals, values, morals, and societal expectations," self-control involves the capacity to delay immediate gratification in favor of achieving long-term goals. In the context of education, students with strong self-control can resist distractions, stay focused on their studies, and maintain discipline even when faced with temptations. They are more likely to set and adhere to long-term academic goals, such as preparing for exams or completing assignments on time, which significantly boosts their chances of success. Students lacking self-control, on the other hand, may struggle with procrastination, impulsivity, and difficulty managing academic responsibilities.

Extracurricular Activities

Participation in extracurricular activities has been consistently linked to positive academic outcomes. Students involved in organized after-school activities such as sports, music, clubs, or volunteer work tend to show better school attendance, higher levels of engagement, and stronger academic performance. These activities not only help improve GPA but also increase the likelihood of pursuing higher education and reduce the risk of school dropout or mental health issues such as depression. For example, involvement in high school sports often correlates with higher academic achievement, particularly among students from urban backgrounds.

However, the relationship between extracurricular participation and academic performance is not always straightforward. Several external factors can influence how much impact these activities have on a student's education. These factors include the student's level of civic engagement, social connections, personal identity development, and overall mental health. Youth who participate in extracurricular activities often develop valuable social skills, receive emotional support, and build confidence, all of which contribute to academic success. Nonetheless, there are also potential drawbacks to such involvement. For instance, excessive time spent on extracurricular activities can lead to stress, burnout, or distractions from academic work. Additionally, certain activities like sports may inadvertently promote unhealthy behaviors, such as alcohol consumption or truancy.

1.20 Achievement in Science

Educational attainment, according to Niemi (1999), is the mastery of important ideas, principles, crucial information, abilities, strategic knowledge, and knowledge integration. In particular, Ruiz-Primo (1998) frequently divides success into different knowledge components. Declarative knowledge, for example, includes domain-specific information and is an essential part of a student's overall learning and understanding.

Achievement is viewed basically as the competence a person has in an area of content. In India, there have been numerous criteria of assessment of achievement in science. Credit points, grading and marking systems are some of them. Now in

C.B.S.E. schools, marks are allotted for performance and they are considered to be true indicators of a student's achievement in a particular subject. Grades are also allotted according to pre-decided criteria.

Achievement in science is considered one of the important criteria for judging a student. Normally, when someone asks about achievement, they ask the marks secured in science and mathematics. This is because they are better indicators of intelligence and efficiency. On the basis of the achievement of a student in science and mathematics, subjects are allotted to him for further study.

Choosing science stream demands a high degree of achievement in science. Hence, evaluation of academic achievement level is necessary so that academic avenues can be planned. Science achievement is the degree to which a student has learnt and mastered all the science skills. This is usually estimated by performance on a prepared and pre-scheduled test. Science achievement is a function of many intellectual and non-intellectual variables.

1.21 Factors affecting Achievement in Science

There are several aspects that might influence pupils' scientific success. Among the most prevalent factors are:

Prior knowledge and abilities: Students with a solid foundation in science and associated skills are more likely to succeed in scientific classrooms and on science tests. Henderson and Mapp (2002)

Instructional quality: The quality of students' scientific success may be significantly influenced by the quality of their teaching and learning experiences. It has been shown that effective teaching practices such as inquiry-based learning and hands-on activities boost scientific learning results. Hofstein and Lunetta (2004) and the National Research Council (2005)

Curriculum and resources: The availability and quality of scientific curriculum and resources may have an influence on students' science success. Access to current texts, laboratory equipment, and technology may help students learn more about science. Sneider, Bar and Kavanagh (2011).

Home environment: The home environment of students, particularly parental engagement and support for scientific study, might have an influence on their science

accomplishment. McNeal Jr (1999)

Gender and ethnicity: Studies have demonstrated that gender and ethnicity may have an impact on scientific success, with female and minority students often underrepresented in STEM disciplines and facing achievement disparities in science. science 2018 National Science Board

Socioeconomic status: Students from low-income families may encounter extra challenges to scientific accomplishment, such as a lack of resources and educational opportunities. National Research Council (National Research Council, 2005)

Motivation and interest: Students' motivation and enthusiasm in science might also have an influence on their success. Students who are engaged and enthusiastic in science are more likely to excel academically and seek jobs in science. Anderman and Midgley (1998) Understanding these variables may assist educators and policymakers in developing methods to increase scientific performance and promote fairness in science education.

1.22 NEED AND SIGNIFICANCE OF THE STUDY

Our nation is one among the developing countries, which has created an enormous contribution to the field of science and technology. Even though we are unable to reach a scientific thinking in our children and adults. In most of schools teachers are active disseminators of information where as children are passive recipients of knowledge.

Students are treated as a blank slate and teachers take initiation to write on a blank slate without considering the child’s prior experiences i.e., based on curriculum they start to impose on children. Due to this, there is no scope to construct the new knowledge, children learn through rote memory and conceptual learning is not on priority. In most of the cases, thinking is not stimulated among the learners.

No way are students involved in the process of learning and independent thinking and there is mere chance for the development of skills among them. As a result of conventional mode of teaching active engagement, inquiry, exploration, questioning, experimentation, data collection, drawing conclusion, generalization, transfer of learning and reflective practices are lagging behind in the system. In order to overcome the problems in education system there is need of learner centered and

learner driven method.

The study investigated the impact of Factor Structure Equivalence, specifically focusing on a model comprising Constructivist Learning Environment, Self-Efficacy, Epistemological Beliefs, and Academic Flow, on enhancing science curiosity and academic achievement in science. This research was timely and innovative, especially in the context of global efforts to improve science education at the secondary school level. The Factor Structure Equivalence-based instructional strategy supported the idea that learners actively construct knowledge based on their experiences, with teachers acting as facilitators and providing an environment conducive to exploration and knowledge expansion. This approach allowed students to construct knowledge through social interaction, fostering both academic achievement and the development of process skills.

The National Curriculum Framework (NCF) 2005 emphasizes the urgent need for educational reform, particularly in the ways teaching and learning processes are structured. It recognizes that student learning is influenced not only by the learners themselves but also by the broader learning environment. This environment is shaped by factors such as the Constructivist Learning Environment, Science Self-Efficacy, Epistemological Beliefs, and Academic Flow.

A growing body of research underscores the significant role that epistemological beliefs play in students' learning experiences. These beliefs, which pertain to students' understanding of the nature of knowledge and the process of learning, influence how they approach tasks, solve problems, and engage with content. Epistemological beliefs impact key aspects of learning, including academic performance, cognitive strategies, comprehension, and motivation.

Scholars such as Ryan (1984) and Schommer (1990, 1994) have demonstrated that students with more advanced or sophisticated epistemological beliefs—those who view knowledge as complex, evolving, and constructed—tend to employ higher-order cognitive strategies. These students are more likely to engage deeply with material,

employ critical thinking, and perform better academically. In contrast, students with more naive or simplistic views of knowledge, who see it as fixed and unchangeable, may rely on surface-level learning strategies, which can hinder their overall academic development.

The interplay between epistemological beliefs and other factors, such as the learning environment and students' sense of self-efficacy, highlights the importance of fostering a supportive and challenging learning environment. Encouraging the development of sophisticated epistemological beliefs can lead to improved learning outcomes and greater academic motivation, ultimately contributing to the overall success of students in the evolving educational landscape outlined by the NCF 2005.

For example, Ryan (1984) observed that dualist students, who hold simpler views about knowledge, typically use low-level strategies like recalling facts, while relativist students, who embrace more complex views of knowledge, engage in higher-order thinking, leading to better academic outcomes. Similarly, Paulsen and Feldman (1999) found a positive correlation between sophisticated epistemological beliefs and academic motivation.

Research also emphasizes those epistemological beliefs, particularly within specific domains like science, impact study strategies and problem-solving. Studies by Buehl and Alexander (2001) and Schommer-Aikins et al. (2005) indicate that epistemological beliefs in domains such as science influence students' approaches to learning. Students with more sophisticated beliefs are more likely to adopt effective learning strategies and, in turn, perform better academically. Additionally, research has shown that epistemological beliefs vary across academic fields. For instance, students in pure fields tend to have more advanced epistemological beliefs compared to those in applied fields, suggesting that students' beliefs about knowledge and learning are domain-dependent.

The role of epistemological beliefs is especially critical during adolescence, as they affect motivation and academic performance. Studies indicate that students' beliefs

about the nature of knowledge and learning influence their academic success (Bruning et al., 1995; Berding et al., 2017). As students' epistemological beliefs evolve, their approaches to learning and academic performance improve, leading to greater success in school.

Furthermore, the relationship between goal orientation and academic achievement is well-documented. Dweck and Leggett's (1988) distinction between mastery and performance goal orientations underscores how students' goals influence their learning outcomes. Mastery goal orientation, focused on improving competence and understanding, is associated with better academic performance, flexibility in overcoming challenges, and long-term success. In contrast, performance goal orientation, which focuses on outperforming others, often leads to a more surface-level engagement with learning. However, a balanced approach, incorporating both mastery and performance goals, can enhance academic achievement.

Recent research further supports the idea that both mastery and performance goal orientations contribute positively to academic success. Studies have shown that students who prioritize mastery goals are more likely to engage in deep learning strategies, while those with performance goals may pursue tasks that guarantee success but lack the flexibility to tackle challenges. This distinction has significant implications for teaching practices, as understanding students' goal orientations can help educators provide appropriate guidance to maximize academic outcomes.

Self-regulated learning (SRL) plays a crucial role in students' academic achievement. SRL refers to the strategies and cognitive processes students use to monitor and control their learning. Zimmerman (1989, 1990) posits that self- regulation is acquired through interaction between self-observation, self-judgment, and self-reactions, and students who effectively employ SRL strategies are more likely to achieve higher academic success. SRL is particularly relevant in the context of science education, as it encourages students to take an active role in their learning, fostering curiosity and deep understanding.

In conclusion, the factors influencing students' academic achievement in science—namely, Constructivist Learning Environments, Self-Efficacy, Epistemological Beliefs, and Academic Flow are interrelated and play a pivotal role in shaping students' learning experiences and outcomes. These elements work together to foster a deeper understanding of scientific concepts, encourage critical thinking, and enhance overall academic performance. The findings of this study highlight the importance of incorporating these factors into instructional strategies, offering valuable insights for educators seeking to promote student engagement and success in science. As educational practices continue to evolve, it is crucial to consider these dimensions when designing innovative teaching approaches that support meaningful learning and foster a lifelong interest in science.

Hence, the investigator felt that it would be highly significant and useful to study the influence of Factor Structure Equivalence i.e., Constructivist Learning Environment, Self-Efficacy, Epistemological Beliefs, Academic Flow on Achievement in science of secondary school students. The following research questions were formulated by the investigator to analyze the role of Factor Structure Equivalence on Achievement in science of secondary school students.

- How do epistemological beliefs impact the science academic achievement of secondary school students?
- To what extent does a constructivist learning environment affect the science academic achievement of secondary school students?
- What role does self-efficacy play in the science academic achievement of secondary school students?
- How does academic flow influence the science academic achievement of secondary school students?

1.22 Statement of the Problem

To address the research questions outlined above, the following problem was articulated:

This study aimed to investigate the effectiveness of constructivist teaching methods in enhancing students' learning outcomes and engagement. Specifically, it sought to explore how students, as active participants in the learning process, construct knowledge through interaction, exploration, and problem-solving within a student-centered, teacher-facilitated environment. The research examined the role of the teacher as a co-participant and facilitator, and how their questioning and guidance influence the construction of meaning and the expansion of knowledge in students. This inquiry contributed to understanding the impact of constructivist pedagogy on student learning experiences and outcomes, comparing it with more traditional, teacher-directed approaches.

"Validation of the Factor Structure Equivalence of the Science Academic Achievement Model across Gender and Batch groups in Secondary School Students".

A constructivist learning environment ignites learning by placing students at the heart of the educational process. Rather than beginning with the teacher's explanations, students are first encouraged to think, explore, predict, experiment, and discover. This shift from receiving knowledge to constructing knowledge transforms the classroom into a space of inquiry and innovation. Every attempt to solve a problem, test an idea, or connect concepts strengthens students' confidence in their own abilities, gradually nurturing a strong sense of science self-efficacy. They begin to believe not only that they can learn science but also that they are capable of thinking and working like young scientists.

As students repeatedly engage in this process of exploration and reflection, they develop sophisticated epistemological beliefs, viewing scientific knowledge as evolving, evidence-based, and open to investigation rather than as fixed information

to be memorized. The powerful synergy between growing self-efficacy and mature epistemological beliefs creates a profound transformation in their learning experience. Science is no longer perceived as a difficult subject but as an exciting journey of discovery. This intellectual and emotional connection draws students into a state of deep engagement, curiosity, persistence, and enjoyment, enabling them to experience academic flow, where learning becomes meaningful, immersive, and intrinsically rewarding. Based on these literature backed relationships among the study variables the objectives were framed.

1.23 Objectives of the Study

1. To study the predictive role of constructivist learning environment on Epistemological Beliefs in Science of Secondary school students.
2. To study the predictive role of constructivist learning environment on Science Self Efficacy of Secondary school students
3. To study the predictive role of Epistemological Beliefs in Science on Academic flow of Secondary school students.
4. To study the predictive role of Science Self Efficacy on Academic flow of Secondary school students.
5. To validate Science Academic Achievement model of secondary school students.
6. To test the factor structure equivalence of the Science Academic Achievement model of secondary school students across gender and batch.
7. To estimate the attenuation index in the reliability coefficient of the science academic achievement model.

1.24 Hypotheses of the Study

1. **Ho_1** : There is no significant predictive role of constructivist learning environment on epistemological beliefs in science of secondary school students
2. **Ho_2** : There is no significant predictive role of constructivist learning environment on Science self-efficacy in secondary school students

3 **Ho_3** : There is no significant predictive role of epistemological beliefs in science on academic flow in secondary school students

4 **Ho_4** : There is no significant predictive role of science self-efficacy on academic flow in secondary school students

5 **Ho_5:** The factor structure of science academic achievement model in secondary school students is measurement invariant with respect to gender and batch groups.

1.26 Operational Definitions:

Constructivist learning environment: It is defined as students' perception on the degree to which the principles of constructivism are implemented in the classroom by the science teacher in the school, measured using CONSTRUCTIVIST LEARNING ENVIRONMENT SURVEY SCALE developed by Rebekah and Nik (2003) with responses recorded on a five point Likert scale of the five dimensions (personal relevance , uncertainty of science, shared control, critical voice and student negotiation) through 30 Items.

Epistemological beliefs: They are defined as individual beliefs about the nature of knowledge (beliefs about what knowledge is)and the nature of knowing (beliefs about knowledge acquisition), measured using EPISTEMELOGICAL BELIEFS IN SCIENCE SCALE developed by Conley (2004) with responses recorded on five point Likert scale of the four dimensions(source, certainty, development and justification) through 26 Items.

Self-efficacy: It is defined as an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments, exert control over one's own motivation, behavior and social environment measured using SCIENCE SELF-EFFICACY SCALE developed by Glynn (2011) with responses recorded on a five point Likert scale of a single dimension through five items.

Science academic flow: It is defined as the perceived sense of complete control over actions, immersion in the task, lack of self-concern and well-being experienced by the activity itself in a science classroom measured using Science Academic Flow Scale developed by Heutte (2019) with responses recorded on five point Likert scale of four

dimensions (cognitive control, time transaction, loss of self-control and autotelic experience) through 12 items.

1.27 Delimitations of the Study: The study was delimited as per the following aspects:

- It was delimited to the CBSE Schools Andhra Pradesh.
- It was limited to the 9th and 10th class students of CBSE schools.
- The measurement invariance study of the model was restricted to Configural invariance hierarchical level.

1.28 Conclusion

The first chapter of this study provides a theoretical foundation, setting the stage for an in-depth exploration of the various factors influencing Science Academic Achievement among secondary school students. The present chapter expands on the significance of validating the factor structure equivalence in the context of science achievement and its relationship with key psychological constructs such as Self-Efficacy, Epistemological Beliefs, and Academic Flow. The chapter explores how these factors interact and contribute to students' success in science education, considering the influence of demographic variables. A critical focus of this chapter is to investigate how constructs rooted in constructivist theories which emphasize active learning, problem-solving, and student-centered approaches impact science achievement. In summary, the chapter offers a comprehensive introduction to the study, presenting the significance of the research questions, the theoretical underpinnings of the study, and the operational definitions that guide the investigation of factors affecting science academic achievement.

CHAPTER -II

REVIEWS OF RELATED LITERATURE

CHAPTER - II

REVIEWS OF RELATED LITERATURE

2.1 INTRODUCTION

Any research effort should include a review of related literature. It is a must for any research project's actual planning and execution. As a result, it gives the investigator important information about the researchers' research. It provides comparison data on which to interpret the significance of one's findings. "A familiarity with the literature in any problem area helps the students discover what is already known, what others have attempted to find out, which methods have been promising and disappointing, and what problems remain to be solved," Best (1963) writes, emphasizing the importance of this review.

Best (1963) writes: "A familiarity with the literature in any hassle place enables the scholars to find out what's already known, what others have tried to discover out, which strategies were promising and disappointing and what troubles continue to be to be solved." Good, Brar, and Scates (1941) suggest that "the careful student of education, the research worker, and the investigator should become familiar with the location and use of the sources of educational information." A review of related literature presents the comprehensive development of the problem's background and highlights prior research that informs the current study.

We use the review to maintain direct relevance to the current study. According to Best (1977), "the investigator is a specialist rather than a generalist" (p. 111). If the researcher is to become a specialist in their area of research, they must thoroughly review all relevant literature and studies in their field. According to Aggarwal (1966), "the study of related literature implies locating, reading, and evaluating reports of research, as well as reports of casual observation and opinion that are related to the individual's planned research" (p. 87).

2.2 IMPORTANCE OF REVIEW OF LITERATURE

The reading of related literature assists in gaining information about field investigations by avoiding unnecessary repetition, guiding the investigator through the procedures, and familiarizing the investigator with the steps. The linked literature can help achieve clarity and concentrate on the issues about the nature of the occurrences by offering a more graphic or visual image of the phenomenon. The goal of this chapter is to evaluate the literature on value orientation, achievement motivation, and academic achievement in depth. It was decided to perform a review of studies on value orientation, achievement motivation, and intellectual achievement.

2.3 NEED FOR RELATED LITERATURE

Any research project's design and implementation must include a study of related literature. According to John W. Best, familiarity with the literature in any difficult situation allows scholars to discover what has already been learned, what assault strategies have proven promising or disappointing, and what difficulties remain unsolved (1963). "The time spent on any such survey is invariably a beneficial investment," argues Monly (1964), "and the survey of the literature is an important feature in the making plans of the observer." Any discipline's advancement is built on the basis of past stories from the same or adjacent subjects.

We conducted an analytical review of the constructivism research to find answers to the following questions.

- What are the main findings of the previous research?
- What was the year of study?
- What was the sample of study?
- What was the school standard of the sample?
- Which method was used to identify the underachievers?
- Which results were obtained?

2.4 CLASSIFICATION OF RELATED LITERATURE:

In this chapter a pertinent review of related literature done in Abroad and India has been classified under the following sub-headings:

- Studies related to Constructivist Learning Strategies
- Studies related to self-efficacy
- Studies related to Epistemological beliefs
- Studies related to Achievement in Science

2.5 STUDIES RELATED TO CONSTRUCTIVIST LEARNING STRATEGIES

Related studies conducted in Abroad:

Puacharearn and Fisher (2004) conducted a study on *"The Effectiveness of Constructivist Teaching on Improving Learning Environments in Thai Secondary School Science Classrooms".* Through an action research technique, the main goal of this study was to find out how teachers may enhance their classroom environments by fusing constructivist teaching methods with cooperative learning practices. The validated Constructivist Learning Environment Survey (CLES) was a useful instrument for Thai scientific researchers and teachers. It offers a useful way to evaluate and improve science classroom settings. By utilizing the CLES, further research can be conducted to foster more effective science teaching, ultimately leading to improved student achievement in the subject.

Kim (2006) conducted a study on *"The Effects of a Constructivist Teaching Approach on Student Academic Achievement, Self-concept, and Learning Strategies".* The objective of this study was to explore the impact of a constructivist teaching approach on students' academic performance, self-concept, learning strategies, and preferences. The sample consisted of 76 sixth-grade students, randomly divided into two groups: the experimental group and the control group. The control group was taught using traditional instructional methods, while the experimental group received

instruction based on the constructivist approach. The study lasted for nine weeks, with a total of 40 hours of teaching. The results revealed that students in the experimental group, who were taught using the constructivist method, significantly outperformed their counterparts in the control group in terms of academic achievement. Statistical analysis showed a significant difference between the groups, with an F-value of 89.11 and a p-value of less than .001, indicating that the constructivist approach had a substantial positive effect on academic performance. These findings suggest that constructivist teaching methods can lead to improved academic outcomes when compared to traditional instructional strategies.

Karaduman and Gultekin (2007) studied "*The Effect of Constructivist Learning Principles based Learning Materials to Students' Attitudes, Success and Retention in Science Studies"*. This study aimed to evaluate the impact of instructional materials developed using constructivist learning principles on students' attitudes toward social science subjects, their academic performance, and the retention of the learned content. The sample included 72 fifth-grade students from Sehit Ali Gaffar Okkan Elementary School in Eskisehir. The participants were divided into two groups: the experimental group (5-C) and the control group (5-B). The results showed that the constructivist-based instructional materials significantly improved students' academic performance and retention of the material in social studies. Additionally, students reported that these materials were effective in enhancing their learning outcomes and engagement, demonstrating the alignment of the resources with constructivist teaching methods.

Seyhan and Morgil (2007) conducted a study on *"the effect of 5E learning model on teaching of acid base topic in chemistry'.* It was observed that the students who made applications with the 5E learning model showed more positive attitude towards chemistry and were more successful in acid-base topic than the students trained in the traditional approach

Castano (2008) conducted a study on *"constructivist science learning environment"* in which ten year old Colombian girls had the opportunity to discuss scientific concepts and socio scientific dilemmas in groups, improved their

understanding of the concepts and the complex relations that exists between the species and the environment. It was revealed through the study that constructivist learning environment had positive results. The study implied that science learning should occur in constructivist learning environments and go beyond the construction of scientific concepts and there must be decision making related to the social and moral implications of the applications of science in a real world.

Cavide (2009) studied *"Constructivist learning Approach in Science Teaching".* In the research, the pupils of sixth class, studying in Yunus Emre Elementary School at city center of Eskisehir, in spring term of 2005- 2006 academic year were chosen. He finds out that: Constructivist learning was more affected on the increase of achievement score than conventional training. Constructivist learning was more affected on the increase of retention score than conventional training.

Aydin and Yilmaz (2010) conducted a study on *"The effectiveness of Constructivist Approach on students".* Higher Order Cognitive Skills, students' Attitude towards Science Education and on gender differences of students' understanding the acid-base concept. Sample of the study was 300 students of eighth class. Pretest posttest two group design was used. Experimental group was treated according to 5E learning and control group through Traditional method of teaching. Acid-Base Knowledge Test, Science Process Skill Test and Logical Thinking Skill Test were administered before commencement of the experiment. The Acid-Base Achievement Test and Attitude Scale towards Science Education were applied as pretest and posttest. Result of the study implied that 5E learning model of Constructivist Approach was more effective in acquiring Higher Order Cognitive Skills and enhance positive Attitude towards Science.

Oludipe and Oludipe (2010) conducted research to examine *"The effectiveness of Constructivist-based teaching Strategy on Academic Performance of integrated Science students".* The investigator of the study has drawn 120 students of four schools from 25 co-educational Junior High Schools in Ijebo-ode local government area of Ogun state, South-West Nigeria. Quasi-experimental research design was used to attain the objective of this study. Findings revealed that experimental group (constructivist instructed students) scored higher than the control group exposed to

conventional method of teaching on the posttest.

Drexler (2010) studied *"A networked learning model for construction of personal Learning environments in seventh grade life science".* The findings of the study were: The following process themes were identified through coding of case study data. Practicing digital literacy, practicing digital responsibility, organizing content, dealing with technology, collaborating and socializing, synthesizing and creating, taking responsibility and control for learning. As a result, models evolved in which various tool were applied. Based on the findings of this study and the value of guided instruction (Mayer, 2004) in an open learning environment (Clarebout & Elen, 2007), the teacher is challenged to develop a design that strikes the delicate balance between structure, guided instruction, and student directed inquiry. Again, the goal of personal learning is to empower the student to independently construct rich, effective networks in support of his or her learning objectives.

Dhoot (2010) studied *"Environmental Subject Of Class 9th Through Traditional Teaching Method & The Constructivist Teaching Method".* A Comparative Study. Objective of the study is to compare Constructivist teaching & Traditional teaching method with reference to post achievement test, to study effectiveness of constructivist method in teaching with compare to traditional teaching method and to study the opinionative of students for constructivist teaching method. For this research, researcher followed the equivalent group pre post-test design. Major findings of the study are as follows- The two methods viz. constructivist method & traditional methods differed significantly from one another in achievement test & teaching. Pupils taught by constructivism method achieved higher scores in achievement test than taught by traditional method. Pupils felt constructivism method was more beneficial than traditional method. Pupils were actively participated in the classroom. Group discussion ability of the pupils could develop by constructivist method. Students learnt more and enjoy learning more by constructivism method. Student could concentrate on learning how to think and understand. Questioning, problem solving, discussion, collaboration etc. skills could be Developed by this method. Constructivism teaching method can be used not only for environment subject but also other subjects.

Etuk et.al, (2011) investigated a study on "Achievement and Attitude towards Primary Science using Constructivist Instructional Strategy". Experimental research design with two intact groups was employed in this research work. The population of pupils was 650 in 21 public primary Senatorial District of River state, Nigeria. Total 180 pupils were taken from four intact classes from four schools in the area. The investigator of the study used Primary Science Achievement Test and Primary Science Attitude Scale to gather data. Statistical analysis used in the study was analysis of co-variance and multiple classification analysis. The researcher summarized that pupils taught With Constructivist Instructional Strategy gained high scores in Achievement Test as well as Attitude test than the pupil taught with expository strategy. Study also concluded that pupils from urban school did well than rural schools' pupils regarding Achievement and Attitude.

Sibel., et.al., (2011) conducted a study on "*Effects of the 5E learning model on students' academic achievements in movement and force issues, Procedia Social and Behavioral Sciences".* The Objective of the study was to evaluate the efficiency of student guiding materials on student achievement, using the 5E learning model. The results of the study showed that, Students could discover and learn the main concepts of the Course on their own by questioning, searching, using primary knowledge, associating with everyday life, arranging testing apparatus, and testing the experiment on their own. To sum up, this study showed that the 5E learning model is an effective teaching method.

Raval (2012) studied *"Effectiveness of Constructivist Approach to the Teaching of Animal Classification in Science and Technology of Standard Ninth".* The main objective of this study was to check the Effectiveness of Constructivist Approach to the Teaching of Animal Classification. For this study the 'Achievement' was selected as the dependent variable, and the 'CIP' was selected as the independent variable, according to the objectives of the study. The researcher had also selected the moderator variable 'Sex' to check their effectiveness on the dependent variable 'Achievement'. After the manipulation of the program, the acquired data was

analyzed and interpreted by the different statistical methods. The Results obtained from the summary of the study and the other aspects of statistical calculations are as under. For the main experiment the results were as follows: The effectiveness of the CIP was found considerable on entire sample as compared to traditional approach. As compared to traditional approach the effectiveness of the CIP was found considerable on boys as compared to traditional approach. The effectiveness of the CIP was found considerable on girls as compared to traditional approach.

Day and Bryce (2013) conducted a study on *"Cooperative learning to socio scientific discussion in secondary school science".* It was found that cooperative learning facilitated a shift in the pattern of typical exchanges away from a teacher dominated discourse towards a more pupil centered open discourse.

Hesbon, E., et al., (2014) conducted a study on "*The Effect of Science Process Skills Teaching Approach on Secondary School Students' Achievement in Chemistry".* The Objectives of the study were to determine the effect of science process skills teaching approach on secondary school students achievement in Chemistry. The results revealed that SPSTA had a significant effect on students' achievement in Chemistry. The outcome of this study may provide an insight for designing instructional strategies that aim to enhance students' performance and contribute to the improvement of teaching and learning of chemistry in secondary schools. The findings of the study showed that eighth grade students achieved higher scores on operative items than the eighth grade students in a more traditional science programme. The interaction with process-skills is evident throughout the students' daily lives and also in science lessons when they engage in practical activities. The activities carried out by the students under this framework will enable them to practice and utilize process-skills. This set of intellectual abilities is referred to as science process skills, which scientists use (Bentley, Ebert & Ebert, 2007)

Mala (2019) conducted a study on "*Effect of constructivist approach of teaching social science on academic achievement and social competence in relation to students,, perception of classroom environment"*. This study aimed to assess the effectiveness of educational resources developed with constructivist learning principles, specifically in relation to students' attitudes towards social science classes,

academic achievement, and retention of learnt material. The sample consisted of fifth-grade students from Sehit Ali Gaffar Okkan Elementary School in Eskisehir. From the participants, we formed an experimental group (5-C) and a control group (5-B). The results of the study show that social studies students' academic performance and retention levels were positively improved by instructional materials created in line with constructivist methods. Furthermore, students articulated that the constructivist-based resources aligned well with constructivist learning concepts, demonstrating their suitability and efficacy in augmenting students' involvement and academic achievements.

Senler (2022) conducted a study entitled *"Relationship Between Student Perceptions of a Constructivist Learning Environment, and their Motivational Beliefs and Self-Regulation of Effort."* The study involved 489 students from five public middle schools in Türkiye and used a correlational research design. Students' perceptions of constructivist learning environments, motivational beliefs, and self-regulation of effort in science lessons were examined using appropriate scales. The findings demonstrated meaningful relationships among students' perceptions of constructivist learning environments, motivational beliefs, and self-regulated learning behaviours. The study suggested that classrooms organized around constructivist principles can contribute to students' motivation and willingness to regulate their learning efforts.

Büyük and Veyis (2023) conducted a study entitled *"An Investigation on Constructive Learning Environments in Secondary Education Religious Culture and Ethics Courses."* The study investigated students' perceptions of constructivist learning environments in Religious Culture and Ethics courses at the secondary education level. The researchers examined whether classroom practices provided opportunities for students to participate actively, express their views, relate learning to their experiences, and construct knowledge. The findings indicated the importance of providing learning environments that reflect constructivist characteristics and encourage active student participation. The study concluded that constructivist

classroom practices can contribute to more meaningful and learner-centred educational experiences in secondary education.

Ering, Tok, and Ering (2024) conducted a study entitled *"Impact of the Constructivist Approach on Academic Achievement in Science Among Secondary School Students."* The study was conducted in Arunachal Pradesh, India, and used a quasi-experimental design involving 30 Class IX students in the experimental group. The researchers examined the influence of a constructivist teaching approach on students' academic performance in Science. The intervention emphasized active participation and the construction of scientific understanding rather than passive reception of information. The findings indicated that constructivist teaching had a positive influence on students' Science achievement, supporting the use of learner-centred instructional approaches at the secondary level.

Arega (2025) conducted a systematic review entitled *"Constructivist Instructional Approaches: A Systematic Review of Evaluation-Based Evidence for Effectiveness."* The review synthesized evaluation-based research examining whether constructivist instructional approaches improve student learning outcomes compared with traditional instructional methods. Rather than focusing on one particular school sample, the study systematically examined evidence across previous empirical studies and identified constructivist approaches that demonstrated effectiveness. The review highlighted the importance of active learning, learner participation, collaboration, inquiry, and opportunities for students to construct knowledge. The findings provided broader evidence that appropriately designed constructivist instructional approaches can support student learning, although their effectiveness depends on how the strategies are implemented in classroom contexts.

Recomez and Elesio (2026) conducted a study entitled *"Shaping Minds Together: Experiences of Junior High School Students in Learning Science in a Constructivist Learning Environment."* The study used a phenomenological design with 10 Grade 9 students in Davao Oriental, Philippines, exploring their experiences of learning Science in a constructivist environment. Data were collected through

interviews and focus-group discussions, focusing on how students constructed understanding through schema development, assimilation, and accommodation. The findings identified adaptive cognition, reflective learning, and teacher-facilitated learning as major themes, showing that students actively constructed knowledge when supported by appropriate classroom facilitation. The study concluded that constructivist learning environments can promote meaningful understanding and active participation among junior high school students.

Adeniran and Owoade (2026) conducted a study entitled *"Effect of Constructivist Learning on Students' Critical Thinking Skills among Senior Secondary School Students in the Gusau Educational Zone of Zamfara State, Nigeria."* The study investigated the effect of constructivist learning on the critical-thinking skills of senior secondary school students in the Gusau Educational Zone using a quasi-experimental pre-test–post-test control-group design. The researchers compared students exposed to constructivist learning with those taught through conventional methods. The findings showed that constructivist learning significantly improved students' critical-thinking skills, indicating that active and learner-centred instruction can be more effective than predominantly teacher-centred approaches. The researchers recommended greater adoption of constructivist teaching strategies and appropriate teacher training in secondary schools.

Alnursa (2026) conducted a study entitled *"Application of the Constructivist Learning Model to Improve Learning Outcomes of Grade X Students in the Subject of Geography with the Lithosphere Material at State Senior High School 34 South Halmahera."* The study focused on Grade X senior high school students and examined the application of a constructivist learning model in teaching Geography, particularly the lithosphere topic. The research investigated whether implementing constructivist learning could improve students' learning outcomes in Geography. The findings reported positive effects of the constructivist learning model on students' learning outcomes, supporting its use as an alternative to conventional teaching approaches. The study suggests that constructivist learning can be effectively applied to subject-specific instruction at the secondary-school level.

Bariere and Emmanuel (2026) conducted a study entitled *"Effect of Social Constructivist Learning Strategy on Students' Interest in Business Studies' Simulation of Office Activities in Tai Selected Secondary Schools."* The study was conducted in four public secondary schools, with schools assigned to experimental and control groups to compare social constructivist instruction with conventional teaching. Students in the experimental group learned office activities through a social constructivist learning strategy, while the control group received conventional instruction. The findings showed that students taught through the social constructivist strategy obtained a higher post-test interest score, with ANCOVA indicating a significant difference between the groups. The study recommended that Business Studies teachers adopt social constructivist strategies and receive professional development for effective implementation.

Related Literature Review Studies Conducted in India:

Sridevi (2005) studied *"The effectiveness of constructivist approach on student's achievement in science, scientific attitude and perception of nature of science at secondary level".* For the study, 37 boys and 31 girls were selected from two schools Demonstration Multipurpose School (DMS), RIE, Mysore, and Kendriya Vidyalaya, Mysore using a quasi-experimental approach and purposive sampling. The participants, consisting of eighth-grade students, were divided into two groups: the control group, which consisted of students from Kendriya Vidyalaya, and the experimental group, comprising students from DMS. Both groups were intact, pre-existing classes. The objective of the study was to assess the effectiveness of the constructivist teaching method in improving various aspects of science instruction. The results showed that the constructivist approach significantly enhanced students' understanding of the nature of science, their science process skills, scientific attitudes, and their overall attitudes toward science. Additionally, the study found no significant gender differences, indicating that the constructivist method had a similarly positive impact on both boys' and girls' academic performance, their views on the nature of science, and the development of science-related skills and attitudes.

Padmanabhan (2007) conducted a study on *"The effectiveness of constructivist approach on the achievement and problem solving ability in science of*

VII standard students of Manasarovar Ushkarni Vidya Ashrama, Mysore". The study involved two groups of 40 students each, the experimental group from Section A and the control group from Section B. The normal teacher instructed the control group using conventional teaching techniques, while the researcher used a constructivist approach to teach the experimental group. The study's findings demonstrated a positive impact of the constructivist teaching methodology on students' science performance. Achieved noticeably higher scores compared to students in the control group, who received instruction using traditional methods. Furthermore, the results showed that the constructivist method improved the scientific performance of both male and female students in an equal amount of time

Sood (2008) in the study- *"learning science as a constructivist / conceptual change process highlighted three issues in contemporary science education mentioned in NCF-2005"* found Science education today faces several challenges that hinder its ability to achieve equity, foster creativity, and move beyond traditional assessment methods. Firstly, despite ongoing efforts, science education still falls short in promoting equity and inclusiveness. Many students, particularly those from marginalized backgrounds, often find themselves excluded from fully participating in the learning process due to systemic barriers in content delivery, teaching methods, and access to resources. The focus is typically on mastering existing knowledge and performing within the boundaries of standardized tests, leaving little room for exploration, experimentation, and original thinking. To truly nurture scientific curiosity, it is essential to move

Dogru and Kalender (2007) conducted a study on *"Science classrooms using traditional teacher-centered approach to those using student- centered constructivist methods".* In the initial assessment conducted immediately after the lessons, methods and those taught using constructivist methods. However, when a follow-up evaluation was carried out 15 days later, the students who had been taught using the constructivist approach showed a significantly better ability to retain the material compared to their peers who had been taught using traditional methods. This suggests

that while both methods might yield similar immediate results, constructivist teaching methods may be more effective in promoting long-term knowledge retention.

Kasinath (2009) conducted a study on *"A holistic view of constructivism and instructional strategies in secondary school students".* These strategies encourage students to engage with one another, share ideas, and solve problems together as part of a group. The key idea is that when students become aware of the factors that influence their thinking such as their beliefs, assumptions, and cognitive processes they are better able to think critically and independently. This self-awareness allows them to select, develop, and defend their own positions more effectively, while also being open to and respectful of differing viewpoints. In this way, students not only gain deeper insights into the material but also develop essential skills in self-reflection, collaboration, and respect for diverse perspectives.

Gautam and Kulshrestha (2011) conducted a study on *"Constructivist Approach based instructional material for XI grade Biology students and determined its efficacy on Attitude of pupil teacher towards Constructivist Approach".* Forty teacher candidates involved in the study, split into 2 types of batches 20 each. A 10-day Constructivist Approach orientation with specifically created teaching materials was given to the experimental group, while the control group received the same orientation but without the extra resources. At the conclusion of the orientation, a self-created Attitude Scale was used to gauge participants' opinions towards the Constructivist Approach. The study's findings demonstrated how well the constructivist approach worked to improve the mindsets of the aspiring teachers. But in the experimental group, which had access to the specially created teaching resources, the effect was noticeably greater. This suggests that the use of these materials enhanced the trainees' understanding and acceptance of the Constructivist Approach, making them more likely to view it positively. In conclusion, the study highlights the importance of well-designed instructional materials in supporting teacher trainees' learning experiences, particularly in the context of modern educational theories like Constructivism. The findings indicate that supplementing a theoretical approach with practical resources can improve trainees' engagement and

foster more favorable attitudes towards innovative teaching methodologies.

Vijayalatha and Krishnaiah (2011) conducted a study on *"the effectiveness of constructivist approach on teaching learning process of science at secondary level".* This study using a pre-test, post-test, equivalent group design. 60 ninth-graders from Jawahar Navodaya Vidyalayam in Mamnoor, Warangal District, were split into two groups at random: 30 children in the experimental group and 30 students in the control group. The study's main conclusions showed that there were no appreciable variations in the two groups' mean pre-test scores, suggesting that their starting levels of knowledge were comparable. But following the intervention, the experimental group's post-test mean score was noticeably higher than that of the control group, indicating that the intervention had a beneficial effect on the students' learning outcomes. Furthermore, the experimental group's post-test performance showed no discernible gender differences, indicating that the intervention was equally beneficial for boys and girls. These findings show that all students, regardless of gender, had an improvement in their learning outcomes as a result of the educational intervention.

Bogar et al. (2012) examined on students *"Academic achievement, retention of knowledge and attitude towards science course in matter of structural and characteristic subject with constructivist education version".* Before and after a four-week instructional intervention, participants' academic performance and attitudes towards science were assessed. The experimental group was given a combination of traditional teaching techniques and constructivist teaching methods, which emphasise active, student-centered learning. Conversely, the control group received instruction exclusively through traditional, teacher-centered techniques. Students in the experimental group outperformed their counterparts in the control group on the post-intervention achievement exam, indicating a significant advantage for the experimental group, according to the data. This implies that academic performance was improved more successfully using the constructivist method. Additionally, the experimental group showed better retention of the material, suggesting that students were able to remember and apply the information over time in addition to having a better understanding of it. These results provide compelling evidence that constructivist teaching strategies are beneficial for raising student achievement, both

in terms of short-term performance and long-term retention. According to the study, using constructivist methods in place of more conventional teaching approaches can result in learning outcomes that are more significant and long-lasting.

Kadem, S. (2013) conducted a study on *"The Effectiveness of constructivist approach on the achievement in science of IX standard students".* The paper emphasises how the Constructivist Approach greatly improves science students' performance. According to the results, pupils who received instruction using this way outperformed those in the control group, who received instruction using more conventional techniques. Furthermore, both male and female students showed consistent efficacy with the constructivist method, resulting in observable gains in their science performance.

Haribhai and Kumar (2012) conducted a study on *"The effectiveness of the constructivist 5 _E' model".* The main purpose was to study the effectiveness of this model compared to the lecture method with reference to achievement and retention. Two randomly assigned urban school and one rural school were taken as sample of the study. The results suggest that, with reference to achievement and retention, the constructivist 5E' model was effective in both schools. It suggested that the 5 E model should be used by the science teachers so that students' achievement and retention could be increased.

Jena (2012) conducted a study on *"The applicability of concept maps in the constructivist approach for individual learning achievement in science".* The study explores the applicability of cooperative modes and hierarchical concept maps for achievement in learning the concepts of science. The method adopted was experimental with sixth grade students from Indian elementary schools as the population. The major findings of the study was that hierarchical concept map and cooperative spider compared to individual learning, outstand in individual learning about the concept of science and the constructivist approach was applicable through concept maps.

Raval (2012) conducted a study on *"The effect of a constructivist approach to the teaching of science and technology".* The main objective was to assess the effectiveness of teaching animal classification through the approach of

constructivism. A quasi experimental design, post-test, opinion scale, and interview schedule were used. A purposive sampling technique was used. The sample of the study was students in the 9th standard. The major finding was that the constructivist approach was effective in comparison with the traditional approach.

Chowdhury (2013) conducted a study on *"The effect of constructivist 5E's learning. The design of the study was quasi experimental in nature".* The pre-test and post-test were conducted for the class nine students, which consists of sixty students. The findings revealed that the constructivist approach has improved the students' achievement in mathematics compared to traditional teaching

Lohidhasan (2013) administered a study on *"The evaluation of the revised biology curriculum at the high school level in the constructivist perspective and practice as perceived by the State Resource Group".* The normative survey method was used. The population was taken from students and teachers of Biology (class VIII, IX and X). The sample was taken from State Resource Group for the subject Biology, which included 120 teachers teaching biology and 960 students. The finding revealed that the philosophical, psychological, and sociological aspects of constructivism were reflected in the high school biology curriculum at a higher level and reflect qualities of the constructivist textbooks. The students belonging to government high schools experience better constructivist practises pertaining to the role of teachers compared to students in aided and unaided schools.

Kadem (2013) conducted a study on "*Effectiveness of constructivist approach on the achievement in science of IX standard students".* The major findings of the article are the Constructivist Approach has a positive effect on the achievement of students in science. It is evident from the analysis that the students taught by constructivist approach scored higher than those taught by conventional method in the control group. It has equally effective for both boys and girls in improving their achievement towards science.

Sridevi (2013) conducted study *"The constructivist approach to science instruction could promote perception of nature of science among eighth grade students".* Purposive sampling was employed to select the schools for the study. Perception of Nature of Science Test was developed by the researcher and was

administered before and after the treatment. Analysis of Covariance test was performed to control the initial variance. The results showed that Constructivist teaching is more effective than Conventional teaching in terms of perception of nature of Science among 8th standard students. It was also found that Constructivist Approach was equally effective for both boys and girls in improving Achievement and Attitude towards Science. A Constructivist environment was preferred to a traditional classroom by the students. The results confirm research supporting the positive effect of constructivist learning practices and view that constructivist approach to teach science is a viable alternative to traditional modes of teaching.

Thomas et al. (2014) conducted a study on *"The Constructivist Strategy enhances affective outcomes among integrated science students".* Total 200 participants of grade 8 were involved in study. Non-equivalent control group design and affective Achievement Test with psychometric integrity was used. The results confirmed that the use of the Constructivist Strategy improves affective outcomes. The results also revealed that the students in conductive psychosocial environment had superior affective outcomes than their counterparts in non-conducive environment. Interactional effects among the variables were not significant. There was no significant difference found between high and low cognitive achievers regarding affective achievement.

Ranumondal (2014) conducted a study on *"The Constructivism Approach towards Teaching Learning in the Secondary school of Santiniketan".* 1. The effectiveness of the CIP was found considerable on entire sample as compared to traditional approach. 2. As compared to traditional approach the effectiveness of the CIP was found considerable on boys as compared to traditional approach. 3. The effectiveness of the CIP was found considerable on girls as compared to traditional approach.

Khan (2015) conducted a study on *"The constructivism towards a paradigm shift in classroom teaching and learning in science."* Established that constructive method of teaching science have been much more successful than the traditional methods. He found that use of online animations, virtual labs; computer software and sensors have increased test scores significantly. The author has also identified reasons

of reluctance in using this method e.g. teachers‟ resistance, time constraint, lack of trained teachers in constructivist methodology, lack access to technology especially in developing countries.

Shaheen and Kayani (2015) conducted a study on *"The effectiveness of the instruction based on 7E instructional model based on constructivism and traditional instructional model for the teaching of biology on 9th grade student's achievement".* Pretest posttest control group design was used in this study. A total number of 122 ninth grade students (62 boys and 60 girls) from four classes of a biology course of two schools were purposively selected. This study continued for eight weeks. Experimental group (61 students) and control group (61 students) were randomly assigned. The students in the control group were instructed with traditional instructional model, while the students in the experimental group were instructed with 7E Instructional model. A subject achievement test (SAT) and integrated science process skill test were used to collect data. It was concluded that the 7E instructional model was more effective than the traditional instructional in terms of students‟ achievements.

Dogra (2015) conducted a study on *"Constructivist classroom activities for Biology learning".* This article reveals that from a constructivist perspective, Science is not the search for truth. It is a process that assists us to make sense of our world. Using a constructivist perspective, teaching biology becomes more like the biology that biologists do. It is an active, social process of making sense of experiences, It is an enjoyable activity and the role of the teacher is very challenging. Learning in classrooms is facilitated by well designed activities. Through different classroom actives, students get an opportunity to reflect and build on and consolidate existing knowledge. Students get an opportunity to construct knowledge.

Krishnaiah (2014) conducted a critical survey on "*The approach of teaching through constructivism in the region of Telangana".* The main aim was to study the place of constructivist approach in teaching and the relationship between various demographic factors of the teacher and student. To study the perfection of teachers, classroom management and assessing the performance by the use of constructivist approach. Random sampling technique was used to select 100 teachers and 300

students. A questionnaire was used to collect the data. The major finding of the study was that the majority of male teachers who are following the constructivist approach are under the impression that it is enables them to create a congenial and democratic environment in the classroom. Teachers demonstrate multi cultural diversity in the presentation. Very few teachers are planning and presenting the contents in the class keeping in view the learners needs. It is observed that though the teachers are using constructivist approach, unfortunately they are not using the suggested evaluation technique for assessing students. Instead they are resorting to the traditional method.

Singh & Yaduvanshi (2015) conducted a study on *"Historical background of constructivism and its importance; the role of mentor and learner in constructivist science classroom".* They have prepared lesson plans for science teachers based on 5E's model -one of the model of constructivism, on the topic „Images formed by concave lenses. Lesson plans facilitated the science teachers in the implementation of constructivism in their classroom.

Qarareh (2016) investigated the *"Effect of using constructivist learning model in teaching science on the achievement of eighth-grade students and their scientific thinking content".* The study sample consisted of 136 male and female eighth graders chosen from two basic schools in Tafila in the scholastic year 2015/2016. The four-class sample was divided into two groups (controlled experimental). The researcher prepared lesson plans using constructivist learning model, achievement test and scientific thinking test, for which validity and reliability were checked. Means, SD, ANOVA and ANCOVA were used to determine the differences in means of the groups of the study. In the light of the study results, the researcher presented a number of recommendations including: extra attention to be given to employ constructivist learning model within science courses, and conducting further studies about the effect of the Constructivist Learning Model on various learning outcomes.

Nath (2015) took up a study on *"The constructivist approach way to promote self-concept and achievement in science for upper primary students".* The goal was to study the effect of the constructivist approach on upper primary students' self – concept and achievement in science. Upper primary (vi-vii) year students studying in Karandighi, Uttar Dinajpur was the population. The sample of the study comprised 50

pupils each studying in two sections of the science. In order to collect the relevant Data Science Achievement Test (SAT)–developed by the researcher and the Self Concept Scale– developed by Raj Kumar Saraswat were used. One section formed the control group and the other section formed the experimental group. Findings of the study revealed that the constructivist approach based experiments as a tool in teaching science did not enhance students‘ self-concept. After the treatment, the two groups of respondents varied statistically in terms of their science achievement.

Shukla (2016) conducted a study on "*Effectiveness of constructivist approach in Teaching Science at the Upper Primary Stage".* The objectives of the study were 1) To develop constructivist approach based teaching-learning strategy of general science for the class VII students. 2) To implement the constructivist approach based teaching-learning strategy of general science for the class VII students. 3) To compare the achievement of students exposed to constructivist approach based teaching-learning with that of students exposed to traditional mode teaching. 4) To find the effectiveness of constructivist approach based teaching- learning strategy of teaching general science with regard to achievement in different dimensions of learning. 5) To study the reaction of students towards constructivist approach based teaching learning strategy. 6) To study the perception of teachers towards constructivist approach based teaching learning strategy. Findings of the study shows that overall achievement of students exposed to constructivist approach of teaching is better than the students exposed to traditional teaching in Physics, Teachers shows the positive perception towards constructivist approach based teaching learning strategy.

Ah-Nam and Osman (2017) conducted a study on *"The instructional strategy that develop constructivist-constructionist learning environment and simultaneously develop chemistry knowledge and 21st century skills".* This study employed quasi-experimental with non-equivalent control group pretest-posttest control group design. Results repored that this approach was able to improve the acquisition of chemistry knowledge and high productivity skill.

Sandhu (2017) investigated *"The effect of constructivist approach on academic achievement in relation to intelligence of elementary school students in biology".* Pre test – Post test control group experimental design was followed. Sample

of 120 students was picked up for the study comprising of two groups of 60 students each viz. control and experimental group. The study shows that constructivist teaching approach exhibit significant higher level of academic achievement and also exhibit significant interaction between the Teaching Techniques and Intelligence on Academic Achievement in biology. The results revealed that Constructivism plays a central role to increase the academic achievement and also acquisition of the concepts of biology.

Singh (2017) conducted a study on *"Aims to differentiate between learning through self-paced modules and a constructivist approach".* Samples of 60 ninth-grade students were chosen using a random sampling procedure. According to the findings, students who learn using a constructivist method and those who study using self-learning modules have significantly different levels of academic achievement. The present study demonstrates that constructivism improves student learning. as a result of the emphasis on the students as creators of meaning and knowledge. Instead of just concentrating on the material to be learnt, it is built on enhancing the students' higher order cognitive skills, such as problem solving and critical thinking. When pupils comprehend how to study, they can use this method to address new and different difficulties in their later lives.

Singh (2018) conducted a study on "*The effect of self learning modules and constructivist approach on the academic performance and thinking skills of secondary school students a comparative study"* The objectives of the study were 1) To study the difference between the Academic Performance of Social Science students taught through Self learning Modules and Constructivist Approach after the experiment. 2) To study the difference in mean gain scores between the academic performances of social science students taught through self learning modules and constructivist approach after the experiment. 3) To study the difference in scores on thinking skills test of social science students taught through self learning modules and constructivist approach before the experiment. Findings of the study shows that there is no significant difference between academic performance of Social science Students taught through self-learning modules and constructivist approach before the experiment. There is no significant difference between the thinking skills of Social

science students taught through self-learning modules and constructivist approach before the experiment. Both the groups are equal in their thinking skills before starting the experiment.

Meher (2021) conducted a study on *"The constructivist learning approach on political science critical thinking".* to determine the degree to which constructivist learning strategies affect critical thinking, application, analysis, synthesis, ability to evaluate, problem solving, and decision-making. Two sections of class IX pupils at the experimental school were divided into the experimental group and control group using a lottery system for this investigation. The present study proven teaching-learning through constructivist style of teaching is more successful than traditional way of teaching in fostering critical thinking in secondary school pupils. The effectiveness of the traditional method of teaching based on the Herbartian approach needs to be replaced gradually although the constructivist learning strategy is superior because it has a positive impact on the growth of some of the higher order cognitive skills within the context of critical thinking.

Suman (2022) conducted a study on *"the impact of constructivist pedagogy on science and mathematics concept attainment and anxiety.* The study's main objective was to explore the role of constructivist pedagogy on concept attainment and anxiety amongst students in the experimental and control groups, taking into account their gender and socioeconomic background. The study adopts an experimental method. The results showed that the low SES students in the experimental group had much lower levels of mathematics anxiety than the high SES students in the control group. Approximately 99.26% of teachers expressed their support for the implementation of constructivist pedagogy in teaching-learning materials, constructivist classes, and students' curiosity to find answers, as well as the importance and rigor of the classroom environment, as well as the teacher and students' joint hard work and demonstrated classroom utility.

Chakraborty and Chechi (2020) conducted a study entitled "*Gender Dimensional Analysis of Constructivist Learning Environment Construct in Secondary School Students from Muslim Minority Community."* The study involved

197 secondary school students, including 105 boys and 95 girls, from the Muslim minority community in Hyderabad, Telangana, India. The researchers examined dimensions of the Constructivist Learning Environment Scale (CLES), focusing particularly on students' perceptions of constructivist classroom environments according to gender. The study highlighted constructivism as an active learning process in which learners receive dynamic learning experiences and participate in knowledge construction. The findings provided evidence concerning the dimensions of constructivist learning environments and their variation across student groups, supporting the relevance of learner-centred classroom practices at the secondary level.

Shahida and Jamal (2025) conducted a study entitled *"Exploring Science Teachers' Perceptions Regarding the Constructivist Approach."* The study was conducted by researchers from the Department of Education, Aligarh Muslim University, Uttar Pradesh, India, and examined Science teachers' perceptions of constructivist teaching. Although the participants were teachers rather than students, the study is relevant to secondary-school constructivist learning because teachers' beliefs and classroom practices strongly influence the implementation of learner-centred instruction. The findings highlighted that constructivist teaching shifts the classroom from teacher-led instruction toward active participation, collaboration, deeper understanding, individualized learning, constructive feedback, and learner responsibility. The study emphasized the need for teachers to create supportive and inclusive learning environments that enable students to construct knowledge actively.

2.6 LITERATURE REVIEW STUDIES RELATED TO SELF-EFFICACY

Related studies conducted in Abroad:

Karaarslan and Sungur (2011) investigated *"Science self-efficacy beliefs of elementary students and function of gender, grade and socio-economic status".* The findings indicated non-significant difference between grade and gender in relation to self efficacy in science. Further, results revealed that Confidence in Science and Technology (CST) and resulted in low scores in students' confidence, whereas self efficacy was higher among girls. The study also established that self-efficacy is reduced as one entered into higher grade. The results also discovered that self-efficacy

in science and technology is closely associated with earnings, books available at home, and frequency of purchasing newspaper.

Sung and Hwang (2013) conducted research on *"Science learning performance and its association with the collaborative game-based learning approach".* Three groups namely experiment group A, control group A and control group B involving 93 students were selected as sample for research. Collaborative educational computer game mixing repertory grid approach was applied on experimental group A. Traditional collaborative game learning without repertory grids was applied on control group A. Individual educational computer game self developed

repertory grids were applied on control group B. The performance of the students was examined via learning of achievements, self-efficacy, attitudes and motivation. Findings revealed the benefits of collaborative educational game in promotion of achievements, self efficacy, attitudes and motivation in Natural Science.

Cheung (2014) conducted a study on *"The collective effects of learning strategies and teaching in classroom on self-efficacy of students in Chemistry".* The questionnaire was used to determine students' observation about instruction based efficacy teaching. It was assumed that efficacy based teaching, like meta-cognitive strategy, was capable of increasing students' self-efficacy in the subject of Chemistry. A sample was collected from Hong Kong involving five hundred ninety secondary school students enrolled in Chemistry. The results indicated that self-efficacy in Chemistry had been significantly influenced by efficacy-enhancing teaching and deep learning strategies.

Reddan (2015) carried a research on the field project, an optional course in the bachelor of exercise science course at Griffith University which consist of factor of each career development learning and work integrated learning. The objective of the research was to examine the influence of the assessment items and learning activities intended for the course on students' self-efficacy in taking positive career decisions. To obtain the data career decision self-efficacy scale and a questionnaire were administered before and after the completion of the course. Investigator found a significant difference with respect to students' confidence in goal selection, occupational information planning, problem solving and self-appraisal. Students perceived the course enhanced their knowledge of personal strengths and weaknesses related to employability and their awareness of occupations related to them.

Hushman and Marley (2015) examined that *"The effectiveness of guided instruction technique for enhancing the Science self-efficacy of elementary students".* Total sixty children, ranging age from 9 to 10 years, were randomly separated into three instructional categories namely "i) guided instruction with examples and student generated explanations, ii) direct instruction with lecture and examples, and iii) minimum instructions with student directed discovery". The result disclosed the higher science self-efficacy among students who were exposed to "minimum

instructions with student directed discovery" have planned a number of experiments correctly and leading to positive self-confidence. The direct and guided instructions technique showed non-significant difference in Science self-efficacy.

Armum et al (2015) conducted a research study on *"self-efficacy of the adolescents from different academic settings of Malaysia".* Social and emotional self-efficacy of the adolescents 81 comprises 16 items, adopted from the Self - efficacy questionnaire for children to assess the social and emotional self-efficacy of children. The result pointed out that there was no significant difference in social self-efficacy across academic ability among adolescents. Furthermore, the research showed that there was no significant difference in efficacy across gender. It also found that the self-efficacy acts as a predictor of academic achievement when it comes to individual from higher socio-economic status. The emotional self efficacy of low achievers was lower than average and high achievers.

Ainscough et al. (2016) conducted a study on *"self-efficacy of Biology student changes during the first-year of a course".* A sample of 614 students was selected and Biology Self-Efficacy Scale was used for pre and post-test observations. There were 21 questions, based on five point Likert scale. The results demonstrated that there was increased level of self-efficacy during the semester.

Bhagat et al (2016) studied on *"The self-efficacy and adjustment of secondary school students in relation to their gender and academic achievement".* The study was conducted over a sample of 200 79 randomly selected secondary school students in class 9th. The results of the study showed that no significant difference was found in the self-efficacy of secondary school students in relation to their gender and academic achievement.

Ogutu et al. (2017) conducted a study on *"self-efficacy affected secondary school students' ability to make career-related decisions".* 364 Kenyan school children from Busia County participated in this study. Results showed that secondary school students' job decisions were significantly influenced by self-efficacy. High self-efficacy pupils will choose careers that are more suitable for them, and vice versa. Additionally, factors including gender, age, and the type of institutions a student attends have an impact on their ability to choose a career.

Kotluk and Kocakaya (2017) examined *"the influence of digital story-telling on the self-efficacy perception, academic achievement and attitude towards physics of secondary school students".* The study consists of an experimental and a no experimental group which were created by equal number of students. Pre-test and post-test experimental design techniques were employed by the researcher. For six weeks students in two physics classes taught by the same teacher. Digital storytelling method was additionally implemented in experimental group. Researcher has used the Non-parametric tests to draw the conclusion from the data obtained from pre and post-test. Study shows that students taught by digital story-telling performed significantly better than non-experimental group students with respect to physics achievement. While in non-experimental group students' self-efficacy perceptions and attitudes toward physics declined, in experimental group there was not any difference. Liu and Cheng (2018) showed that self-efficacy significantly linked with achievement motivation, and the self-identity partially mediated the relation between self-efficacy and achievement motivation in adolescents, and the hope moderated the mediating paths.

Ahmadi (2019) conducted a study on *"the connection between academic self-esteem and academic performance".* All Urmia second-cycle high school students were included in this study's demographic objective. Stratified random sampling was used to collect data from 365 individuals. The College Academic Self – Efficacy Scale and the BASE (a standard questionnaire for measuring academic self- esteem) were both utilized to gather data (CASES). The conceptual pattern was examined using path analysis to see how latent and observable factors interacted. Students' academic self-efficacy was shown to be directly connected to all components of academic self-esteem except success/failure, according to the results of the course research. Aside from success/failure, all components of academic self- esteem were connected indirectly to academic accomplishment through academic self-efficacy, which is a different construct entirely

Hasan and Parvez (2019) reported significant positive correlation between the self-efficacy and academic achievement. Moreover, self-efficacy reported no significant differential effect on the academic achievement. Gender was reported to

have significant differential effect on the self-efficacy. While, gender and locale were also found to have significant differential effect on the academic achievement of secondary school students.

Ahmadi (2020) conducted a study on of "*academic self-esteem except success/failure were associated directly with the academic self -efficacy of students".* Moreover, all elements of academic self-esteem except success/failure were related indirectly to academic achievement through academic self -efficacy.

Peiffer et al., (2020) studied *"the self-concept and self efficacy in higher education".* Sample of the study comprise of 1243 German psychology students. Self-concept and self-efficacy were evaluated at the same level of specificity, only cognitive self-concept items were employed, and multiple academic domains were considered. Researcher showed the structure of self-concept and self-efficacy taking into account a multidimensional or hierarchical structure and examined the empirical distinction of both constructs on various levels of generality. Findings of the study supported the empirical distinction of self-concept and self efficacy with medium-sized positive latent correlations between self-concept and self efficacy on various levels of generality. On the basis of the findings researcher suggested that the information about the internal structure of students' self-concept and self-efficacy and the distinction of both constructs can aid to grow domain specific and construct-specific mediation approaches.

Sholikah, et al. (2021) conducted a study on *"Self-Efficacy and Academic Performance to Improve Career Readiness":* Career Maturity as a Mediating Factor. The goal of this study was to determine how self-efficacy and academic success affected vocation status outside of the calling by using career maturity as a middle step. Using an example of 80 understudies, the review strategy using a quantitative methodology was used in this study. The sample was chosen for this study in light of a purposeful examination of all Office Organization students at the State College of Semarang. This investigation discovered that self-efficacy and career maturity decidedly and essentially impacted profession status outside the calling. Academic achievement, for this situation, likewise influences profession preparation, however not significantly. The job of career maturity as intercession significantly affects self-

efficacy on career readiness to some degree.

Chun and Kim (2021) conducted a study on *"The Impact of Middle School Students' Self-Efficacy and Reading Strategies on Career Maturity:*. By using the many reading strategies suggested in the 2015 Revised National Curriculum, this learning aim to appreciate the functions of reading. Through interviews and factual assessment of an overview completed by center school students, information was acquired. Studies revealed that basic reading has an impact on the certainty and conclusiveness of professional maturity. The arrangement of career maturity was also influenced by reading material that was close to home and inventive. Certainty, self-regulating efficacy, and task difficulty preference were all modified by basic reading. Studies also shown that in-depth reading has an impact on self-regulation effectiveness. Eventually, basic reading and conclusion were overridden by the conviction of self-efficacy in the middle. This review adds to directing perusing guidelines for experts and school educational plans to foster self-efficacy.

Kurniasari and Sunawan (2021) conducted a study on "*The Effect of Group Counseling using Cognitive Restructuring Techniques to Decrease Cheating and Increase Self-efficacy.* The experimental design used randomized pretest-posttest examination bunch setup, with 14 students serving as study participants who were specifically chosen from a total of 123 class X students. The self-efficacy scale is measured using the Motivated Strategies for Learning Questionnaire (MSLQ), and the demeanor scale is measured using the Attitude toward Cheating (ATC). According to the acceptable level of these techniques' efficacy, the study's findings show that applying cognitive restructuring strategies to lower attitudes toward cheating and boost student self-confidence has considerable effects. This study confirms the validity of cognitive restructuring procedures to lessen the propensity to cheat by lowering conning attitudes and raising self-efficacy.

Zysberg and Schwabsky (2021) examined *"School Climate, Academic Self-Efficacy and Student Achievement."* The study was conducted among 1,641 middle and high school students in Israel and investigated whether academic self-efficacy mediated the relationship between school climate and academic achievement. Students completed measures of academic self-efficacy and school climate, while

mathematics and English achievement data were also considered. The findings indicated that positive school climate, particularly interpersonal relationships and students' sense of belonging, was associated with stronger academic self-efficacy, which in turn was related to better academic achievement.

Khan, Reba, and Shahzad (2021) investigated *"A Comparative Study of Academic Self-Efficacy Level of Secondary School Students in Rural and Urban Areas of District Peshawar, Pakistan."* The researchers selected 600 secondary school students, including 300 from urban schools and 300 from rural schools, using stratified random sampling. A standardized academic self-efficacy instrument was administered and the data were analysed using the t-test. The study found that students in both rural and urban schools generally believed that adequate study effort could improve their academic performance, although many students reported difficulties in challenging academic situations. However, no significant difference was found between the academic self-efficacy levels of rural and urban secondary school students.

Lei, Cui, and Zhou (2022) examined *"Academic Self-Efficacy and Academic Performance among High School Students: A Moderated Mediation Model of Academic Buoyancy and Social Support."* The study involved 860 high school students in China, with an average age of approximately 16.39 years. Students completed questionnaires measuring academic self-efficacy, academic buoyancy, and social support, while academic performance was assessed through standardized tests. The results showed that academic buoyancy partially mediated the relationship between academic self-efficacy and academic performance, while social support moderated part of this mediation process. The findings suggest that students with stronger academic self-efficacy are more capable of coping with everyday academic setbacks and achieving better academic outcomes.

Weißenfels, Hoffmann, Dörrenbächer-Ulrich, and Perels (2023) studied *"Linking Academic Buoyancy and Math Achievement in Secondary School Students: Does Academic Self-Efficacy Play a Role?"* The research examined secondary school

students and focused on the relationship between academic buoyancy, academic self-efficacy, and mathematics achievement. The study investigated whether academic self-efficacy could explain the mechanisms linking students' ability to cope with everyday academic setbacks to their mathematics performance. The findings indicated that academic self-efficacy played an important role in explaining the relationship between academic buoyancy and mathematics achievement. The study therefore emphasized academic self-efficacy as an important psychological resource for successful mathematics learning among secondary students.

Uygur, Asici, and Kocer (2023) investigated *"Prediction of Academic Resilience in Adolescents through Academic, Social and Emotional Self-Efficacy and Gender."* The participants were 346 adolescents aged 12–18 years, consisting of 227 girls and 119 boys from Türkiye. Academic resilience and academic, social, and emotional self-efficacy were measured and analysed using correlation and multiple regression techniques. The results showed that academic, social, and emotional self-efficacy were significant predictors of academic resilience, together explaining approximately 49% of its variance. Academic self-efficacy emerged as the strongest predictor, indicating that students who have stronger beliefs in their academic capabilities are more likely to remain resilient when facing academic challenges.

Okweye and Onoyase (2024) conducted *"Academic Self-Efficacy and Academic Performance of Secondary School Students in Delta North Senatorial District."* The population comprised 16,473 Senior Secondary School III students in government-owned secondary schools in Delta North Senatorial District, Nigeria, and the researchers employed a correlational research design. The study examined the relationship between students' academic self-efficacy and academic performance. The findings indicated a relationship between academic self-efficacy and students' academic performance, suggesting that students' confidence in their academic capabilities is relevant to their achievement. The study provides evidence from the Nigerian secondary-school context that academic self-efficacy should be considered when examining factors associated with students' academic performance.

Sani, Tuominen, Turunen, and Kilpi-Jakonen (2026) examined *"How Loneliness and School Connectedness Associate with Academic Self-Efficacy in Upper Secondary Education: A Longitudinal Analysis."* The researchers used panel data from Finnish upper-secondary students across the first three semesters and applied individual-level fixed-effects regression. The study found that academic self-efficacy generally declined during the transition into upper secondary education, while increasing loneliness was negatively associated with academic self-efficacy. School connectedness was positively associated with academic self-efficacy, with this relationship particularly strong among vocational students. The findings emphasize that reducing loneliness and strengthening students' sense of belonging and connectedness at school may help protect academic self-efficacy during secondary education transitions.

Schlichtenhorst (2026) conducted the systematic review *"School-Based Interventions to Enhance Academic Self-Efficacy in Secondary Education: A Systematic Review Emphasizing Socioeconomically Disadvantaged Students."* The review analysed 18 empirical studies published between 2000 and 2024 involving secondary education students and school-based interventions targeting academic self-efficacy. The synthesis found that 14 of the 18 studies reported significant improvements in academic self-efficacy, with many interventions showing moderate-to-large effects. Interventions combining self-regulation, motivation, social relationships, structured feedback, guided reflection, and social-emotional learning were particularly effective. The review concluded that school-based, relational, and context-sensitive interventions can substantially strengthen academic self-efficacy, especially among students experiencing socioeconomic disadvantage.

Related Studies Conducted in India:

Chan and Lam (2008) looked across "*the differences in the writing Self-Efficacy of students (involved in vicarious learning) in competitive and non-competitive classrooms".* A total of 71 (25 boys and 46 girls) middle school students of Hong-Kong participated in the study. On analyzing the performance of the students in both the environments it was found that Self-Efficacy of students significantly decreased in a competitive learning setup whereas it was unaffected (statistically) in a noncompetitive classroom.

Raja (2009) conducted a study on *"the influence of Emotional Intelligence, Self-Efficacy and Reflectiveness on Academic Achievement of high school students".* Findings revealed a significant relationship between Academic Achievement and various dimensions of Self-Efficacy, the Academic Achievement of students and their reflectiveness. No significant relation was found between Emotional Intelligence and Academic Achievement.

Gafoor and Ashraf (2012) conducted a study on *"Academic Self Efficacy in a sample of higher secondary school students in Kerala".* The sources of Self- Efficacy namely mastery experience (noted as a previous Academic Achievement), vicarious experience (noted as school image) and social persuasion (noted as parental encouragement) emerged as the best contributing factors (9.42%) towards Academic Self-Efficacy of adolescents.

Ahmad and Safaria (2013) conducted a study on *"the effects of Self- Efficacy on the Academic Performance of students".* The analysis revealed that Achievement is positively correlated with Self-Efficacy. Moreover, the content analysis indicated that students with high Self-Efficacy prefer more complex future prospects as compared to those with low Self-Efficacy.

Dinther et al. (2014) conducted a study on *"Self-Efficacy to play a predictive role in determining the learning outcomes of the students".* Self-Efficacy was reported to mediate the relationship between Students‟ Perception of Assessment and their Learning Outcomes.

Taylor (2014) studied *"the correlation between Self-Efficacy and Academic Success of middle school students".* The Morgan Jinks Self-Efficacy Scale (1999) was

used for recording Self-Efficacy levels. The results indicated enough evidence of a positive relationship between Self-Efficacy and Academic Achievement.

Pasricha (2015) conducted a study on "*Academic Stress and Self-Efficacy in relation to Study Habits, Personality and Academic Achievement of adolescents".* The sample for the study consisted of 400 (200 males and 200 females) senior secondary school students. It was found that Self-Efficacy vary significantly (positively) with Introversion Extroversion, Academic Achievement and Study Habits of adolescents while Academic Stress was found to have a negative relationship with all three variables.

Bhalla (2016) investigated "*Adolescents' career decision-making challenges in connection to self-efficacy, personality, and decision-making style".* Her focus was on Chandigarh's senior secondary government schools. The researcher randomly picked 533 secondary pupils that attend Government secondary schools. One of the findings displayed that boys and girls did not be different considerably in the two areas namely self-appraisal and problem solving. She also discovered that there was no discernible difference between boys and girls in the three aspects of their decision-making style, namely self-confidence, panic, and avoidance, but there was a clear difference between boys and girls in their impulsive decision-making style, which favored girls. This indicated that girls were more impulsive in making decision than their boys 'counterparts.

Javed (2016) investigated *"the interaction among career decisions; self-efficacy and self-esteem of students came from different private and government schools".* 100 girls and 100 boys selected for a sample. Students with high self-understanding faced fewer difficulties in a selection of career and have more confidence in their choices and vice-versa. Moreover, boys_ students showed more confidence in their career choices as compared to girls_ students. In addition to this, students who studied in private schools felt fewer difficulties than students came from government schools.

Ahuja (2016) studied on "*self -efficacy, educational aspiration and academic achievement than boys".* A statistically significant positive correlation was found between sel f-efficacy & educational aspiration, self-efficacy & academic

achievement and educational aspiration & academic achievement of secondary school students.

Ahuja (2016) studied on *"A Study of Self-Efficacy among Secondary School Students in relation to Educational Aspiration and Academic Achievement".* It was found out that girls had statistically significant higher scores in self-efficacy, educational aspiration and academic achievement than boys. A statistically significant positive correlation was found between self-efficacy & educational aspiration, self-efficacy & academic achievement and educational aspiration & academic achievement of secondary school students.

Bhagat and Baliya (2016) studied on *"Self-Efficacy and Adjustment of Secondary School Students in Relation to their Gender and Academic Achievement".* The results of the study showed significant differences in the adjustment of secondary school students in relation to their gender. Female students of secondary schools are found less adjusted than male students of secondary schools. No significant difference is found in the self-efficacy of secondary school students in relation to their gender and academic achievement.

Armum and Chellappan (2016) conducted a study "*the Self-Efficacy of adolescents from different Academic Achievement levels in Malaysia".* The researcher selected a sample of 169 students from various academic settings in Malaysia. An adapted version of the Self-Efficacy Questionnaire for Children was used to assess the Social and Emotional Self-Efficacy of children. The findings revealed that there is a significant difference in Emotional Self-Efficacy across the academic ability of adolescents. However, no significant difference was found in Social Self-Efficacy across academic ability among adolescents.

Bartimote-Aufflick et al. (2016) conducted a study "Self Efficacy and its relationship with learning outcome of the students". It was concluded that Self-Efficacy has strong correlations with Student Achievement, Self-Regulation, Motivation and Strategy Use. The study also established the fact that teachers" intervention can go a long way in improving Self-Efficacy beliefs of the students.

Susheela (2017) **i**nvestigated *"the Academic Achievement and psychological wellbeing of secondary school students in relation to their Self-Efficacy and*

Emotional Intelligence". The findings revealed a positive significant relationship between Academic Achievement and Self-Efficacy, and Academic Achievement and various dimensions of Self-Efficacy (academic, social and emotional). A significant positive relationship between Self-Efficacy and Academic Achievement and Self-Efficacy and Educational Aspiration was reported.

Emon (2018) conducted study on *"the self-efficacy of higher secondary level pupils in relation to their gender and type of management".* The collected data was analysed through Mean, S.D. and 't' test. The results of the study visualized that there was no significant difference in self-efficacy of higher secondary level pupils in relation to their gender and management type.

Bhati et al., (2022) **c**onducted a study on "*academic self-efficacy significantly influences students' academic achievement".* Furthermore, the results showed that science students with high levels of academic self-efficacy outperformed their counterparts in terms of academic achievement.

Ganie and Ganai (2021) conducted a study entitled *"Academic Anxiety and Self-Efficacy among Adolescents of Kashmir."* The study included 400 secondary school students, comprising 200 males and 200 females, selected from government and private schools in Kulgam and Baramullah districts of Kashmir. Data were collected using an Academic Anxiety Scale and a Self-Efficacy Scale and were analysed through percentages, t-tests, and Pearson correlation. The findings showed that 66.50% of students had low self-efficacy, 22.75% moderate self-efficacy, and 10.75% high self-efficacy; importantly, academic anxiety was significantly and negatively correlated with self-efficacy. The researchers concluded that higher academic anxiety was associated with lower self-efficacy among secondary school students.

Shivani (2023) conducted an Indian study entitled *"Development and Validation of Science Self-Efficacy Scale (SSES) for Secondary School Students."* The scale was validated with 300 students aged 14–15 years studying science in government schools of Haryana, India. Initially, 55 items were developed across five dimensions: self-confidence, self-regulation, self-concept, perceived science efficacy,

and outcome expectancy; following item analysis, 41 items were retained. The final scale demonstrated good reliability, with Cronbach's alpha of 0.86 and split-half reliability of 0.76. The study concluded that the SSES is a useful instrument for assessing science self-efficacy among secondary school students and can support future educational research and interventions.

Dadandı (2023) examined *"Academic Self-Efficacy, Study Skills and Academic Achievement: A Serial Mediation Model."* The study involved 92 secondary school students who completed measures of academic self-efficacy and study skills, including systematic study and homework/examination preparation. The researcher examined whether study skills mediated the relationship between academic self-efficacy and academic achievement. The results revealed positive relationships among academic self-efficacy, study skills, and academic achievement, while systematic study and effective homework and examination preparation serially mediated the relationship. The study suggested that enhancing both students' academic self-efficacy and study skills could contribute to improved academic achievement.

Malik and Behera (2025) investigated *"Career Self-Efficacy and Academic Performance of Secondary School Students: An Empirical Analysis."* The study included 130 secondary school students from Cuttack district, Odisha, India, selected through simple random sampling. Career self-efficacy was measured using the Career Decision Self-Efficacy Scale, while academic performance was assessed through recent examination scores. The findings showed that most students had high career self-efficacy, with no significant gender difference, while a significant but weak positive relationship was found between career self-efficacy and academic performance ($r = .248$, $p = .004$). The researchers recommended career guidance, mentoring, and skill-building activities to strengthen students' career self-efficacy and academic development.

Yasmin and Laskar (2026) conducted *"Empowering Readers: The Impact of Self-Efficacy on Secondary School Students' Reading Ability."* The study used a

quantitative descriptive survey design with 501 secondary school students from four districts of West Bengal, India, selected through stratified random sampling. The researchers administered the Self-Efficacy Scale and Silent Reading Ability Test and analysed the data using t-test, Pearson correlation, and regression techniques. The findings demonstrated that self-efficacy significantly influenced students' reading ability in government-aided secondary schools. The study recommended targeted educational interventions to improve students' self-efficacy and reading proficiency, thereby supporting more effective learning among secondary school students.

2.7 LITERATURE REVIEW STUDIES RELATED TO EPISTEMOLOGICAL BELIEFS

Related studies conducted in Abroad:

Louca, Elby, Hammer and Kagey (2004) conducted a study on *"epistemological resources in science instruction".* This study was divided into two sections. In the first section the researcher discussed and compared different resources framework (developmental framework, belief framework and resource framework) for explaining personal epistemologies which could support and could account as evidence for developmental and beliefs frameworks. In the next section, the researcher administered the three frameworks to a specific epistemological science lesson of 3rd grade. The teacher asked questions to students viz. "why do leaves change colour?" and "what's going on inside of the leaf that makes it change colour?" To this the student's written responses were analyzed and it was concluded that the developmental frameworks and beliefs framework did not give incorrect predictions. But, the problem with these two frameworks was that they could not provide a proper language for explaining the teacher's intervention. On the other hand, the resources framework, very properly described the teacher's intervention as tapping into epistemological resources and also for the success of that intervention.

Young, (2005) examined *"the nature of knowledge among students and their learning, epistemological beliefs and how the epistemological beliefs of students affect their motivation, selection of study strategies and academic performance".* The sample of the study consisted of 293 students studying the marketing subject. The

findings of the study indicated that students holding naïve epistemological belief used short-term learning strategies whereas, students holding sophisticated epistemological beliefs used higher level of learning strategies. Academic achievement was high in students holding sophisticated epistemological beliefs. The study also gave certain recommendations for developing sophisticated epistemological beliefs such as: (i) promoting opportunities for construction of knowledge among students. (ii) giving guidance in organization and integration of knowledge (iii) emphasized upon classroom discussions for sophisticated epistemological perspectives.

Fraser and Giddings (2012) conducted a study on *"the impact of interactive science teaching on students' epistemological beliefs".* The study included 240 high school students from a suburban school district. Using the Epistemological Beliefs Inventory (EBI) and classroom observations, the findings highlighted the positive impact of interactive science teaching on students' epistemological beliefs. Specifically, students exposed to more inquiry-based teaching exhibited more constructivist epistemological beliefs compared to those exposed to traditional lecture-based teaching.

Greene and Azevedo (2013) explored "*the impact of metacognitive prompts on students' epistemological beliefs".* The study involved 150 middle school students from an urban school district. Utilizing the Metacognitive Prompts Inventory (MPI) and the Epistemological Beliefs Inventory (EBI), the findings revealed a positive influence of metacognitive prompts on students' epistemological beliefs. Specifically, students who received metacognitive prompts exhibited more constructivist epistemological beliefs compared to those who did not receive such prompts.

Kaymak and Ogan-Bekiroglu (2013) carried out a study on *"How Students' Epistemological Beliefs in the Domain of Physics and Their Conceptual Change are related."* The study was conducted on 17 students of tenth grade in Turkey. It was suggested that epistemological beliefs of high school students in the domain of physics was close to sophistication. Also, positive relation was found between students' epistemological beliefs in the domain of physics and their learning gains. Overall, the study suggested that conceptual change can be facilitated among the students by developing their domain specific epistemological beliefs and by

improving their learning strategies.

Duran and Mıhladız (2014) conducted a study to determine "*the epistemological beliefs of 6th grade elementary school students about science".* The sample of the study comprised of 155 students. The major findings drawn out of the study to the questions were: (a) The students were asked question; "how do they understand whether information is scientific or not?" the students stated that they decided whether the information is scientific or not, as majority of the students gave opinion that scientific information can be acquired through experiment, observation, research, resources and survey. (b) The students were asked question; "do you believe in the correctness of the information written in scientific books?" the students stated that the correctness of the scientific information can be assessed by scientific researches, from internet and library, from experiments and observations, by studying, from encyclopedia and journals, by using our mind and lastly by learning from anyone. (c) Next finding of the study suggested that 23.2% students thought that information given by scientists was correct, 66.5% of students think that information given by scientists was not correct and 7.1% of students think that it was sometimes correct and 3.2% students agreed with none of these three opinions. The students' explanation was: (i.) it was important for people, (ii) scientific information led to research conduction, (iii) it gave precise information, (iv) it described the unknown about life, (v) it is needed, (vi) it generated new researches.

Sen, Yilmaz and Yurdugul. (2014) carried out a study *"the relationship between achievement motivation, learning strategies and their epistemological beliefs".* The sample of the study consisted of 446 undergraduate students from the Faculty of Education, Hacettepe University, Turkey. The findings from the path analysis were that the path coefficients between the belief that learning depends on ability and motivation and learning strategies were not significant. Therefore, the alternative model was applied and it was found learning depends on effort made by the students and it affected the learning strategies directly, and along with this it also affected the learning strategies indirectly with the motivation variable. Overall, it was concluded in this research that the learning strategies selected and used by students were predicted by motivation variable.

Simon and Johnson (2015) investigated *"the influence of epistemological beliefs on self-regulated learning in science through a middle school case study".* The study included a sample of 20 middle school students from an urban school district. Employing the Epistemological Beliefs Inventory (EBI) and the Self-Regulated Learning Questionnaire (SRLQ), alongside classroom observations, the study revealed that higher levels of constructivist epistemological beliefs were associated with elevated self-regulated learning. Furthermore, epistemological beliefs influenced students' self-regulated learning strategies, such as goal setting, monitoring, and help-seeking.

Pintrich and Lin (2018) aimed to investigate *"the relationship between students' epistemological beliefs, self-regulated learning, and scientific literacy".* The study involved 250 high school students from a suburban school district. Utilizing the Epistemological Beliefs Inventory (EBI), Self-Regulated Learning Questionnaire (SRLQ), and Scientific Literacy Inventory (SLI), results indicated that students with higher levels of constructivist epistemological beliefs and self-regulated learning demonstrated higher levels of scientific literacy. Self-regulated learning mediated the relationship between epistemological beliefs and scientific literacy.

Hofer et al. (2018) aimed to investigate *"the relationship between epistemological beliefs, self-regulated learning, and expert performance".* The study involved 120 experts from various fields. Employing the Epistemological Beliefs Inventory (EBI), the Self-Regulated Learning Questionnaire (SRLQ), and expert performance measures, the findings indicated that experts had higher levels of constructivist epistemological beliefs and self-regulated learning compared to non-experts. Selfregulated learning mediated the relationship between epistemological beliefs and expert performance.

Sandoval and Brew (2019) investigated "*the relationship between students' epistemological beliefs and their metacognition in science".* The study included 150 middle school students from an urban school district. Utilizing the Epistemological Beliefs Inventory (EBI), Metacognitive Awareness Inventory (MAI), and science concept maps, findings revealed that students with higher levels of constructivist epistemological beliefs exhibited higher levels of metacognition in science.

Epistemological beliefs influenced metacognitive skills, such as planning, monitoring, and evaluating. Higher constructivist epistemological beliefs were associated with better planning, progress monitoring, and evaluation of understanding

Ruiz-Primo et al. (2020) investigated *"the relationship between students' socio epistemological beliefs and their development of scientific literacy".* The longitudinal study included 180 middle school students from an urban school district. Utilizing the Epistemological Beliefs Inventory (EBI) and the Scientific Literacy Inventory (SLI), the findings revealed that students' socio-epistemological beliefs became more constructivist over time. Higher levels of constructivist epistemological beliefs were associated with higher levels of scientific literacy.

Ugulu (2021) carried out a study to explore "*the scientific epistemological beliefs of gifted students".* The study also investigated the age, gender and grade-level differences in scientific epistemological beliefs among students. The sample of the study comprised of 120 gifted students (67 female students, 53 male students). These students were from three grades i.e., 5th grade, 6th grade and 7th grade. The findings of the study suggested that the average survey score of fifth and sixth-grade students were nearly equal, the highest mean of epistemological beliefs survey score was at the seventh-grade level. Accordingly, it was found that the gifted students who received more science education in higher grade showed positive change towards scientific epistemological beliefs. The second finding revealed that there was no significant difference between gifted students belonging to different ages with respect to scientific epistemological beliefs. The third finding was that there was no significant difference between female and male gifted students with respect to scientific epistemological beliefs.

Schiefer et al., (2022) carried out research to study *"epistemic beliefs in science".* The researchers categorized the data into six data sets to examine the profiles of epistemic beliefs in students of elementary and secondary schools. The findings of the study suggested that similar type of profiles of epistemic beliefs (multiplistic, absolutistic, evidence-based, sophisticated and others) occured in different samples in science students. The relationship between epistemic belief profiles with student covariates were also examined and the researchers found

desirable relationship for sophisticated profiles, undesirable relationship for absolutistic and intermediate relationship for multiplistic profiles. Overall, the study highlighted that large epistemological diversity existed within the samples for both the students from academic track and non-academic track.

Xu and Wang (2023) aimed to investigate "*the influence of epistemological beliefs and argumentation strategies on high school students' scientific literacy".* The study included a sample of 240 high school students from a suburban school district. Employing the Epistemological Beliefs Inventory (EBI), Toulmin Argumentation Rubric (TAR), and Scientific Literacy Assessment (SLA), results indicated that students with higher levels of constructivist epistemological beliefs and more effective argumentation strategies demonstrated increased scientific literacy. Furthermore, an interaction effect was observed, highlighting that students with high levels of constructivist epistemological beliefs, coupled with effective argumentation strategies, exhibited the highest levels of scientific literacy.

Liu et al. (2023) investigated "*the relationship between middle school students' epistemological beliefs, metacognition, and scientific argumentation".* The study involved a sample of 200 middle school students from an urban school district. Utilizing the Epistemological Beliefs Inventory (EBI), Metacognitive Awareness Inventory (MAI), and Scientific Argumentation Assessment (SAA), findings revealed that students with higher levels of constructivist epistemological beliefs exhibited elevated levels of metacognition and scientific argumentation. Furthermore, metacognition was identified as a mediating factor in the relationship between epistemological beliefs and scientific argumentation.

Sun and Zhang (2023) investigated "*the relationship between epistemological beliefs and argumentation skills in Chinese middle school students".* aimed to discern how students' epistemological beliefs influence their ability to construct and evaluate scientific arguments. The sample consisted of 160 middle school students from a Chinese urban school district, and data were collected using the Epistemological Beliefs Inventory (EBI) and the Toulmin Argumentation Rubric (TAR). Results revealed that students with higher levels of constructivist epistemological beliefs exhibited superior argumentation skills compared to their peers with lower levels

of constructivist epistemological beliefs. This positive association between epistemological beliefs and argumentation skills was manifested in students' inclination to provide evidence, consider alternative perspectives, and critically evaluate the strength of their arguments.

Chen and Sun (2023) aimed to investigate "*the relationship between middle school students' epistemological beliefs, metacognition, and collaborative learning".* The study included a sample of 160 middle school students from an urban school district. Employing the Epistemological Beliefs Inventory (EBI), Metacognitive Awareness Inventory (MAI), classroom observation protocol, and think-aloud protocols, findings revealed that students with higher levels of constructivist epistemological beliefs and metacognition demonstrated more effective interactions and contributions in collaborative learning groups. Moreover, epistemological beliefs and metacognition influenced students' interactions and contributions in collaborative learning groups, such as their likelihood to share ideas, ask questions, and provide feedback

Chen and Chang (2023) conducted a study o *"the relationship between Taiwanese college students' epistemological beliefs, metacognition, and collaborative learning".* The research involved a sample of 180 college students from a Taiwanese university engineering program and employed the Epistemological Beliefs Inventory (EBI), Metacognitive Awareness Inventory (MAI), Collaborative learning observation protocol, and Think-aloud protocols. The findings indicated that students with higher levels of constructivist epistemological beliefs and increased metacognition demonstrated more effective interactions and contributions in collaborative learning groups compared to students with lower levels of constructivist epistemological beliefs and lower levels of metacognition. Additionally, the study highlighted that epistemological beliefs and metacognition influenced students' interactions and contributions in collaborative learning groups, with students exhibiting higher levels of constructivist epistemological beliefs being more likely to share ideas, ask questions, and provide feedback.

Nachtigall and Firstein (2024) studied *"Exploring the Impact of Authentic Learning Activities on School Students' Epistemic Beliefs in the Social Sciences and*

Humanities." The researchers conducted two studies involving 152 students in educational sciences and 150 students in linguistics, examining whether authentic learning activities could influence students' epistemic beliefs. Students participated in authentic learning experiences conducted in an out-of-school laboratory setting. The findings indicated that authentic learning activities could contribute to changes in students' epistemic beliefs concerning knowledge in the social sciences and humanities. The study suggests that providing students with opportunities to engage directly with authentic disciplinary practices can support more sophisticated understandings of knowledge and knowing.

Savaş and Demirbağ (2026) investigated *"The Examination of the Relationships Among Middle School Students' Epistemological Beliefs, Goal Orientations, and Achievement Emotions: A Structural Equation Modeling Study."* The study examined middle school students and used structural equation modelling to investigate relationships among epistemological beliefs, achievement-goal orientations, and achievement emotions. The research is particularly significant because it examines epistemological beliefs together with students' motivational and emotional processes rather than treating beliefs as an isolated variable. The findings showed meaningful relationships among students' epistemological beliefs, goal orientations, and achievement-related emotions. The study provides recent evidence that students' conceptions of knowledge are connected with how they approach learning tasks and experience emotions during academic activities.

Related Studies Conducted in India:

Sandoval (2005) conducted a study on *"understanding students epistemological beliefs through multiple research approaches".* The author aimed to provide an overview of diverse research approaches employed in the investigation of students' epistemological beliefs. This contribution is featured in the "Handbook of Research on Science Education," encompassing a thorough exploration of the strengths and limitations associated with each approach. Sandoval delves into a variety of research methods, including surveys, interviews, observations, and think-aloud protocols, without presenting a specific list of instruments. The results of the

study underscore the absence of a singular optimal approach to examining students' epistemological beliefs. Rather, different research methodologies offer distinct insights, and a synergistic combination of these approaches yields a more holistic understanding. The study further reveals the intricate and evolving nature of students' epistemological beliefs, emphasizing their complexity and multifaceted dimensions, which can undergo transformation over time.

Pandey and Singh (2016) conducted a study on *"Epistemological Beliefs were equal between male and female pupil teachers in online learning environments".* One Indian study showed that 70 self–regulated learning and epistemological beliefs significantly predicts academic achievement of pupil teachers in online learning environments. Epistemological Beliefs were equal between male and female pupil teachers in online learning environments. The study aims to reveal the relationship between achievement goal and epistemological beliefs in a specific Indian population. The Nyaya defines the possibility of epistemology to include in it valid knowledge and what are sources of knowledge and evaluation of tests and criteria of validity. In Indian philosophy, knowledge is one of the vital issues concerned with life and world knowledge regarding reality. So very few studies showed the connection of Achievement goal and epistemological beliefs in specific Indian population.

Niranjana (2018) conducted a study on *"the influence of students' epistemological beliefs, students' achievement goals and students".* Several important of learning strategies and how they affect higher secondary students in Kerala's performance in the academic subject of accounting. A sample of 1,200 Class XI students from the Kerala State Board's commerce stream participated in the study. The following are the primary conclusions: Disparities by Gender: According to the study, students' self- regulated learning practices, achievement goals, and epistemological beliefs are significantly influenced by their gender. In particular, girls did better than boys in terms of epistemological beliefs, indicating that girls often have more sophisticated, which may promote better academic performance and self-control. Influence of School Management Type**:** The study found that the type of school management (government or private) did not significantly impact students'

epistemological beliefs, achievement goals, or achievement levels in Accountancy. This suggests that the management type of the school has little to no direct effect on students' academic outcomes in this subject. Rural vs. Urban School Differences: A notable finding was that students from rural schools had higher achievement goals and better performance in Accountancy compared to their urban counterparts. This suggests that factors related to the rural educational environment, such as community support or lower competition, may contribute to better academic outcomes in Accountancy.

Yang, Bhagat and Cheng (2019) carried out a study on *"The domain of science specific field of epistemological beliefs".* This study's main objective was to compare the epistemological views of Taiwanese and Indian university students, with an emphasis on their experiences learning science and mathematics. 126 students enrolled in scientific and math programs were included in the sample, 67 of whom were from Taiwan and 59 of whom were from India. The results showed significant disparities between the two nations' pupils' epistemological views in three important areas: justification, development, and certainty. While Indian students demonstrated a more balanced approach to their science learning experiences, Taiwanese students in particular demonstrated higher scientific reasoning abilities. The study also looked at the connections between students' scientific reasoning skills and their epistemological beliefs, as well as the relationship between science learning experiences and epistemological beliefs. These connections differed across the two groups, indicating that students' attitudes towards learning and information had varying effects on how they approached scientific thinking and how they learnt in general. The study concludes by highlighting the potential influence of cross-cultural variations in epistemological views on scientific learning and reasoning among Taiwanese and Indian university students.

Tali and Dar (2020) conducted *"A Study of Epistemological Belief of Senior Secondary Students."* The study included 600 senior secondary students from higher secondary schools across six districts of Kashmir, India. The researchers used an Epistemological Belief Questionnaire based on Schommer's framework and examined students' beliefs across dimensions such as simple knowledge, certain

knowledge, quick learning, and innate ability. The findings showed that 62% of students had moderate epistemological beliefs, 21% mature beliefs, and 17% naïve beliefs; significant gender differences were found in the simple-knowledge dimension. The study concluded that male and female students differed significantly in one dimension, while no significant gender differences appeared in certain knowledge, quick learning, and innate ability.

Ahmed and Hasan (2021) conducted a study on *"The postgraduate students of different disciplines to study their scientific epistemological views (SEV)".* The study aimed to investigate the scientific epistemological perspectives of postgraduate students, considering factors such as gender, academic discipline (science vs. non-science), and locality (rural vs. urban). A total of 150 postgraduate students from Aligarh Muslim University, India, were randomly selected to participate in the study. The findings indicated that students enrolled in science disciplines generally held more advanced views on scientific epistemology than those in non-science disciplines. This suggests that science students have a more sophisticated understanding of scientific knowledge and its processes. When examining the role of locality, the study revealed no significant difference in the scientific epistemological views of students from urban and rural areas. However, students from urban regions tended to score higher on these views, implying that urban environments might have a subtle influence on the development of scientific epistemological beliefs. Regarding gender, no significant differences were found between male and female students in terms of their scientific epistemological perspectives. Although female students had slightly higher scores on average than their male counterparts, this difference was not statistically significant.

Shah and Choudhary (2022) examined *"Exploring the Relationship between Students' Epistemological Beliefs about Science and Their Approaches to Learning Science."* The study involved 379 secondary science students from four public schools in Chitral, Pakistan, and therefore provides useful South Asian comparative

evidence, although it is not an Indian study. Students completed measures of approaches to learning and epistemic beliefs about science. The findings showed that students' epistemological beliefs were significantly related to their approaches to learning science. The authors emphasized that students' beliefs about the nature and acquisition of scientific knowledge influence how they engage with science learning.

Paubsanon (2023) studied *"Epistemological Beliefs: Implications to the Grade 11 Senior High School Students' Academic Performance in English."* The research involved 129 Grade 11 senior high school students from four sections of a public school in Zamboanga del Sur; this study is from the Philippines rather than India and is included here only as a closely relevant Asian study. The researcher employed a descriptive-correlational design and used a questionnaire based on Schommer's epistemological-belief framework. The study examined the relationship between students' epistemological beliefs and their academic performance in English. The findings supported the importance of students' beliefs about knowledge and learning in understanding their academic performance.

Ahmed and Alshumaili (2023) conducted a study on *"The role of epistemological beliefs and metacognition in Emirati high school students".* Problem-solving performance. The study aimed to investigate the relationships among Emirati high school students' epistemological beliefs, metacognition, and problem-solving performance, as well as to examine how these factors jointly influenced students' ability to solve engineering problems. The sample included 150 high school students from an Emirati urban school district. Furthermore, the study revealed that epistemological beliefs and metacognition played a synergistic role in shaping students' problem-solving performance, enhancing their abilities in problem identification, planning, progress monitoring, and solution evaluation.

Pilla and Chakraborty (2025) conducted *"A Study on the Relationship Between Epistemological Beliefs and Academic Achievement of Secondary School Students."* The sample consisted of 200 secondary school students from Krishna District, Andhra Pradesh, categorized into high-, average-, and low-performing

groups. The researchers examined students' beliefs concerning the nature, certainty, simplicity, and acquisition of knowledge in relation to academic achievement. The findings showed a significant positive relationship between epistemological beliefs and academic achievement, with students holding more sophisticated and complex beliefs tending to demonstrate better academic performance. The study is particularly relevant to Indian secondary education because it provides direct evidence from Andhra Pradesh.

2.8 LITERATURE REVIEW STUDIES ON ACHIEVEMENT IN SCIENCE

Related Studies Conducted in Abroad:

The literature on achievement often focuses on understanding the effectiveness of instruction and identifying factors that influence achievement levels. When it comes to studies related to achievement in science, the emphasis is generally placed on how instructional strategies, student engagement, and external factors such as socio-economic status, teacher quality, and educational resources impact students' performance in scientific subjects.

Ruby (2001) conducted the study on "Science Activities and Achievement in Science" found that hands-on science activities significantly contribute to improved achievement in science among middle school and junior high students. These findings suggest that engaging students in practical, interactive learning experiences enhances their understanding and performance in science. However, the study did not provide substantial evidence to support the effectiveness of performance test programs, particularly those designed to assess knowledge gained through hands-on instruction. In essence, while hands-on activities are beneficial for student learning, the study questioned whether traditional performance tests truly reflect the depth of learning achieved through such experiential methods.

Olatoye, and Ogunkola (2008) conducted a study on "The Relative and Combined Influences of Parental Involvement and Interest in Schooling on Science Achievement of Selected Secondary School Students in Ogun State, Nigeria" reveals some important findings. This suggests that students whose parents are more involved in their education tend to perform better in science. Parental involvement can include activities such as providing academic support at home, attending school events, or encouraging their children’s academic aspirations. Additionally, the study highlights that students who show a greater interest in schooling whether through motivation, engagement in class, or a positive attitude toward learning are also more likely to achieve higher results in science. Furthermore, the study suggests that both parental involvement and student interest in schooling work independently to enhance

students' science performance. When considered together, these two factors likely have a combined effect, reinforcing each other and contributing to even better science achievement. In conclusion, the findings emphasize the importance of both family support and student engagement as key drivers of academic success in science, suggesting that interventions aimed at fostering these factors could potentially improve students' performance in the subject.

Delen (2011) examined The study titled "The Effects of Information and Communication Technologies (ICT) on Students' Science Achievement" explored the impact of ICT on the academic performance of students in Turkey. There were 4,996 pupils aged 15 in the sample. The results showed that students' exposure to technology and familiarity with ICT tools significantly contributed to closing achievement gaps in science and maths, both within and between schools. According to the study, incorporating ICT into the classroom is essential for improving learning outcomes and should be carefully taken into account when creating learning spaces.

Zeid Al-bashaireh (2011) conducted a study on *"The achievement of Tafila schools students in science"*. According to the study, female pupils and the experimental group of students performed noticeably better in science than the other groups. Nevertheless, there was no discernible relationship between the students' gender and the teaching strategy. Several suggestions were given in light of these findings: Given that it seemed to improve science achievement in this study, a holistic approach is recommended for teaching other topics and at various student levels. To better understand how the systemic approach affects scientific student accomplishment, more study is advised to evaluate its efficacy with alternative teaching strategies. In conclusion, the study urges more research to examine its wider use and recommends the employment of a systematic approach to improve student performance in science, especially for female students.

Oludipe (2012) studied about "*Gender Difference in Nigerian Junior Secondary Students' Academic Achievement in Basic Science".* The study found no significant differences in academic performance between male and female students on the pretest, posttest, and delayed posttest assessments. These findings suggest that interventions should not only focus on enhancing the academic performance of girls

but also on making science-related careers more attractive to young, talented women. Such efforts are essential to inspire more women to pursue careers in the pure sciences and science-based fields, ultimately contributing to greater gender diversity in these areas.

Udeani (2012) conducted a study on *"The relationship if any among the variables of study habits, facilitating anxiety and debilitating anxiety on achievement in secondary school science".* The results show that students' study habits were usually positive. Students who established productive study habits tended to do better in science, as evidenced by the strong positive association found between these study habits and their scientific achievement. This implies that students who suffered from crippling anxiety tended to do worse in scientific classes. Curiously, the study also revealed no connection between crippling anxiety and study habits, nor between facilitating anxiety and worry, which might occasionally serve as a motivator for students. This suggests that although anxiety may have an impact on academic performance, its influence on study habits or overall success is more nuanced and cannot be adequately described by a straightforward correlation between these variables.

Sun, Bradley, and Akers (2012) performed the study on "The factors that influence the science achievement of 15-year-old students" revealed several key determinants that contribute to students' success in science. The results showed that the following elements significantly influenced science achievement: Student Gender: It was discovered that gender disparities affect students' performance in science, potentially as a result of differing degrees of support in science courses, cultural expectations, or resource availability. Self-Efficacy: There was a high correlation between students' performance and their confidence in their own capacity to excel in science. Higher science results were more likely to be attained by those who felt more assured of their skills. Family Socioeconomic Status (SES): A student's success in science was significantly influenced by their family's financial and educational circumstances. In general, students from households with higher socioeconomic status had greater access to resources like books, individual tutoring, and encouraging classroom settings. School SES Composition: The school's general

socioeconomic composition was also important. There were generally less resources and difficulties that could affect the general performance of pupils at schools with a larger proportion of kids from lower socioeconomic backgrounds.

Musau and Migosi (2015) aimed to study on *"The teacher qualification influenced students' academic performance in Science".* Eight secondary schools in Kitui County were chosen for the study using random selection and an ex-post-facto survey research design. Both descriptive and inferential statistical techniques were used to analyse the data. The findings showed that student achievement in Science, Mathematics, and Technology (SMT) courses at the Form Four level did not differ statistically significantly in mean performance between teacher qualifications ($F(1, 37) = 0.017$, $p > 0.05$). Subsequent investigation revealed that most SMT teachers had taken in-service or refresher courses and were qualified graduates. Although student performance improved somewhat as a result of these courses, overall student results were not significantly impacted. For SMT teachers to stay current with new pedagogical technology and improve their efficacy as teachers, the study suggests more regular and structured in-service and refresher training programs.

Ataha and Ogumogu (2013) studied *"The level of scientific attitude of senior school science students of Edo state of Nigeria".* Through a descriptive survey study. Results affirmed that majority of the sampled students possessed moderate level of scientific attitude. Also no meaningful difference was found between the boys and girls in their level of scientific attitude. The investigators recommended that the students should be involved in continuous experimentation and other laboratory activities to improve their scientific attitude.

Jen and Yong (2013) conducted a study on *"Student's motivational orientations towards learning of science and achievement in combined science".* The sample consisted of class XI government secondary schools of Brunei Muara district. The Six dimensions of motivation considered in the study were intrinsic motivation, extrinsic motivation, personal relevance, assessment anxiety, self efficacy and self determination. Students were found to have moderate level of motivational orientations taken as a whole. However the level of extrinsic motivation and assessment anxiety in combined science was found to be high. Girls were found to

have better level of motivation in science in comparison to the boys. The high ability group students had high level of motivation whereas the low ability group had moderate level of motivation. Also the correlation analysis revealed positive correlation between motivation and achievement in science of the students.

Osman and Vebrianto (2013) conducted a study on *"The science process skills and enhancing the achievement of students in biology".* The study was carried out on first-year junior high school students in Riau, Indonesia, Malaysia, using a quasi-experimental research methodology. Three groups were randomly selected from among the pupils. Some ICT multimedia tools were used to teach biology to the first group. The third group received no treatment, whereas the second group studied biology in a natural setting. They used traditional ways to study biology. All three groups were given pre- and post-tests on biological achievement and process abilities. Significant differences in the three groups' science process skills and accomplishments were discovered after examination. The group that received ICT treatment had the best outcomes, followed by the second group that received instruction using an environmental module. Therefore, it can be claimed that teaching with ICT and the natural environment enhanced students' understanding of biology and promoted science process abilities.

Sukarno, Permanasari and Hamidah (2013) investigated *"The status of science process skills of students studying in junior high schools of Jambi city, Indonesia".* The pupils chosen as the study's sample were given a questionnaire with twenty multiple-choice questions on fundamental science process abilities. The resulting score was then transformed to a percentage. According to the survey's findings, the majority of students have poor basic science process skills. Thus, the researcher concluded that the current method of teaching science in Jambi City's junior high schools is insufficient to help students acquire the necessary science process abilities.

Abungu, Wachanga and Okere (2014) conducted a study on *"The impact of the teaching approach based on science process skills on students"* Chemistry students' self-concept in secondary schools in Kenya's Nyando district. The control and experimental groups were randomly assigned to the students chosen using the purposive sampling technique. The control group was treated using a science process

skills teaching methodology. Following the treatment, the two groups were given the chemistry self-concept test once more, and the results were once more collected. Both the pre-test and post-test results were examined. The results of the score analysis showed that students' self-concept in chemistry was significantly impacted by the science process skills teaching methodology. Chemistry performance was higher for students who received the process skills treatment than for those who did not.

Musau and Abere (2015) conducted a study on *"Teacher Qualification and Students Academic Performance in Science in Kenya".* The study involved 121 participants and used two primary instruments for data collection: the IPIP-50, which evaluates the Big Five personality traits, and the Self-Rating Scale of Self-Directed Learning (SRSSDL). Students' final grades served as indicators of academic achievement. The findings indicated a significant correlation between the Big Five personality traits and self-directed learning (SDL). Moreover, the analysis revealed that self-directed learning was a key predictor of academic performance, with students who engaged more in independent study tending to achieve higher grades. These results highlight the crucial influence of personality traits and self- directed learning on students' academic success.

Zeidan and Jayosi (2015) conducted a study on *"The knowledge level of science process skills and attitude of students towards science with reference to their gender and residence".* The relationship between these two variables was also studied. The investigators conducted this study on secondary school students of Palestine. When compared with respect to their residence, the students from villages scored higher than the students from cities. However as far as the attitude towards science is concerned, both female and male, as well as students from villages and cities did not differ significantly. Relationship analysis indicated significant association between the two variables namely, process skills and attitude towards science of the students from Palestine.

Deborah et.al., (2015) **s**tudied about *"The Effects of using inquiry-based learning on science achievement for eighth-grade students."* In the IBL group,

students demonstrated effective collaboration as they worked together to research the task and find solutions to the assigned problem. Field notes revealed that students were actively engaged, helping each other understand the steps being taken to complete the task. They brainstormed ideas for potential solutions and, as a class, shared their thoughts on the sequence of steps required for the activity. Comments like, "I'll hold this wire, and you hold the battery, and you can hold the light bulb" reflected the students' ability to stay focused, delegate roles within the group, and work independently with minimal support from the teacher-researcher. These behaviors indicated that the students were not only cooperative but also demonstrated strong problem-solving skills and task management throughout the process.

Mani, et.al, (2015) studied *"Motivation and Engagement as a Predictor of Students' Science Achievement Satisfaction of Malaysian of Secondary School Students".* discovered that students are highly motivated, engaged, and satisfied with their accomplishments. While there is a strong correlation between students' motivation and academic achievement, no significant relationship exists between students' involvement and their satisfaction with achievement.

Nuni, Francis and Andrew (2016) studied *"The effect of the activities of science club on motivation and achievement in Physics of secondary school students of Kenya".* The study sought to explore the relationship between students' interest in Physics and their academic performance. Two groups of students were chosen for the study: one group participated in science club activities, while the other did not. Both students and teachers reported that involvement in the science club significantly boosted students' motivation and interest in Physics. Additionally, the students who took part in the science club showed a modest improvement in their performance compared to their peers who were not involved. These findings suggest that extracurricular activities, such as science clubs, can enhance students' engagement and positively impact their academic achievement in science.

Sen., (2016) conducted the study **"***A study was conducted to explore the relationship between secondary school students' self-regulated learning (SRL) skills and their science achievement".* Key components of self-regulated learning (SRL), including task value, performance approach goals, time management, and study

surroundings, were found to have a high positive correlation with students' academic success in science. Path analysis also showed that metacognitive learning techniques, mastery-approach goals, and effort control had a significant impact on students' capacity to efficiently manage time and study environments. Furthermore, it was discovered that the indirect impacts of effort regulation, metacognitive techniques, and mastery-approach goals on science performance were mediated by time and study environment management. These findings demonstrate the critical role that certain SRL elements have in enhancing academic achievement, showing that encouraging metacognitive abilities and goal- setting can enhance time and study environment management, which in turn can result in improved academic performance.

Aslam., and Ali., (2017) studied about *"Effect of Self-Efficacy on Students Achievement in Science".* A study conducted on secondary school students in Pakistan highlighted that both their intellectual and social self-efficacy levels were significantly elevated. The research underscores the importance of knowledge acquisition in enhancing students' emotional self-efficacy. Furthermore, the findings revealed a strong correlation between students' self-efficacy and factors such as their parents' employment status and educational background. The study suggests that the academic and professional achievements of parents play a pivotal role in shaping the students' sense of confidence and capability in various areas of their lives.

Ado Abdu Bichi., et al., (2017) studied about *"Evaluating secondary School Students Science Achievement".* The study suggests that while students' overall performance in science is satisfactory and generally positive, there are notable differences in how male and female students perform across cognitive (knowledge-based), affective (attitudes and values), and psychomotor (skills and physical tasks) domains. These differences indicate the presence of gender disparities in students' science achievements. To address these disparities, the study recommends that teachers take proactive steps to foster an environment that encourages all students, regardless of gender, to take ownership of their learning. Students should be encouraged to take ownership of their learning through self-directed approaches, fostering a sense of responsibility for their academic growth. In addition, cooperative learning should be prioritized, where students collaborate in teams to solve problems

and complete tasks. This can be achieved by emphasizing self-management, teamwork, and equal participation in scientific learning activities.

Ayibatonye and Ikechi (2017) conducted a study on *"The academic achievement of Nigerian students of River States in relation to their parent's socio-economic status, education and the locality of the school".* It was confirmed from the results that parents' educational level and locality of the school does not play a significant role in their wards performance in science subject. However the socio economic condition of the parents was acknowledged as a potent factor in determining their wards achievement in basic science subjects. Also the combined effect of all these variables was found to effect the achievement of the students in basic science subjects.

Irwanto, Rohaeti, Widjajanti and Suyanta (2017) conducted a study on *"the analytical thinking skills and science process skills of X th grade students of in relation to their learning of chemistry".* It was acknowledged that among the various science process skills, students are good at planning of experiments but find creating of graphs to be a difficult task. Three dimensions of analytical thinking ability considered in this study were the ability of organizing, differentiating and attributing. The students were found to be slight good in the ability of differentiating but they possess very low level of attributing. On the whole the students were found to have low level of analytical thinking ability and process skills in chemistry.

Villa, Candeias and Neto (2017) aimed to investigate the impact of students' attitudes toward the school subjects of Physics and Chemistry, as well as their reasoning abilities, on their academic achievement in these subjects. The ninth-grade Portuguese pupils were the main emphasis. The results showed that students' attitudes towards physics and chemistry and their academic achievement in these courses were positively and significantly correlated. This implies that kids who see certain subjects more favourably typically perform better academically. The study also made clear how important students' thinking skills are to improving their performance in chemistry and physics. In conclusion, the study highlights how critical it is to help students develop good attitudes and excellent reasoning abilities because these elements are crucial for academic achievement in the sciences.

Al-Mutawah and Fateel, (2018) conducted the study examining the influence of grit and attitudes on students' achievement in science, the findings revealed some interesting insights. According to the study, grit—which is characterized as tenacity and enthusiasm for long-term objectives—was positively and significantly correlated with scholastic success in arithmetic alone. This implies that kids with higher grit levels performed better in maths, maybe as a result of the perseverance and fortitude needed to handle the subject's frequently difficult and problem-solving character. However, there was a positive and significant correlation between academic achievement in both science and maths and attitudes towards these topics. This suggests that pupils generally performed better academically in maths and science when they had more positive attitudes and were more interested in both subjects. A positive attitude toward a subject can contribute to increased motivation, engagement, and effort, all of which are essential for academic success. In summary, while grit appears to be more closely tied to success in math, a positive attitude toward both math and science plays a crucial role in enhancing achievement in both subjects. These findings suggest that fostering both perseverance and a positive mindset could be key strategies for improving students' performance in STEM education.

Prinsloo., et al., (2018). conducted a study on *"the impact of language factors on learner achievement in science".* This study is considered significant not only because it draws on data from a reputable international source, but also because it addresses the complex language dynamics commonly encountered in South African schools. The relationship between teaching and home languages, poverty, and other related language conditions is not straightforward, yet the article provides valuable insights into the relative contributions of these factors. However, further research is necessary to explore more nuanced distinctions, particularly concerning school-level socioeconomic status (SES), teacher proficiency, and student motivation to engage with Science.

Anuruba (2019) conducted a study on *"Scientific Aptitude, Science Interest and Learning Environment in Relation to Achievement in Chemistry among Secondary Students in Pondicherry",* The study aimed to evaluate students' achievement in Chemistry and examine factors such as Scientific Aptitude, Science

Interest, and the Learning Environment. The research provided insights into the levels of achievement in Chemistry, scientific aptitude, interest in science, and the characteristics of the learning environment. The findings revealed significant differences in students' scientific aptitude, interest in science, and the learning environment, all of which were closely related to their performance in Chemistry.

Santy (2019) in their study on, *"Utilization of science laboratories in government and private secondary schools students and teachers in Kollam District Kerala a comparative study",* intended to compare the available laboratory facilities and the extent of utilization of science laboratories by the students and teachers of government and private higher secondary school in the district of Kollam in Kerala.

Shakerian et al., (2020) conducted a study on "*The Use of the Jigsaw Cooperative Learning Technique for the Health Science Students in Iran".* The Jigsaw approach was compared to other teaching styles in experimental and quasi-experimental studies that were part of the study. Numerous cognitive and non-cognitive outcomes were evaluated, including communication skills, teamwork, and knowledge retention. In order to ensure an estimation of the overall influence of the Jigsaw technique, the analysis employed Comprehensive Meta-Analysis software with a fixed-effects model to summarise the results. In order to ascertain whether the findings were consistent across various groups and circumstances, the research' heterogeneity was also assessed. The Jigsaw method is infrequently used in medical education, according to the national literature survey, which raises the possibility that this technique has unrealised potential in this area. The results highlight the necessity of creating and incorporating cooperative learning strategies like the Jigsaw approach within medical education institutions, given the favourable impacts seen in both cognitive and non-cognitive outcomes throughout the research. These methods could improve students' academic achievement as well as their teamwork and interpersonal abilities, which are vital in the medical field.

Yilmaz., (2020) conducted to investigate the impact of instruction using concept cartoons on students' academic achievement in science. The study tested the performance of fourth-grade primary school pupils in the science lesson on "The Earth's Crust and Movements of the Earth." According to the findings, pupils in the

experimental group who were instructed using concept cartoons— performed noticeably better academically than those in the control group. There was a noticeable difference in the experimental group's performance on the accomplishment test. According to these results, students' comprehension and academic achievement in science were improved by the use of concept cartoons as a teaching tool.

Bara and Xhomara., (2020) studied about *"The Effect of Student Centered Teaching and Problem-Based Learning on Academic Achievement in Science".* Although there is a connection, it is not particularly strong, according to the study's minimal positive association between academic accomplishment and a student-centered teaching strategy. However, it showed notable differences, indicating that the student-centered approach may have had some effect on academic achievement. Furthermore, the study found a moderately positive relationship between academic success and problem-based learning (PBL). This suggests a stronger, albeit still modest, correlation between enhanced academic performance and PBL utilization. Once more, notable distinctions between the experimental and control groups were discovered, highlighting how well problem-based learning can raise students' academic achievement. The study also showed that a comparatively large portion of the variation in academic achievement levels could be explained by the combination of problem-based learning and the student-centered teaching method. This implies that the combination of these teaching strategies has a significant effect on students' academic achievement.

Funa and Prudente (2021) conducted a study entitled *"Effectiveness of Problem-Based Learning on Secondary Students' Achievement in Science: A Meta-Analysis."* The study synthesized 11 studies conducted from 2016 to 2020, including six studies with junior-high-school students (n = 1,047) and five with senior-high-school students (n = 375) across Eurasia, Africa, and the Americas. The meta-analysis examined the effectiveness of problem-based learning in improving achievement across different science disciplines. The findings revealed a large positive overall effect (Hedges' g = 0.871) of problem-based learning on secondary students' science achievement. The authors concluded that problem-based learning is an effective approach for improving science achievement among secondary school students.

Schneider et al. (2022) investigated *"Improving Science Achievement—Is It Possible? Evaluating the Efficacy of a High School Chemistry and Physics Project-Based Learning Intervention."* The study involved high school students participating in a project-based learning intervention in chemistry and physics, with treatment and control groups. Students in the intervention experienced a coherent approach involving modeling practices, teacher professional learning, and formative assessment. The treatment group performed approximately 0.20 standard deviations higher than the control group on an independently developed summative science assessment. The researchers concluded that coherent project-based learning approaches can produce meaningful improvements in secondary students' science achievement.

Hu, Peng, and Ma (2022) examined *"Examining the Contextual Factors of Science Effectiveness: A Machine Learning-Based Approach."* The researchers analysed 79,963 science scores of secondary students from 53 countries/economies using PISA 2015 data. The study examined student-, classroom-, and school-level contextual factors associated with high and low science achievement. Using machine-learning techniques, the researchers identified 30 important factors from 127 contextual variables that differentiated high- and low-performing students. The findings demonstrated that science achievement is influenced by a multidimensional combination of student characteristics, classroom conditions, and school-level factors.

Dong, Chiu, Zhou, and Zhang (2024) conducted *"The Effect of Mobile Learning on School-Aged Students' Science Achievement: A Meta-Analysis."* The researchers reviewed 44 controlled experimental studies involving 4,145 primary and secondary students, producing 57 effect sizes. The meta-analysis examined whether mobile-learning approaches improved achievement specifically in science and investigated possible moderators related to learning activities. The findings showed a large positive overall effect ($g = 0.857$) of mobile learning on science achievement. The authors concluded that appropriately designed mobile-learning activities can substantially improve science learning outcomes among school-aged students, including secondary students.

İnce (2023) investigated *"Examining the Role of Motivation, Attitude, and Self-Efficacy Beliefs in Shaping Secondary School Students' Academic Achievement in Science Course."* The study focused on secondary school students in Türkiye and examined how motivation, attitudes toward science, and science self-efficacy were associated with academic achievement. Data were collected using measures of students' motivation, attitudes, and self-efficacy together with their science achievement. The findings indicated that motivational beliefs, positive attitudes, and self-efficacy were important factors associated with students' academic achievement in science. The study highlighted the importance of addressing both cognitive and affective factors when attempting to improve secondary students' science achievement.

Cebrero (2025) conducted a systematic review entitled *"21st Century Skills and Science Achievement among Secondary School Students: A Systematic Review."* The researcher searched 17 major online databases and initially identified 684 studies, of which 17 studies met the inclusion criteria. Most of the selected studies examined the development of 21st-century skills and used quasi-experimental approaches with secondary students. The review found that pedagogical approaches designed to develop critical thinking, collaboration, communication, problem-solving, and other 21st-century skills generally supported improved science achievement. The study concluded that integrating 21st-century skills into science instruction can contribute to better learning and achievement among secondary school students.

Related Studies Conducted in India:

Kaur (2012) revealed that achievement in science has no significant relationship with study habits but some learning styles had favourable effects.

Mohammadpour (2012) in the journal "The Trends in International Mathematics and Science Study (TIMSS)" reported significant changes in the science achievement of secondary school students over time. Notably, the TIMSS 2007 cycle revealed a considerable widening of the gap in science achievement at both the student and school levels when compared to the 1999 and 2003 assessments. This indicates that disparities in student performance and school outcomes have become more

pronounced, suggesting a growing achievement divide or the emergence of different educational contexts during the 2007 cycle.

Nataraj and Manjula (2012) conducted a research study on *"the effect of gender, religion and area of school on scientific aptitude and academic achievement in science subject of students studying in high schools".* The study found that gender did not significantly influence scientific aptitude or achievement in science. Additionally, the research examined the impact of students' religion categorized as Hinduism, Islam, and Christianity on their scientific abilities. The findings indicated no notable differences in scientific aptitude and achievement based on religious affiliation. However, a significant distinction was observed between students from urban and rural areas, with rural and urban students displaying differing levels of aptitude and achievement in science. Furthermore, the study revealed a positive correlation between scientific aptitude and achievement, meaning that as one increased, so did the other.

Mehar and Kumar (2013) research showed that students taught physics using audiovisual aids achieved significantly higher scores compared to those who were taught using traditional methods.

Mondal, Mondal and Saha (2013 found that there was no discernible difference in secondary school achievement between male students in urban and rural areas. Additionally, secondary school achievement varies greatly between urban and rural female pupils.

Sekar and Mani (2013) conducted a study on "*The status of science attitude of biology group students studying in class XI of higher secondary schools of Thiruvannamalai district of Tamil Nadu"*. For the study, the researchers used the survey approach. The results showed that students who lived permanently in cities had a higher degree of scientific attitude than students who lived in rural areas. There were also notable differences between the children in terms of how their school was run. When contrasted based on their attitude towards science, pupils from government and government-aided schools performed worse than those from unassisted schools.

Ksheerasagar and Kavyakishore (2013) conducted a study on "*The relationship of achievement in science and scientific attitude among students of ninth grade of Bangalore".* The findings indicated that girls outperformed boys in scientific classes. Additionally, it was discovered that pupils attending private schools outperformed those attending public schools in terms of their science achievement. It was discovered that students' attitudes towards science were a predictor of their success in the subject. There was a positive correlation between students' science performance and their attitude towards science. i.e., their achievement is high when their attitude towards science is high, and vice versa.

Mukhopadhyay (2013) conducted a study on *"The relationship of aptitude in physics, scientific attitude and deep study approach with achievement in physics of class XII students studying in schools affiliated by West Bengal council of higher secondary education".* The findings of the investigation revealed that aptitude in physics, scientific attitude and two sub-dimensions of deep approach to study namely, use of evidence and relating ideas were found to strongly correlate with achievement in physics of the students. i.e. presence of these factors positively contribute in enhancing the performance of the students in physics. At bi-variate level one of the sub-dimensions of deep study approach namely deep processing was found to be related with students' performance in physics. However it was not found to predict achievement at multivariate level. Also at both the levels, intrinsic motivation dimension of deep study approach was not found to be a potent factor of students' achievement in physics.

Mishra and Yadav (2013) conducted a study on "*Effect of Activity Based Approach on Achievement in Science of Students".* The data analysis indicates a significant difference in the mean achievement scores between the control group, which received traditional instruction, and the experimental group, which was taught using an activity-based approach. Based on this analysis, the hypothesis is supported. Consequently, it can be concluded that the activity-based teaching strategy has a substantial positive impact on the academic performance of Class VII students, both in subject-specific areas and broader skills.

Narmadha and Chamundeswari (2013) conducted to investigate the relationship between students' attitudes toward learning science and their academic achievement in science at the secondary school level. Their findings revealed several noteworthy trends: Attitude Towards Learning Science: Students from Central Board schools exhibited a significantly more positive attitude towards learning science compared to their peers in State Board schools. However, when comparing Matriculation Board students to those in Central or State Board schools, no significant differences in attitudes were observed. Academic Achievement in Science: Central Board students outperformed students from both State and Matriculation Board schools in academic achievement in science. This suggests that the educational framework of the Central Board might be contributing to higher academic performance in science. Gender Differences: Female students consistently displayed a more favorable attitude towards learning science across all three school boards. Additionally, girls in Central and Matriculation Board schools performed better than boys in secondary-level science courses, indicating a noticeable gender gap favoring girls in both attitudes and academic achievements in science. Relationship Between Attitude and Achievement: A positive correlation was found between students' attitudes towards science and their academic performance in the subject, regardless of the school board they attended. This underscores the importance of fostering a positive attitude towards learning science to improve academic success.

Singh and Imam (2014) analysis showed that students' attitudes towards science and their scientific achievement were positively correlated. Additionally, it was discovered that pupils' success in science was positively correlated with the educational attainment of their parents. Furthermore, there was a favourable correlation between students' scientific achievement and the size of their family.

Chandrasekaran (2014) conducted a study on *"Interest, scientific attitude, critical thinking and creative intelligence of in teaching and learning biology through synectics techniques at secondary level to students"* The purpose of the study was to evaluate how Synectics practices affected students' critical thinking, scientific attitude, interest, and creative intelligence. Thirty students from the XI class of a

government higher secondary school in Chennai who were all enrolled in biology as an elective made up the sample. These pupils were split up into two groups, each consisting of 15 students: the experimental group and the control group. Based on their pretest results in the chosen area of biology, the two groups were equated to make sure they were equivalent. This means that the groups were matched in terms of their prior knowledge before the intervention. The experimental group received the Synectics technique as part of their learning process, according to the data. According to the study, using Synectics procedures significantly improved a number of important variables. Interest in biology, scientific mindset, critical thinking, and creative intelligence all improved in the experimental group. This shows that using Synectics techniques in biology classes might help students become more engaged and develop cognitively, especially when it comes to improving their creativity and problem-solving abilities. Additionally, the study took gender into account as a variable, examining any possible variations in how the treatment affected male and female pupils.

Nambikkai and Manoharan (2014) studied *"The science attitude of secondary school students with respect to gender, locality, religion, father educational qualification, father's annual income".* A sample of 145 secondary school students from the Pondicherry region participated in a study examining their attitudes towards science, which led to several notable conclusions: No Significant Difference in Students' Attitudes towards Science: The study found that there were no significant variations in students' overall attitudes towards science. This suggests that factors like individual characteristics or educational background may not play a major role in shaping how students perceive science. No Significant Difference between Rural and Urban Students: There was no noticeable difference in the attitudes of rural and urban students towards science. This indicates that despite potential differences in their learning environments or resources, both groups shared similar perspectives and interest levels in science. Fathers' Educational Background Does Not Impact Students' Attitudes: The research revealed that a student's attitude towards science was not significantly affected by the educational background of their father. This suggests that factors beyond parental education, such as personal experiences or the quality of

instruction, may have a more substantial influence on students' attitudes towards science. No Impact of Fathers' Financial Status: The study also found that the financial status of a student's father did not appear to affect their attitude towards science. This implies that socioeconomic factors, as indicated by parental income, do not directly influence students' attitudes towards science. No Significant Difference Based on Religion: The study showed no significant differences in students' attitudes towards science based on their religious backgrounds. This finding suggests that exposure to scientific information and educational practices might have a greater influence on students' views of science than religious affiliations.

Srivastava (2014) conducted a study on *"The achievement in science contributes to prediction of scientific attitude in intent as well as action".* A sample of 480 ninth-grade students from Allahabad, India—240 boys and 240 girls were included in the study. K.S. Misra's Scientific Attitude Questionnaire and the researcher's Science Achievement Test (Form A) were the two evaluation instruments utilized. The results showed significant gender variations in the association between scientific mindset and science achievement. Male students' scientific attitude, especially with regard to intent, was not significantly influenced by their scientific knowledge, understanding, or application. In particular, male students who showed a greater capacity to understand scientific ideas did not exhibit a commensurate gain in their practical scientific attitude. On the other hand, it was discovered that among female students, scientific comprehension was a significant predictor of their scientific attitude with regard to aim. Furthermore, scientific knowledge was found to be the most important predictor of their activities' scientific attitude. This implies that girls' attitudes towards science were significantly shaped by their level of knowledge as well as their comprehension of scientific concepts. With female students demonstrating a larger correlation between cognitive achievement and attitudinal outcomes in science, these findings emphasize gender variations in how scientific knowledge and comprehension impact students' scientific attitudes.

Singh and Imam (2014) conducted a study on *"The science achievement of ninth grade students of central Uttar Pradesh in reference to their attitude towards science, gender, size of the family and parental education".* From the findings boys

and girls differed significantly in their science performance. Size of the family also affected students' achievement in science. Students coming from smaller families performed better than those coming from larger families. Furthermore the study also showed that the education of the parents was also associated with their wards' performance. Wards of more educated parents were found to have better performance in science than wards of less educated parents.

Panneerselvam and Muthamizhselvan (2015) studied "*The performance of the students in science subject studying in class IX of Cuddalore district of Tamil Nadu".* The analysis of data revealed that gender, school management, and the level of scientific attitude significantly influence students' performance in science. Specifically, girls in Class IX and students from private schools outperformed boys and those from government schools, respectively, in science achievement. Additionally, students exhibiting high and moderate levels of scientific attitude achieved better results compared to those with a low level of scientific attitude. This indicates that a positive scientific attitude is strongly correlated with higher performance in science. Therefore, it can be concluded that scientific attitude is a crucial factor influencing students' success in science education.

Kaur et al (2015) studied *"The achievement in science of senior secondary school students in Sangrur District of Punjab State in relation to the gender, habitation and scientific attitude".* The study employed a descriptive survey research design, utilizing simple random sampling to select a total of 200 senior secondary (Grade XII) students from both urban and rural areas within the district. The aim was to assess their achievement in science and their scientific attitudes. The findings revealed no significant differences between male and female students, nor between students from rural and urban regions, regarding their achievement in science. However, when examining scientific attitude, several notable patterns emerged. Gender Differences: Boys demonstrated a higher level of scientific attitude compared to girls. Location-Based Differences: Urban students exhibited a stronger scientific attitude than their rural counterparts. Medium of Instruction: Students studying in English-medium schools showed a higher level of scientific attitude than those in

Telugu-medium schools. School Type: Students from self-financed schools displayed a more positive scientific attitude than those attending government or aided schools. These findings suggest that while achievement in science is not influenced by gender or geographical location, factors such as gender, medium of instruction, and type of school attended have an impact on students' scientific attitudes.

Stanley (2016) studied *"The scientific aptitude and its relationship with science achievement".* This study was conducted on class IX students of Pondicherry region. The result revealed that majority of students had low level of scientific aptitude and their performance in science was also not satisfactory. A moderate positive relationship is found to exist between achievement and aptitude in science. Hence scientific aptitude is an important determinant of students' achievement in science. Higher the level of scientific aptitude better will be the students' performance in science.

Sangwan (2016) studied "*The Effect of mastery learning has described about the Effect of mastery learning strategy on pupils achievement in Science*". their self concept adjustment and classroom trust behaviour. Similarly, Joshi, Sarita (20-Oct-2014) has described the Effectiveness of mastery learning model, concept attainment model and traditional methods in teaching science in context of self efficacy persistence and study habits.

Kaur (2016) studied *"The secondary school students' academic performance was examined in connection to their metacognition and problem-solving abilities".* Both boys and girls in the science stream of Amritsar District's CBSE and PSEB districts were included in the random sample of 200 students in XI grade. The data was collected using the Metacognition Inventory and the Problem-Solving Ability Test Students in the medical track of CBSE and PSEB schools showed no significant differences in metacognition and problem-solving abilities between females and boys. Medical students from CBSE and PSEB schools have vastly different problem-solving abilities, though. No correlation exists between metacognition, problem solving skills, and secondary school pupils in the medical stream's academic performance. Secondary school pupils in the medical stream, however, showed no significant connection between metacognition and problem- solving abilities.

Singh (2019) studied *"Effect of cooperative and personal learning ways on vital thinking and learning outcomes in science in relevance intellectual ability".* The style of the study was pretest posttest management cluster. Sample of the study was 102 students of Hoshiapur, Punjab. The most findings discovered that cooperative and Individualized learning unit significantly effective in up necessary thinking, accomplishment and interest in science of the students, but cooperative learning is less complicated as compared to Individualized learning. These ways put together showed stable effects at delayed post check stage. Students with high ability performed higher as compared to students with average ability in necessary thinking. Students with high ability performed a bit like students with average ability in accomplishment and students with average ability performed above students with high ability in interest. There was important interaction impact of treatment variables (cooperative and individualized learning) and ability groups.

Lalrinmawia and Lallianzuali Fanai, (2020) conducted a study on *"The achievement in science among higher secondary school students of Aizawl".* This study's main goals were to evaluate the degree of science proficiency among upper secondary school pupils, compare the performance of male and female students, and examine the differences in performance across government, deficit, and private schools. A sample of 298 pupils from government, public, and private schools were given a science achievement test that was created and standardized by Drs. SC Gakhar and Rajnish. With 95.64% of participants falling into the "below average" group, the results showed that students' overall science achievement was noticeably low. There were no discernible variations in male and female pupils' science achievement, according to the analysis. Additionally, there were no appreciable distinctions in academic performance between government and private school pupils. Nonetheless, a notable distinction was noted between students from government and private schools and those from deficit schools, with the former group outperforming the latter.

Kumar (2021) conducted a study on *"Achievement in science of secondary school students in relation to their attitude towards science".* This study examines the connection between science achievement and secondary school students' attitudes towards science. The results show a strong beneficial relationship between students' science performance and their attitudes towards the subject. Students who have more

positive attitudes towards science demonstrate better levels of science achievement than those who have average or negative attitudes, according to the results of the 't' test. This emphasizes how crucial it is to foster a favorable attitude towards science from the very beginning of education. One important tactic for raising pupils' academic achievement in science is to encourage a positive attitude towards the topic. Therefore, it is crucial to put policies in place that encourage students to have a positive scientific mindset from the very start of their education.

Joshi and Sheela (2020) conducted *"A Study of Critical Thinking Ability and Achievement in Science among Secondary School Students."* The study used a descriptive survey method and examined secondary school students using a researcher-developed critical-thinking test and science achievement test. The researchers used Pearson's product-moment correlation and t-test to analyse the data. The findings showed significant gender differences in both critical-thinking ability and achievement in science, with female students showing higher critical-thinking ability while male students demonstrated higher science achievement. A positive relationship was also found between critical-thinking ability and achievement in science, indicating that students' higher-order thinking is associated with better science learning outcomes.

Saha, Bagchi, and Bairagya (2021) studied *"A Study of Achievement Motivation and Attitude towards Science across Gender for Secondary Students and Their Impact on Achievement in Science."* The study examined Grade 10 secondary students and investigated achievement motivation, attitudes toward science, gender, and science achievement. The researchers found no significant gender differences in achievement motivation, attitude toward science, or science achievement. However, significant differences in science achievement were observed across different levels of achievement motivation and different types of attitudes toward science. The study therefore suggested that students' motivation and attitudes toward science may be more important for science achievement than gender alone.

Dar and Majid (2022) conducted *"Scientific Aptitude as a Predictor of Achievement in Science: A Study of Economically Disadvantaged Students."* The

study focused on economically disadvantaged secondary school students in Jammu and Kashmir, India, examining their scientific aptitude and achievement in science. The researchers sought to determine the level of science achievement among economically disadvantaged students and investigate whether scientific aptitude could predict their achievement. The study reported differences in scientific aptitude and examined its relationship with science achievement. The findings indicated that scientific aptitude is an important factor to consider when understanding science achievement among economically disadvantaged secondary school students.

Sharma and Yadav (2023) investigated *"Scientific Attitude of Secondary School Students in Relation to Their Achievement in Science."* The study included 250 secondary school students and examined the relationship between scientific attitude and science achievement, along with gender and type of educational institution. The findings indicated that female students demonstrated a significantly more positive scientific attitude than male students. The study further examined the relationship between students' scientific attitudes and their academic achievement in science. The results emphasized the importance of developing positive scientific attitudes as part of improving students' science learning and achievement.

Pal and Dey (2024) conducted *"Exploring Gender Disparities in Science Achievement: The Impact of Student Engagement among Secondary School Students in West Bengal."* The study used a cross-sectional survey involving 1,232 secondary school students in West Bengal selected through multistage sampling. Student engagement was measured through emotional, behavioural, and cognitive dimensions, while science achievement was based on students' end-of-year examination marks in physical science. The findings showed a significant relationship between student engagement and science achievement, with emotional, behavioural, and cognitive engagement significantly predicting achievement. The researchers recommended engaging classroom activities and supportive teaching practices to improve students' participation and science achievement.

Thokchom, Aribam Devi, and Singh (2025) examined *"Evaluating Science Academic Achievement of Secondary School Students: A Study on Subject-Wise Performance*

and Gender Differences." The study involved 387 Class IX and X students from secondary schools in Thoubal District, Manipur, selected through simple random sampling. A standardized Science Achievement Test was administered to assess students' performance in physics, chemistry, and biology. The findings showed an average overall science achievement, with a mean score of 49.37 out of 75; achievement was highest in biology, followed by chemistry and physics. Female students obtained a higher mean science-achievement score than male students, indicating the need for innovative and learner-centred approaches to strengthen science learning.

2.9 Significant Relationship between Variables

Tsai (2000) found it is essential for educators to recognize and understand students' epistemological orientations toward scientific knowledge when designing learning experiences. By aligning teaching strategies with students' epistemological preferences, especially for those with a constructivist orientation, teachers can create more effective and engaging science lessons. For students who lean toward constructivist epistemologies those who view knowledge as actively constructed rather than passively received lesson designs that emphasize inquiry-based, hands-on activities and collaborative problem-solving will be particularly beneficial. These types of learning experiences support deeper understanding and critical thinking, fostering an environment where students are encouraged to actively engage with, question, and build upon scientific concepts. Ultimately, by catering to these epistemological preferences, teachers can enhance science learning and promote more meaningful, long-lasting knowledge acquisition.

Paul (2003) in his study demonstrated that young children possess epistemological beliefs about science, particularly regarding the sources, certainty, development, and justification of knowledge. These beliefs evolve as children grow, with noticeable changes over time. However, factors such as gender, ethnicity, and

socioeconomic status (SES) do not appear to have a significant impact on children's epistemological thinking and beliefs.

Usher and Pajares (2008) investigated the one-dimensional factor structure of the Children's Self-Efficacy Scale by Bandura across elementary, middle, and high school student groups. It aimed to assess the measurement invariance of the scale, focusing on gender and school level. This analysis ensures that the scale is measuring the same underlying construct (self-efficacy) in the same way, regardless of gender or educational level. By testing measurement invariance, the study aimed to determine whether the scale provides consistent and reliable results across different groups of students, allowing for meaningful comparisons between gender and school level categories. The results from this study are important as they confirm the applicability of the Children's Self-Efficacy Scale across diverse educational stages (elementary, middle, and high school) and for both male and female students. Establishing measurement invariance helps ensure that any observed differences in self-efficacy between gender or school level are not due to measurement biases, but rather reflect true differences in the construct of self-efficacy. This strengthens the validity of the scale for use in educational settings and research across various demographic groups.

Ogan-Bekiroglu and Sengul-Turgut (2008) observed that teaching methods and strategies grounded in the constructivist approach facilitated students in advancing their epistemological beliefs in physics to higher levels. Through activities such as group work, brainstorming, and discussions, students had the opportunity to reflect on their own beliefs and experiences, while also becoming more aware of their peers' perspectives. This collaborative environment fostered the argumentation and exchange of different ideas, enhancing their understanding and engagement with the subject matter.

Ozkal and Tekkaya (2009) suggested that students' perceptions of a constructivist learning environment can directly and indirectly influence their learning approach, with this impact occurring through their scientific epistemological beliefs. Specifically, how students view and engage with a learning environment based on constructivist principles may shape their beliefs about knowledge and the

nature of science, which in turn affects how they approach learning tasks and challenges.

Alt (2015) demonstrated that students in a problem-based learning (PBL) environment perceive the learning atmosphere as more aligned with constructivist principles and report higher levels of academic self-efficacy compared to those in a traditional lecture-based setting.

Fatih Ayaz (2015) research suggested that the constructivist learning approach has a more substantial impact on learners' academic achievement compared to traditional teaching methods. Constructivism, which emphasizes active learning through exploration, problem-solving, and collaboration, encourages students to construct their own understanding of concepts. This stands in contrast to traditional methods that often rely on rote memorization and passive reception of information. By promoting critical thinking and deeper engagement with content, constructivism helps students develop skills that are essential for long-term academic success. Additionally, the personalized nature of constructivist learning fosters greater motivation and retention, contributing to improved academic performance.

Halis (2015) in his findings revealed a statistically significant relationship between the belief that learning is dependent on talent, along with other sub-dimensions of epistemological beliefs, and academic achievement.

Singh (2015) emphasized the urgent need to reform our teaching practices in accordance with the recommendations of the National Curriculum Framework (NCF) 2005. In this context, she advocated for adopting constructivism as a core approach to teaching science. According to her, constructivism goes beyond viewing science merely as a body of knowledge or language; it is a dynamic process that enables students to actively make sense of the world around them, fostering deeper understanding and critical thinking. This approach encourages learners to engage with scientific concepts through exploration, inquiry, and real-life applications, making learning more meaningful and relevant.

Dagar and Yadav (2016) focused that effective education is a process where the teacher, children and school involved and participated actively. In his journal, he

outlined the necessity of reimagining education to emphasize critical thinking through the lens of constructivist pedagogy. He proposed that every learner brings a unique set of concepts and skills what he described as a "toolkit" which they must actively use to build knowledge and tackle real-world challenges. This process, he argued, requires educators to create environments that encourage problem-solving and intellectual exploration, allowing students to engage with complex issues and refine their cognitive abilities in the process.

Bircan Dokmecioglu, Yasemin Tas and Sundus Yerdelen (2018) found that students' confidence in their own scientific efficacy were positively and statistically significantly impacted by every perceived aspect of a constructivist science learning environment. The study specifically showed that students tend to become more confident in their capacity to understand science when they are actively involved in their education, given the chance to ask questions, take part in class discussions, and share what they have learnt with their classmates. According to the results, students are more likely to have greater levels of self-efficacy in science if they believe that their science learning environment is more constructivist and includes these interactive and student-centered elements. Put another way, students' confidence in their ability to excel in science is positively impacted by a constructivist approach to teaching the subject.

Mustafa (2019) research showed a strong positive correlation between academic flow and academic achievement. It has been suggested that experiencing flow in academic tasks can significantly predict higher academic performance, particularly at the secondary school level. Students who enter a state of flow characterized by deep focus, intrinsic motivation, and engagement are more likely to achieve better academic outcomes compared to those who do not experience flow in their studies.

Chandi (2020) emphasized its positive impact across various educational fields. He argued that implementing constructivist principles helps students develop key skills such as problem-solving, flexible thinking, and reflective reasoning. Additionally, it encourages learners to make meaningful connections between the subject matter and their personal experiences. Through this approach, students learn

to express their ideas clearly, engage in effective communication, and collaborate with others while sharing their findings. Ultimately, the constructivist approach nurtures a deeper, more dynamic understanding of content and enhances critical thinking skills.

Singh (2020) explained that constructivist classroom is productive and outcomes from its participants are significantly greater than traditional classroom. Constructivist classrooms become multi-dimensional, with different type of activities at different levels taking place instantaneously. Constructivism is a system for education to give more responsibility on learner for the construction of their understanding.

Ongowo (2021) found that Epistemological beliefs of the domains of certainity and justification were predictors of science achievement.

Eka Apristian Pantu (2021) observed that an increase in academic self efficacy will also increase academic flow. He concludes that there is a significant and positive effect of academic self efficacy on academic flow which means the academic self efficacy that exists in individuals can be a predictor of their academic flow.

2.10 Identification of the Research Gap

The review of related literature reveals that considerable research has been conducted on constructivist learning strategies, self-efficacy, epistemological beliefs, and achievement in science among school students. Studies on constructivist learning strategies have generally demonstrated that learner-centred, inquiry-oriented, problem-based, and constructivist approaches can enhance students' science achievement. Similarly, research on self-efficacy has established that students' beliefs in their capabilities are positively associated with academic and science achievement, although anxiety and other contextual factors may influence this relationship.

The literature indicates that constructivist learning strategies and self-efficacy have frequently been examined as separate variables, rather than as interconnected factors influencing secondary school students' achievement in science. Although some studies have investigated the relationship between self-efficacy and science

achievement, relatively fewer studies have examined whether constructivist learning environments can strengthen students' self-efficacy and subsequently contribute to better science achievement. This creates an important conceptual gap in understanding the psychological mechanism through which learner-centred teaching approaches may influence students' learning outcomes.

A further gap is evident in relation to epistemological beliefs. Existing studies have shown that secondary students differ in their beliefs concerning the certainty, simplicity, source, and justification of knowledge, and that these beliefs can be related to learning approaches and academic outcomes. Nevertheless, epistemological beliefs have comparatively rarely been integrated with constructivist learning strategies, science self-efficacy, and science achievement within one comprehensive research framework. In particular, there is a need to determine whether students who hold more sophisticated beliefs about scientific knowledge respond more positively to constructivist learning experiences.

Another important gap concerns the Indian context. Recent Indian research has examined science self-efficacy among secondary students and has developed instruments specifically for measuring science self-efficacy. There are also Indian studies examining constructivist approaches and science achievement. However, the available literature remains comparatively limited when all four variables are considered together. Thus, more empirical evidence is required from Indian secondary schools, particularly across different gender, locality, school-management, socioeconomic, and academic-background groups.

There is also a methodological gap. Much of the existing research uses descriptive, correlational, or quasi-experimental designs focusing on one or two variables at a time. For example, science self-efficacy studies have examined its relationship with achievement, while intervention studies have focused primarily on the effectiveness of constructivist teaching. There is a need for research employing a more comprehensive design to examine the direct and interrelated contributions of constructivist learning strategies, self-efficacy, and epistemological beliefs to students' achievement in science.

2.11 Critical Appraisal and Summary of the Related Literature

A review of the related literature is essential for planning and conducting meaningful research. The review of studies presented in the preceding sections indicates that a number of researchers have investigated Constructivist Learning Strategies, Epistemological Beliefs, Self-Efficacy, and Achievement in Science among school students. The findings of several studies indicate significant positive relationships among these variables. Some studies have also reported significant differences in these variables with respect to gender, locality (rural and urban), and type of school management (government and private schools)**.** However, the findings of different studies are not always consistent, indicating the need for further investigation.

The review further reveals that most studies conducted in India and abroad have examined these variables either independently or in pairs. Although Constructivist Learning Strategies have been found to contribute positively to students' learning and achievement, comparatively fewer studies have examined their relationship with Self-Efficacy and Epistemological Beliefs simultaneously. Similarly, several studies have established the importance of Self-Efficacy in students' academic performance and science achievement, while relatively limited research has examined how Self-Efficacy interacts with students' Epistemological Beliefs and their exposure to Constructivist Learning Strategies.

The review also indicates that Epistemological Beliefs have received comparatively less attention at the secondary school level, particularly in the Indian context. Students' beliefs about the nature, certainty, simplicity, source, and justification of knowledge may influence the way they engage in learning and construct scientific knowledge. However, only a limited number of studies have investigated Epistemological Beliefs in relation to Constructivist Learning Strategies, Self-Efficacy, and Achievement in Science within a single research framework.

Furthermore, although studies have reported differences based on gender, rural–urban locality, and school management**,** there is insufficient evidence regarding

the combined influence of these variables among secondary school students. The review also reveals a need for more systematic empirical research involving larger and more diverse samples of secondary school students, particularly in the Indian educational context.

Thus, the critical appraisal of the related literature reveals a clear research gap. There is a need for an integrated study examining Constructivist Learning Strategies, Epistemological Beliefs, and Self-Efficacy in relation to Achievement in Science among secondary school students. The present study is therefore undertaken to address these gaps and to provide empirical evidence regarding the relationships among these variables and their possible differences across selected demographic and educational variables. The findings of the study may contribute to a better understanding of the instructional, cognitive, and psychological factors associated with science achievement at the secondary school level.

2.12 CONCEPTUAL FRAMEWORK DEVELOPED AFTER COMPLETING THE LITERATURE REVIEW

The following conceptual framework is developed based on the detailed review of the literature of the variables of the present study and the identified research gaps:

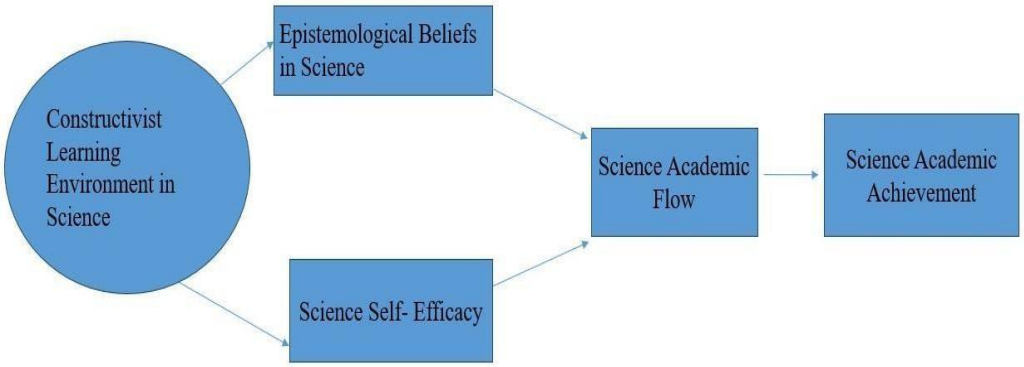


Fig. 2.1 Conceptual Framework of the Study

2.13 Conclusion

In summary, the critical evaluation of the literature indicated that these studies' conclusions were limited to their scope of application and hence to the stated problem. The current study has recognized the need to view the situation from several angles, and it is hoped that the findings will surely deal with today's educational and psychological challenges.

CHAPTER-III

RESEARCH DESIGN

CHAPTER – III RESEARCH DESIGN

3.1 INTRODUCTION

Research design is a critical juncture in the investigation of any research problem which acts as the fruition of the efforts placed during the literature review stage and is the seed of successive exercises of data collection analysis and interpretation. The present chapter discusses in detail the methodology adopted to collect the empirical data from the sample subjects optimally representing the population of the study from the entire state of Andhra Pradesh. It also discusses in detail about means or the instruments used to collect the data by scientifically selecting the sampling units.

3.2 METHODOLOGY

In this study, a descriptive survey method was employed as the core research design. This approach involves a quantitative analysis of trends, opinions, or attitudes within a population, based on a sample drawn from that population (Creswell, 2016). Descriptive research seeks to characterize the features of a sample and explore relationships between phenomena, situations, and events observed by the researcher (Rubin and Babbie, 2008; Thomlison, 2001). The focus of this method is to address the fundamental questions of *who, what, when, where,* and *how*, providing insights into the characteristics and dynamics of the sample under study.

A survey, as defined in this context, is the process of gathering data from a sample of individuals through their responses to specific questions or items designed to measure the variables of interest (Check and Schutt, 2012). This design offers flexibility in terms of participant recruitment, data collection strategies, and the use of various instruments to capture relevant data.

In the present study, a cross-sectional study design was utilized. This design involves collecting data from the study subjects at a single point in time, allowing the researcher to measure both the outcomes and exposures simultaneously within the

same group of participants (Setia, 2016). This approach provides a snapshot of the relationship between variables without the need for long-term observation, making it particularly useful for understanding trends and correlations at a specific moment.

3.3 SAMPLING DESIGN

3.3.1 POPULATION

The population of the present study comprised secondary school students belonging to the 9^{th} and 10^{th} classes of the CBSE board and of an average age of 14.5 years from the state of Andhra Pradesh, India. These students from the mentioned class levels represent the age group that is eligible to appear for the Program for the International Student Assessment (PISA) test which measures the academic performance of adolescents in science along with mathematics and reading at international levels. The data obtained from this test is utilized by the member countries to bring positive changes in their education policies and outcomes, especially with respect to STEM education. The Indian Government, in 2019, signed an agreement with the Organisation for Economic Corporation and Development (OECD) which conducts the PISA test and allows the participation of Indian students in this prestigious test from the year 2021 onwards. According to this agreement, schools run by Kendriya Vidyalaya Sangatans (KVS), Navodaya Vidyalaya Samithi (NVS), and schools in the Union Territory Chandigarh were considered to participate in this test, with the students taught the curriculum designed by the CBSE and NCERT (Press Information Bureau, Gov. of India Ministry of Education 2019).

3.3.2 SAMPLING FRAME



Fig 3.1 Districts of Andhra Pradesh State

The state of Andhra Pradesh is located in the Southern Peninsula of India and is divided into 13 districts. In these districts, there are 685 schools affiliated to the Central Board of Secondary Education (CBSE) and 60 schools are directly governed by the Central Government under Kendriya Vidyalayas Sanghata and Navodaya Vidyalayas Samithi with the details given below as per the website SARAS.cbse.gov.in:

Table 3.1

Sampling frames of the Districts wise CBSE schools of Andhra Pradesh State

Sl.No	District	No of CBSE schools	10% of the total number of schools as per the Central Limit Theorem
1	SRIKAKULAM	25	3
2	VIZIANAGARAM	26	3
3	VISAKHAPATNAM	64	6
4	EAST GODAVARI	44	4
5	WEST GODAVARI	46	4
6	KRISHNA	80	8
7	GUNTUR	137	13
8	PRAKASAM	75	7
9	NELLORE	21	2
10	KADAPA	40	4
11	KURNOOL	56	6
12	ANANTAPUR	45	4
13	CHITTOOR	28	3

As per Central Limit Theorem 10% condition, when the sample is drawn without replacement, the sample size n should not be more than 10% of the population. Moreover, the Law of Statistical Regularity states that when the sample size is large and the subjects are selected randomly, the statistics of the sample would be similar to the parameter of the population, even if only 10% of the population is included in the study. A list of district-wise 10% of the total schools was prepared in an Excel sheet which formed the sampling frame from the population. The school to ultimately visit for data collection was selected randomly from the sampling frame list in the Excel sheet using the command = RANDBETWEEN (1, N) where N is the number of CBSE schools listed in the sampling frame list.

3.3.3 SAMPLE

918 secondary school students from 7 schools of an equal number of districts belonging to the classes 9th and 10th from the final sample subjects of the research study. The sample subjects comprised of 400 girls (43.57%) and 518 boys (56.42%). Similarly, there were 520 students (56.64%) from 9th class and 398 students (43.35%) from 10th class.

3.3.4 SAMPLING TECHNIQUE

In this study, the stratified random sampling technique was used due to the large geographical area of Andhra Pradesh. This probability sampling method involves the division of a population into smaller subgroups known as strata, as shown below:

Table 3.3: Stratified Random Sampling Technique

Sl.No	**Strata -1**	**Strata -2**	**Strata-3**		**Strata-4**	
	District	**Name of the randomly selected school for the final visit**	**Class**		**Gender**	
			9th	**10th**	**Boys**	**Girls**
1	Vizianagaram	Sri Chaitanya E.M School	73	43	65	51
2	Krishna	Chitturi Public school	86	25	64	47
3	West Godavari	Little Angles	62	50	59	53
4	Guntur	Vignan Vihar English Medium High School	79	47	68	58
5	Eluru	Sri Siddhartha High.School	52	49	49	62
6	Palnadu	A.P Model School	55	60	73	42
7	Nandyala	Arabindo High School	64	53	69	38
8	Chilakaluripet	Bhashyam Public School	49	71	71	49
Total Sample Size: 918			520	398	518	400
Stratum: All CBSE school students are of age 14 to 15 years						

3.3.5 DATA COLLECTION PROCEDURE

The investigator personally visited the randomly selected above-mentioned district-wise CBSE schools. The purpose of the visit was explained and permission was sought from the Head of the Institution, to collect the required data. The investigator introduced the self and interacted with the sample subjects to build a rapport with them. During the interaction, the purpose of the visit was explained, the anonymity of the collected data was assured, and confidentiality with respect to the usage of the data was assured along with the seeking of voluntary participation in the data collection exercise. The final tool was administered to the subjects in the presence of the 2class teacher during regular classroom sessions after providing clear instructions on how to fill the tool. The subjects took 40-45 minutes to carefully read the items, fill in the responses, and return the tool back to the investigator. The study was approved by the Institutional Ethics Committee (IEC) of Lovely Professional University bearing the registration number EC/NEW/INST/2022/3110.

3.4 VALIDATION OF THE TOOLS OF THE STUDY

Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are data driven and theory driven traditional methods of extracting factors of psychological scales and validating the factor structure. Network psychometrics is an emerging approach that focus on hidden constructs and their direct interaction among observe manifest variables. It is considered as a powerful modern tool for understanding the structure and function of complex psychological constructs.

Network psychometrics helps the researcher to identify patterns and trends in the relationship between entities in a network and influence the components of the construct in the form of its clusters, nodes and edges forming an eco-system as a whole.

The validation of the three psychological tools, of constructivist learning environment, epistemological beliefs and science flow constructs was done using network psychometrics, which is a state of the factor extraction and validation technique, science self-efficacy developed by Glynn and Koballa (2006) was already adapted in the Indian context by Biswal and Chakraborty (2024) on secondary school students and hence did not require further validation. The sample size of the study to

validate the constructivist learning environment scale comprised of 939 secondary school students, followed by 548 sample subjects for the validation of epistemological beliefs scale and 342 sample subjects to validate the science academic flow scale respectively. The investigator is herself the Principal of a secondary school and has professional relationship with several similar educational institutions in the city, which aided in the collection of data of moderate to high sample sizes for the validation of her three research tools. Prior to the commencement of data collection exercise, ethical approval was obtained from the Institutional Ethics Committee of the Lovely Professional University, under approval number EC/NEW/INST/2022/3110. The details of the results obtained on conducting the validation of the psychological instruments are mentioned below:

3.4.1 VALIDATION OF CONSTRUCTIVIST LEARNING ENVIRONMENT SCALE USING NETWORK PSYCHOMETRICS APPROACH

For validating the constructivist learning environment scale, prior permission from the head of a school was taken. The investigator physically visited the selected school for data collection. The head of the school was explained the purpose of the visit and provided a formal request for data collection from the students of the grades of 9^{th} and 10^{th} classes of the institution. After explaining the purpose of the visit to the head and providing the assurance of confidentiality of the data of the school students and its usage solely for research purposes, the points of voluntary participation, use of the research, voluntary participation and right to disengage from any stage of data collection, in the informed consent letter was read before the participants. Those students who provided their verbal consent were selected for the study as inclusion criteria and those who declined, were not considered for the study forming the exclusion criteria. The head of the institution signed the informed consent letter on the behalf of the participating students. Then physical copies of the questionnaire were distributed to the subjects while the classes were in session and the help of the school teachers taking the class was sought in the smooth administration of the questionnaire and collection of the same. The students took 25 minutes of average to complete the task. The sample size comprised of 945 secondary school students. On identifying and removing the outliers using mahalanobis distance, the final sample size

reduced to 939 secondary school students. 493 students were boys making up 52.50% of the sample size. 445 students belonged to the gender of girls making up 47.39% of the sample size. Similarly, 617 students belonged to the class of 9th (65.70%) and 322 students belonged to the class 10th (34.29%) of the sample size.

3.4.1.1 Exploratory Graph Analysis (EGA)

Exploratory graph analysis conducted (Golino and Epskamp, 2016) using LASSO estimation method (Tibshirani, 1996) and Walktrap community detection algorithm, through *EGAnet* package of RStudio identified four clusters of the 30 nodes of the Constructivist Learning Environment scale in the first run. 11 nodes displayed split loading and hence were removed to conduct the run again. The second run of the EGA with the remaining 19 items produced again four clusters with the nodes loading well on their appreciate clusters as shown by fig.3.3

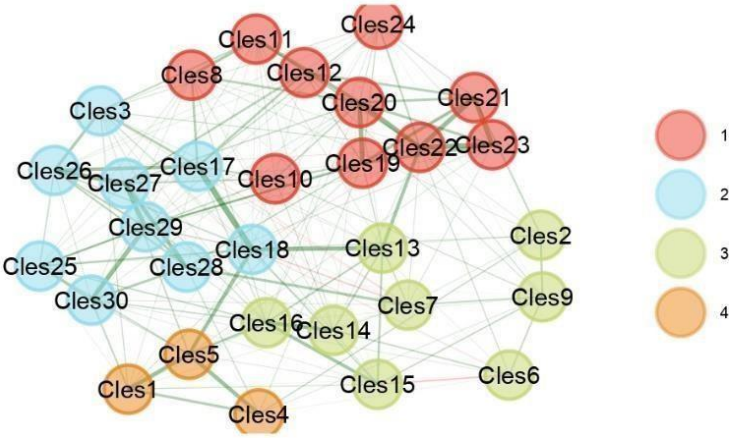


Fig.3.2-Network of CLES Scale on 1st run

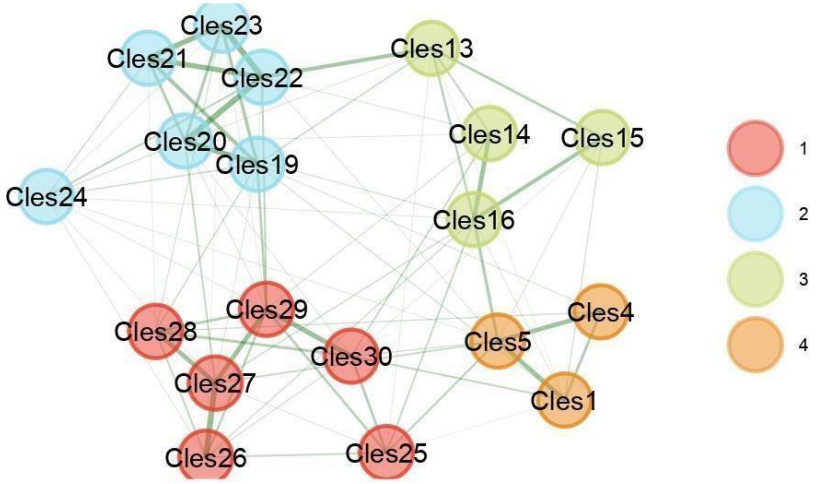
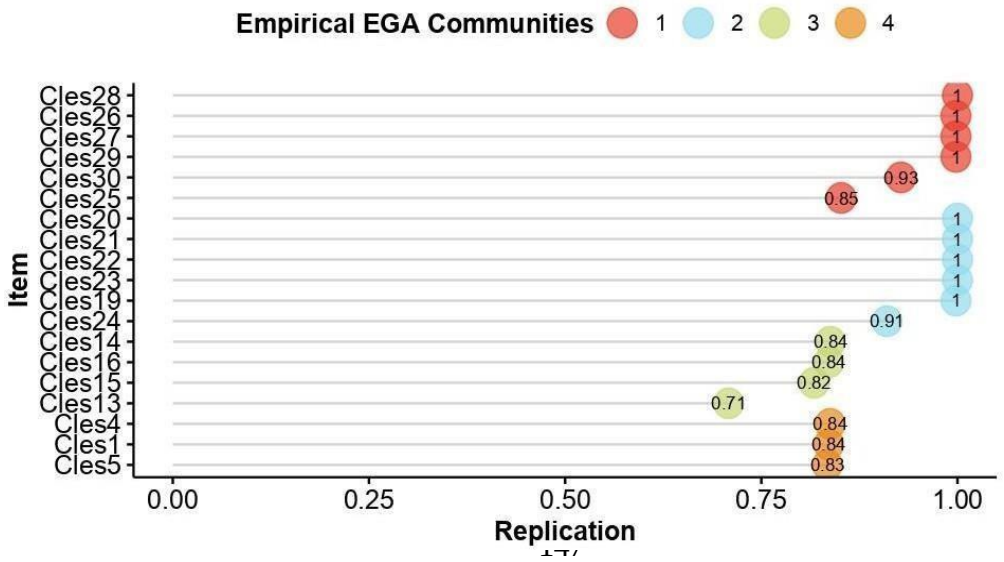


Fig.3.3- Final Network of CLES Scale on 2nd run

If the EGA reveals distinct clusters of items, it suggests that the tool is capturing multiple dimensions or sub-constructs of the psychological concept. For example, if three clusters emerge, the tool may measure three underlying factors. A clean, interpretable structure supports the tool's construct validity. Nodes 1,4 and 5 remained in the first cluster, nodes 13,14,15 and 16 remained with second cluster, nodes 19, 20, 21, 22, 23 and 24 remained with third cluster and nodes 25, 26, 27, 28, 29 and 30 remained with the fourth cluster.

3.4.1.2 Structural Consistency



Structural consistency (Christensen et al., 2019) assesses the stability and replicability of the network's nodes loading on their respective clusters by conducting bootstrapping and generating multiple samples from the data provided. Here it is checked for how many times a node loads on its respective cluster and how many times does it load on any other cluster, in several samples generated using bootstrapping. While loading of a node on its respective cluster represents internal consistency, its simultaneous disassociation with other clusters indicates external heterogeneity. Hence, structural consistency clubs both the concepts of internal consistency and external heterogeneity. Almost all nodes of the network replicated to their respective clusters 80% of times and more. Also, item stability indices were above 0.80 for all items, indicating that the item-to-dimension assignments were robust across resamples. The nodes 25, 26, 27, 28, 29, and 30 loaded on these respective clusters 85% to 100%, nodes 19, 20, 21, 22, 23, 24 loaded on their respective clusters 91% to 100% on various bootstrapped samples. Items 13, 14, 15, 16 were loaded on their respective samples 71% to 84% of times and rest of times loaded on different samples during bootstrapping. Nodes 1, 4 and 5 loaded on their respective cluster 83-84% of time during bootstrapping. In this way, 19 retained nodes of the 4 clusters displayed acceptable structural consistency in the network.

3.4.1.3 Network Loadings:

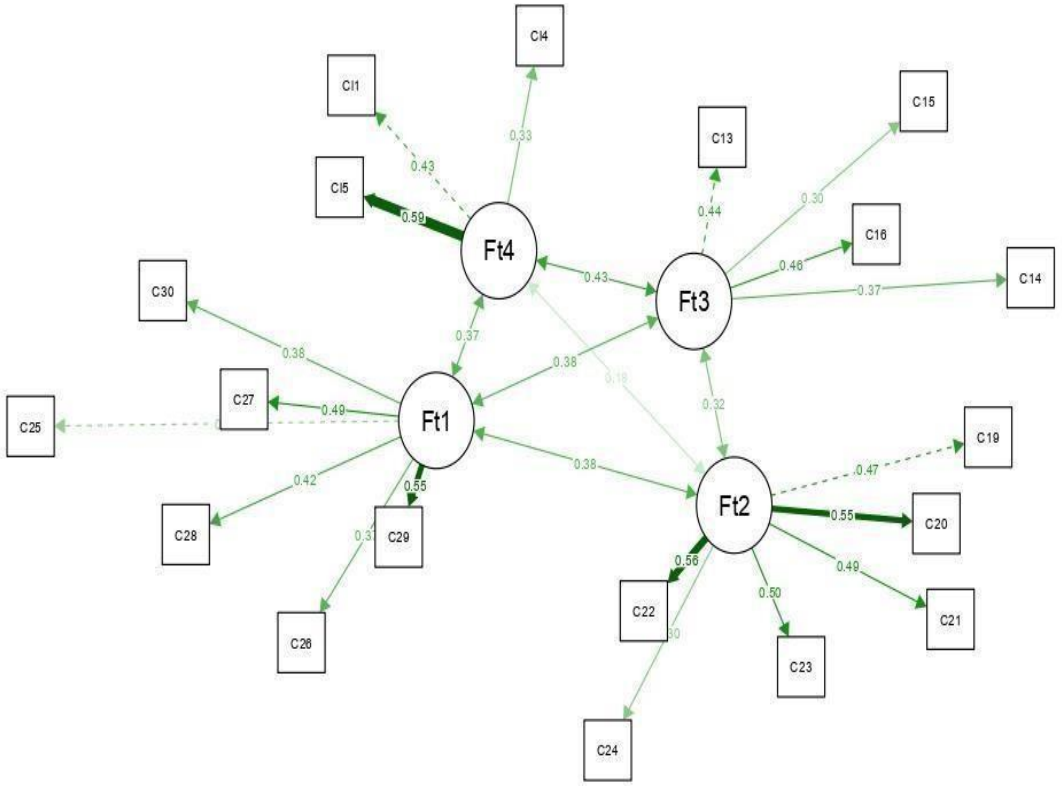


Fig.3.4 **Network Loadings**

Network loadings were estimated using the *LAVAAN* Package. The retained 19 nodes loaded on their respective clusters and the Network Structure with the loading are shared below in figure 3.4. The goodness of the estimates were estimated using the estimator Weighted least Square Mean and Variable (WLSMV) since the survey data obtained using a questionnaire is of ordinal data type.

Estimand	**CFI**	**TLI**	**SRMR**	**RMSEA**	**CFI Robust**	**TLI Robust**	**SRMR Bentler**	**Robust RMSEA**
Bench mark	>0.9	>0.9	<0.08	<0.06	>0.9	>0.9	<0.08	<0.06
Estimate	0.95	0.942	0.04	0.026	0.898	0.880	0.034	0.032

The goodness of fit estimates as obtained are shown above. All these indices of goodness, treating the data to be both Interval and ordinal indicated acceptable

goodness of fit of the Network Structure. The regularized network structure of the scale with the retained nodes and the quaint essential edges of the network is shown below

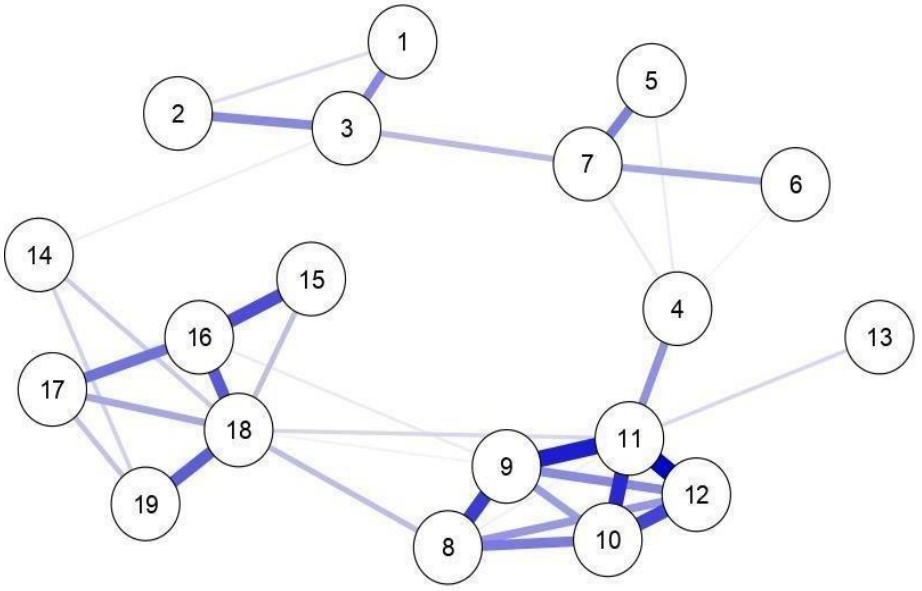


Fig-3.5 Regularized Network of CLES

3.4.1.4 Centrality Indices

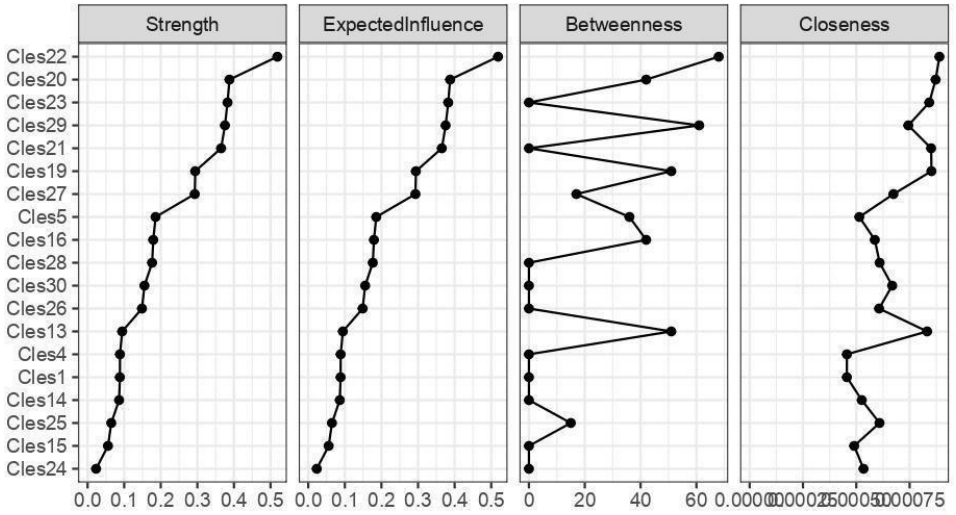


Fig-3.6 Network Centrality Indices

The importance of a node in the network can be estimated using certain estimands like strength, expected influence, betweenness and closeness, together comprising the centrality indices of the network (Costantini et al., 2015; Newman, 2010; Opsahl et al., 2010). In the network of constructivist learning environment, , with node 24 being the weakest of all the nodes. Influence of the nodes in the network follow the same pattern that of strength of the nodes. Nodes 22, 20, 29, 19, 16 and 13 have finite betweenness estimates and come in between the edges connecting other nodes of the network. All the nodes are fairly close to each other since this particular estimand has its estimates well above 0.5 in the network.

3.4.1.5 Edge Weight Accuracy

The edge weights with respect to their strengths in descending order were obtained taking into consideration the sample date & the bootstrapped data. Confidence intervals for edge weights provide a sense of how certain the connections between items are. Narrow intervals indicate strong evidence of a connection between two items, while wide intervals suggest that the relationship is less stable.

The confidence interval displaying the significance of the difference between bootstrapped and sample data-based edge weights is shown below:

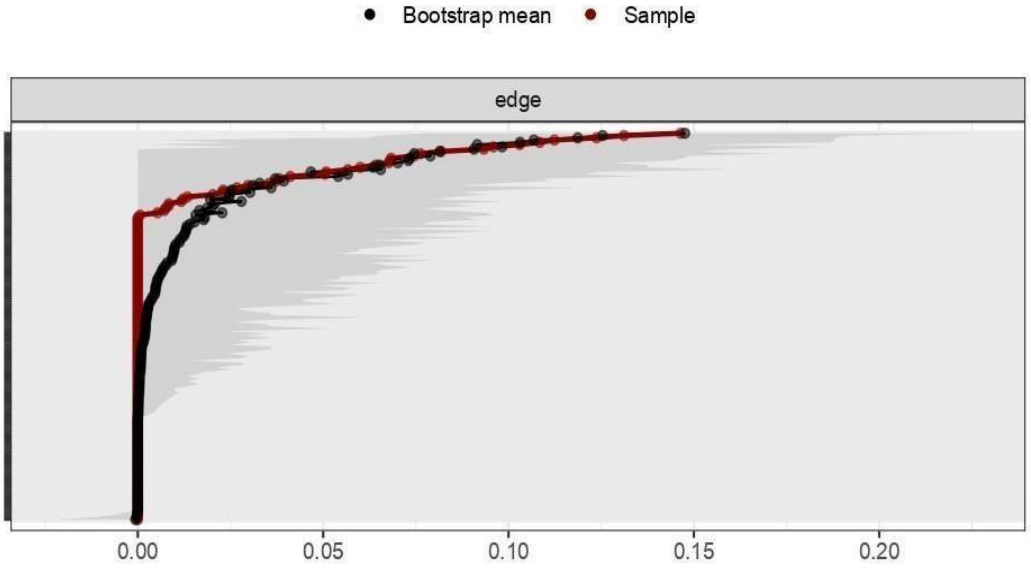


Fig-3.7 Edge Weight Accuracy Confidence Intervals

From the plot of the edge weight accuracy, it is evident that a non-significant result is obtained since the bootstrapped confidence interval contains zero in it and hence such a result implies that the ordering of the edges as obtained in this study from the collected data might not get replicated in future studies and as such these ordering have to be considered with caution.

3.4.1.6 Correlation Stability Analysis

Correlation stability analysis assesses the minimal sample size at which the present network is formed and duly strengthens with the addition of new cases. The correlation stability of the network with the original sample and successively reduced sample cases was obtained as a plot as shown below

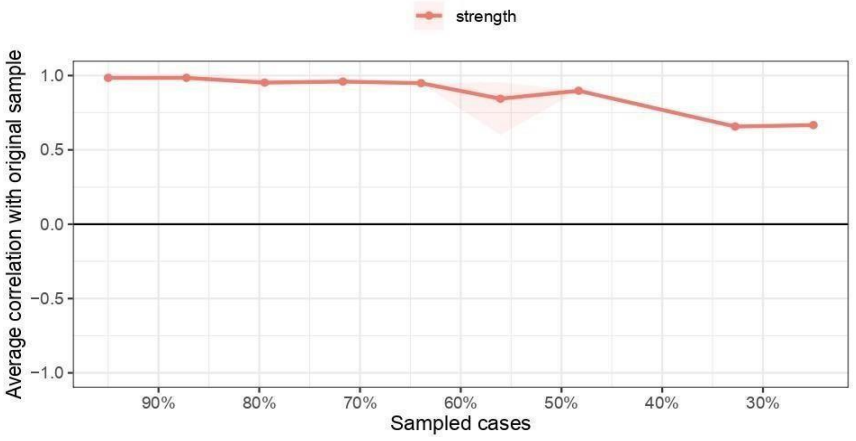


Fig-3.8 Correlation Stability Analysis

The correlation stability with respect strength is found to be 0.361 which is higher than the minimum desired value of 0.25 (Epskamp and Fried, 2018). This result indicates the relative stability of the obtained network.

Conclusion

The network psychometrics validation approach provides a comprehensive evaluation of the psychological tool. EGA and CFA confirm the dimensional structure, while centrality indices highlight key items. Confidence interval and stability analyses ensure the reliability of the findings. Together, these results suggest that the tool is both structurally valid and psychometrically sound, with clear implications for item selection and construct measurement.

3.4.2 VALIDATION OF EPISTEMOLOGICAL BELIEFS IN SCIENCES SCALE

For validating the epistemological beliefs scale in science, prior permission from the head of a school was taken. The investigator physically visited the selected school for data collection. The head of the school was explained the purpose of the visit and provided a formal request for data collection from the students of the grades of 9^{th} and 10^{th} classes of the institution. After explaining the purpose of the visit to the head and providing the assurance of confidentiality of the data of the school students and its usage solely for research purposes, the points of voluntary participation, use of the research, voluntary participation and right to disengage from any stage of data collection, in the informed consent letter was read before the participants. Those students who provided their verbal consent were selected for the study as inclusion criteria and those who declined, were not considered for the study forming the exclusion criteria. The head of the institution signed the informed consent letter on the behalf of the participating students. Then physical copies of the questionnaire were distributed to the subjects while the classes were in session and the help of the school teachers taking the class was sought in the smooth administration of the questionnaire and collection of the same. The students took 20 minutes of average to

complete the task. The sample size comprised of 548 secondary school students. 260 students were boys making up 47.44% of the sample size. 288 students belonged to the gender of girls making up 52.55% of the sample size. Similarly, 229 students belonged to the class of 9^{th} (41.78%) and 319 students belonged to the class 10^{th} (58.21%) of the sample size. On identifying and removing the outliers using mahalanobis distance, the final sample size reduced to 533 secondary school students.

3.4.2.1 EXPLORATORY GRAPH ANALYSIS (EGA)

FIRST NETWORK

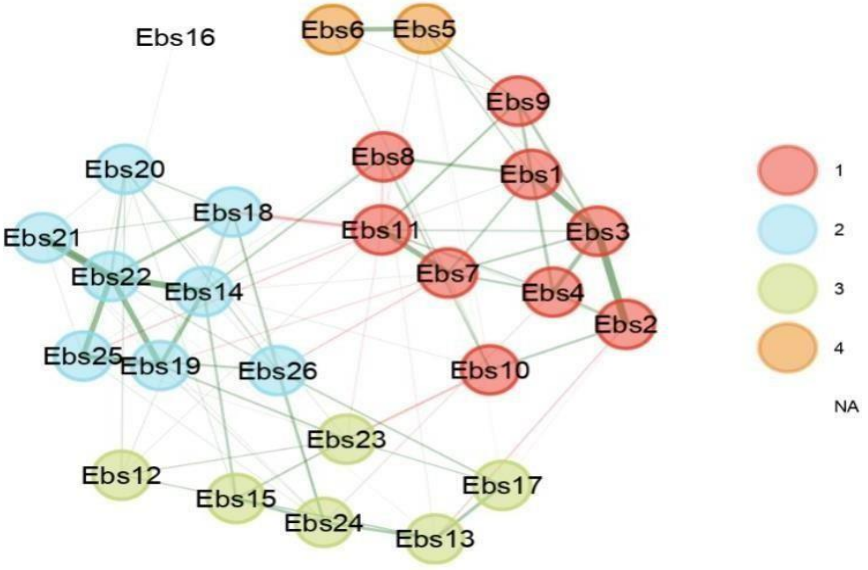
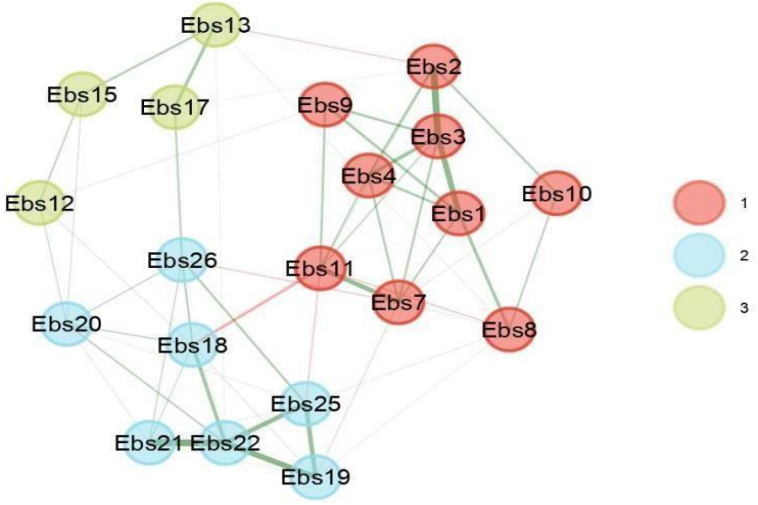


Fig.3.10 the network of partial correlations is visualized

While each node represents an item in the network of Science Epistemological beliefs with clusters of Source, Certainty, Development and Justification, the edges represent the partial correlation relationship between the nodes. The nodes are color-coded according to their respective clusters: Cluster 1 (Source), Cluster 2 (Certainty), Cluster 3 (Development), and Cluster 4 (Justification). The thickness of the edges reflects the strength of the partial correlation relationships between two nodes keeping the influence of all other nodes of the network constant. Upon examination, it is apparent that certain nodes have weak associations, as indicated by thin edges. These weak correlations are likely to represent minimal or no meaningful relationships between the associated variables. As a result, some edges were deemed insignificant and were removed during the analysis process. After eliminating these weak correlations, the analysis was re-run to refine the network representation and focus on stronger relationships.

SECOND NETWORK



Fig; 3.11 Network of partial correlation

Estimated using graphical lasso, showing the patter of SEBQ items per cluster, Cluster 1 = Source and Certainty, Cluster 2= Development, Cluster 3 = Justification. It is clearly observed that some of the edges were very light indicates a poor relation, are removed and test was re-run

THIRD NETWORK

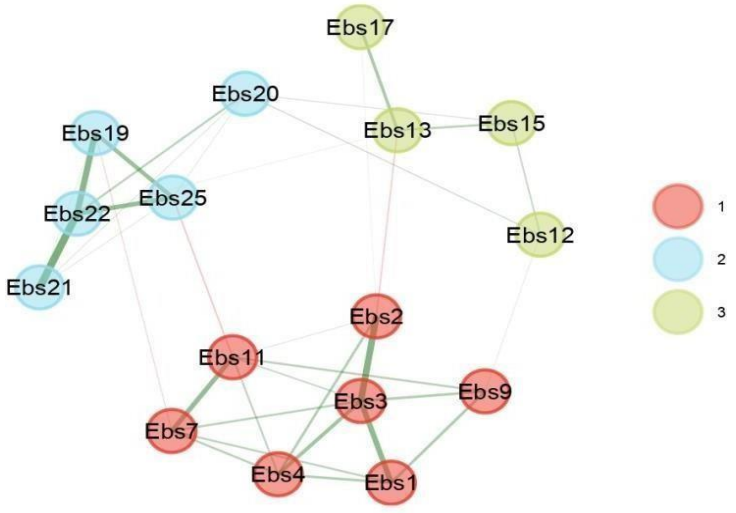


Fig.3.12: *Network of partial correlation*, estimated using graphical lasso, showing the patter of SEBQ items per cluster, Cluster 1 = Source and Certainty, Cluster 2= Development, Cluster 3 = Justification.

It is observed that the number of nodes was decreased from 4 to 3, it states that there were only 3 dimensions where the 1st and 2nd dimension formed as one cluster and named as Source and Certainty. Under the analysis of Network Psychometrics we can observe a strong relationship between the 16 items of the variables. Using the R/R-Studio version 4.2.3 package boot net, exploratory graph analysis (EGA) was performed on the collected data items. The resulting network, illustrated in Fig. 3, reveals three distinct clusters: the first cluster, consisting of seven nodes, represents Source and Certainty, while the second cluster consisting of four nodes, represents Development and the third cluster with five nodes represents Justification.

3.4.2.2 STRUCTURAL CONSISTENCY

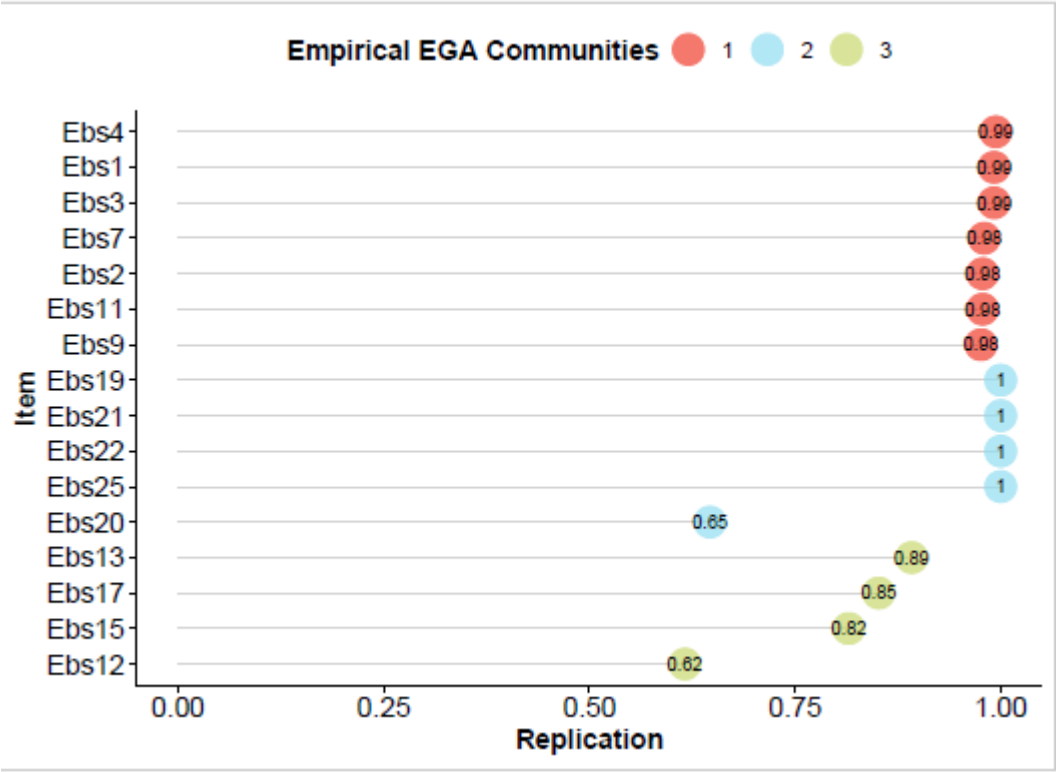


Fig.3.13 Structural Consistency Plot of Epistemological Belief Scale Network Structure

Nodes 20 and 12 have the weakest structural consistency characteristics owing to their 65% and 62% times of replication correctly into their respective clusters in the network. Rest of the 35% and 38%, these nodes display split loading. Nodes 13, 15 and 17 are fairly stable with 80% above replication of proper cluster loadings in bootstrapped samples. Rests of the 14 nodes nearly perfectly load on their respective clusters in all the bootstrapped samples.

3.4.2.3 FACTOR STRUCTURE

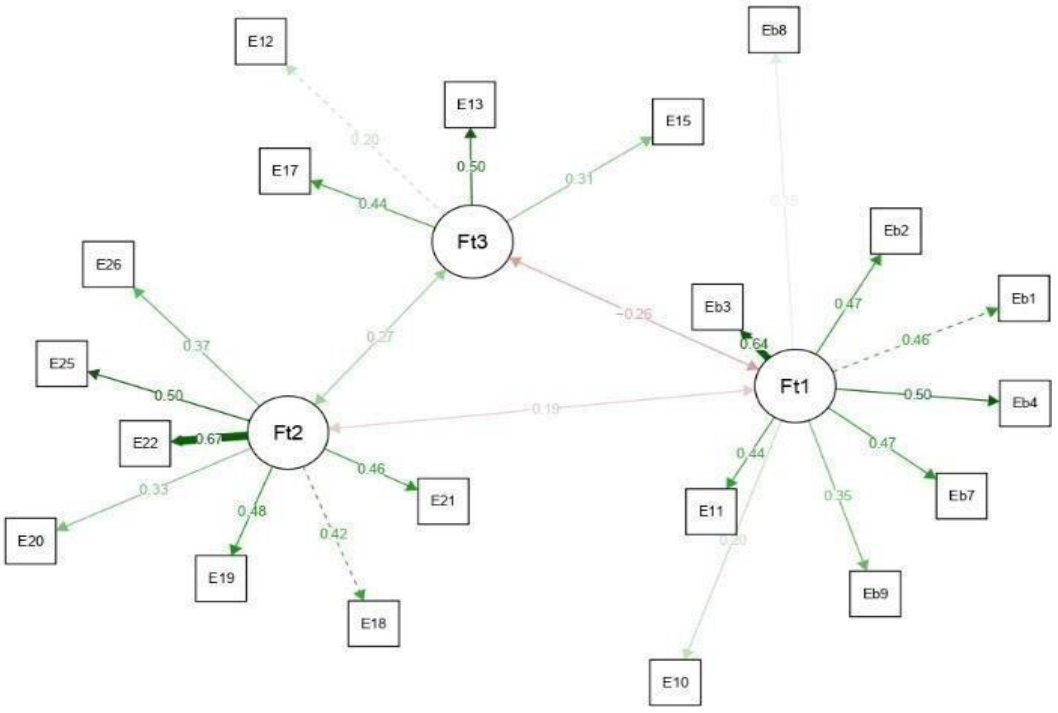


Fig.3.14: Ordinal Confirmatory Factor Analysis Structure of the Epistemological Beliefs Scale

According to Christensen and Golino (2021), the network's loadings under Network Psychometrics are comparable to factor loadings of CB-SEM confirmatory factor analysis. Node E22 has the highest loading in the network at 0.67, followed by nodes 3 at 0.64, respectively. An ordinal confirmatory factor analysis was performed using the weighted least square mean variance (WLSMV) estimator in the lavaan package (Rosseel, 2012). The results showed a comparative fit index (CFI) of 0.949, a Tucker-Lewis index (TLI) of 0.935, a root mean square error of approximation (RMSEA) of 0.046, and a standardized root mean square residual (SRMR) of 0.054. These fit indices, typically estimated using the Maximum Likelihood (ML) estimator, indicate a good fit for the interval-type data. For the ordinal analysis, the robust CFI was 0.877, the robust TLI was 0.843, the Bentler SRMR was 0.042, and the robust RMSEA was 0.062. According to Hooper et al. (2008), CFI and TLI values

are considered acceptable if they are above 0.9, while SRMR and RMSEA values are acceptable if they are below 0.05 and 0.08, respectively. Despite the relatively small sample size in this study, these indices are strong enough to demonstrate the network's construct validity. The goodness of fit estimates are acceptable.

3.4.2.4 REGULARIZED NETWORK

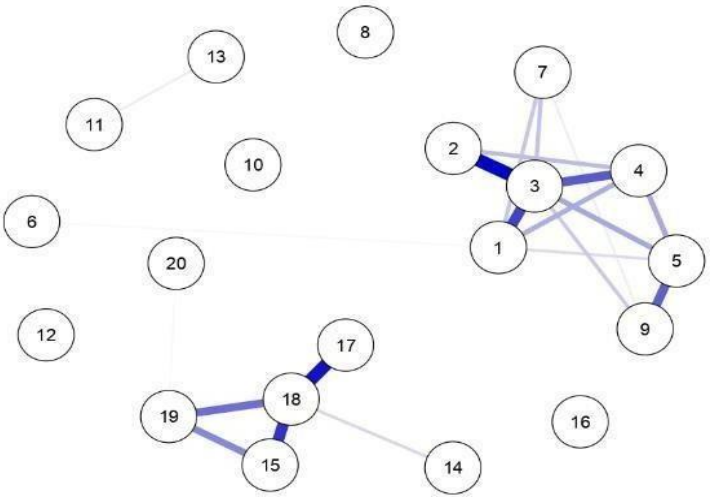


Fig.3.15: Regularized Network

The Least Absolute Shrinkage and Selection Operator (LASSO) is used in regularized network structures to highlight only the strongest connections between nodes, setting weaker connections to zero. In networks with fewer nodes, the number of edges is also limited, so the regularized network represents the final acceptable network structure.

3.4.2.5 CENTRALITY INDICES

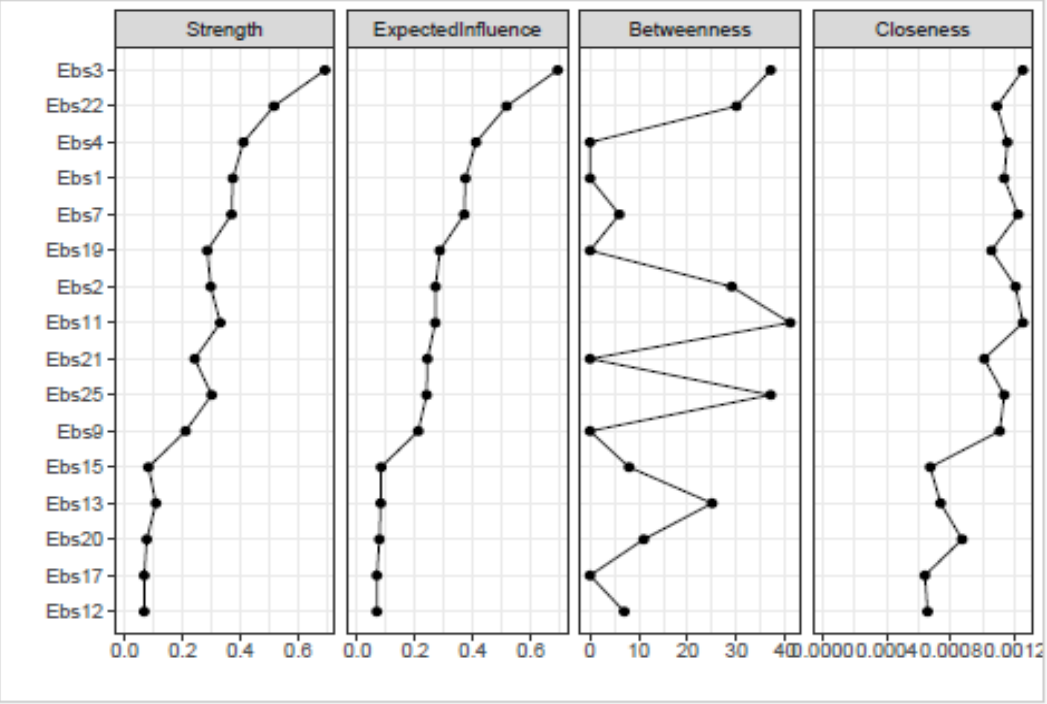


Fig.3.16: Centrality Indices

Strength and expected influence wise, the node 3 is the strongest node, followed by nodes 22 and 24. Node 12 is the weakest node in the network. Node 11 is the prominent node betweenness wise and almost all the nodes are quite close to each other indicating the stability of the network.

3.4.2.6 EDGE WEIGHT ACCURACY

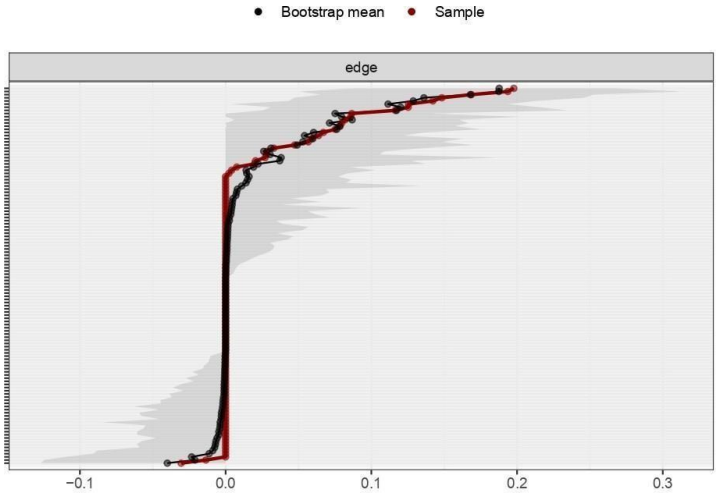


Fig.3.17: Edge Weight Accuracy

The edge weight accuracy plot with bootstrapped confidence interval contains zero and hence it represents a non-significant result. The ordering of the edge weights as obtained in this study are to be hence considered with caution.

3.4.2.7 CORRELATION STABILITY

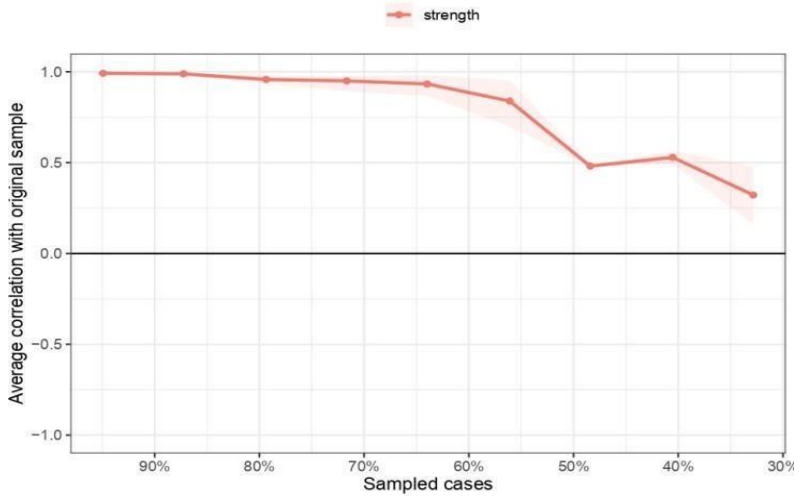


Fig.3.18: Estimation of Stability of Edges of the Epistemological Beliefs Scale

A stable, straight line suggests that the network is robust and could replicate well in future studies. The CS-coefficient evaluates the network stability by analyzing how the network changes when the sample size is reduced by certain percentage each time using bootstrapping. The present study obtained the CS-coefficient with respect to strength as 0.283 which is above the minimum benchmark of 0.25.

Table 3.7

Item details-Post Network Psychometrics based tool Validation of Epistemological Beliefs in Science Scale (EBSS)(Hofer & Pintrch (1997)adopted by Anne(2004)

Sl.no	Name of the Dimension	Original items	Retained items
1.	Score	1-5 (5)	1,2,3,4 (4)
2.	Certainty	6-11 (6)	7,9,11 (3)
3.	Development	12-17 (6)	12,13,15,17 (4)
4.	Justification	18-26 (6)	19,20,21,22,25 (5)

	Total	**26**	**16**

The original Epistemological Beliefs Scale consisted of 26 items across four dimensions. However, the analysis revealed a more refined structure, reducing the items to 16, which were then grouped into three distinct clusters.

3.5 VALIDATION ANALYSIS OF EDU-FLOW FACTOR STRUCTURE

The Eduflow scale developed by El-Mawas and Heutte (2019) was adapted in the context of science education for secondary school students by the investigators. All the 12 items of the Eduflow scale, with three items each of cognitive control, immersion and time transformation, loss of self-consciousness and autotelic experience dimensions, were changed to make them science classroom specific and are presented below:

Table 3: 8

Items of the Edu-flow scale and Science Academic Flow Scale

S.No.	Items of Edu-flow Scale	Items of the Science Academic Flow Scale
1	"I trust my ability to meet the high demands of the situation"	"I trust my ability to meet the high demands of the science classroom situations"
2	"I am wholly absorbed in what I am doing"	"I am wholly absorbed in what I am doing during a science class."
3	"I don't care about what others may think of me"	"I don't care about what others may think of me in a science theory class."
4	"I have the feeling I am living a very exciting experience"	"I have the feeling I am living a very exciting experience during a science class."
5	"I feel completely in control of my actions"	"I feel completely in control of my actions in a science class"
6	"I am deeply focused on what I am doing"	"I am deeply focused on what I am doing, while performing a science activity."
7	"I am not concerned about the judgement of others"	"I am not concerned about the judgement of others of me as a science student."
8	"This activity brings me a sense of well-being"	"Science activities bring me a sense of well-being."

9	"At each step, I know exactly what I have to do"	"At each step, I know exactly what I have to do in a science class."
10	"I am losing track of time"	"I am losing track of time in a science class."
11	"I am not worried about what others might think of me."	"I am not worried about what others might think of me in a science practical class."
12	"When I talk about this activity, I feel such a deep emotion that I want to share it."	"When I talk about science activities, I feel such a deep emotion that I want to share it with others."

The above mentioned statements were shown to highly experienced government school teachers teaching the science subjects of Mathematics, Physics and Biology to secondary school students to seek content validity. The language of the items was reviewed by a government school English teacher. The scale was also validated for its content by a faculty of Educational Psychology working in a state university. All the responses of the scale were collected using 7- point Likert scale where 1 = Strongly disagree and 7 = Strongly agree.

Post content validity establishment exercise, the tool was administered on targeted sample subjects of secondary schools students. Prior permission from the head of a school was taken. The investigator physically visited the selected school for data collection. The head of the school was explained the purpose of the visit and provided a formal request for data collection from the students of the grades of 9^{th} and 10^{th} classes of the institution. After explaining the purpose of the visit to the head and providing the assurance of confidentiality of the data of the school students and its usage solely for research purposes, the points of voluntary participation, use of the research, voluntary participation and right to disengage from any stage of data collection, in the informed consent letter was read before the participants. Those students who provided their verbal consent were selected for the study as inclusion criteria and those who declined, were not considered for the study forming the exclusion criteria. The head of the institution signed the informed consent letter on the behalf of the participating students. Then physical copies of the questionnaire were distributed to the subjects while the classes were in session and the help of the

school teachers taking the class was sought in the smooth administration of the questionnaire and collection of the same. The students took 15 minutes of average to complete the task. The final sample size was 342 comprising 213 girls and 129 boys secondary school students belonging to grades 9th and 10th. 62.28 % subjects were girls and 37.71 % subjects were boys. 200 (58.47 %) of them belonged to 9th grade and the remaining 142 (41.52 %) belonged to 10th grade.

3.5.1 Descriptive Statistics:

For detecting outliers, Mahalanobis distance was estimated for the gather data. No outliers were detected. Then, the measures of central tendency, dispersion and asymmetry of the four dimensions of the cognitive absorption model of the science academic flow scale, were estimated using mean, standard deviation, skewness and kurtosis estimands, followed by measure of relationship through Pearson Product Moment Correlation coefficients of the items, using SPSS Statistics Ver 23.0. and the obtained estimates are displayed below:

Table 3.9 Descriptive Statistics

Dimension	Mean	Std. Deviation	Skewness	Kurtosis
Cog_Control	5.3470	1.15434	-0.948	0.864
Imm_Time_Trans	5.1481	1.17795	-0.509	-0.450
Loss_of_Self_Con	5.4610	1.16353	-0.951	0.372
Autotelic_Exp	5.3791	1.14058	-0.771	0.122

Table 3.10

Measure of Inter-Item Relationship Estimated using Pearson's Product Moment Correlation Coefficient:

Correlation	Cog_ Control	Imm_Time _ Trans	Loss_of_Self _ Con	Autotelic_Exp
Cog_Control	1.000	.450**	.435**	.455**
Imm_Time_Trans		1.000	.361**	.302**
Loss_of_Self_Con			1.000	.390**
Autotelic_Exp				1.000

Table 3.11

Estimates of Floor and Ceiling Effect:

S.No	No. of Subjects with Lowest Score of the Scale of 12	No. of Subjects with Highest Score of of the Scale 84	Total Subjects	Floor Effect Estimate	Ceiling Effect Estimate	Benchmark of Acceptance	Result	Remark on Item Floor or Ceiling Effect
1	0	2	342	0%	0.584%	15%	Both Floor and Ceiling effects estimates are less than the benchmark	*Absent*

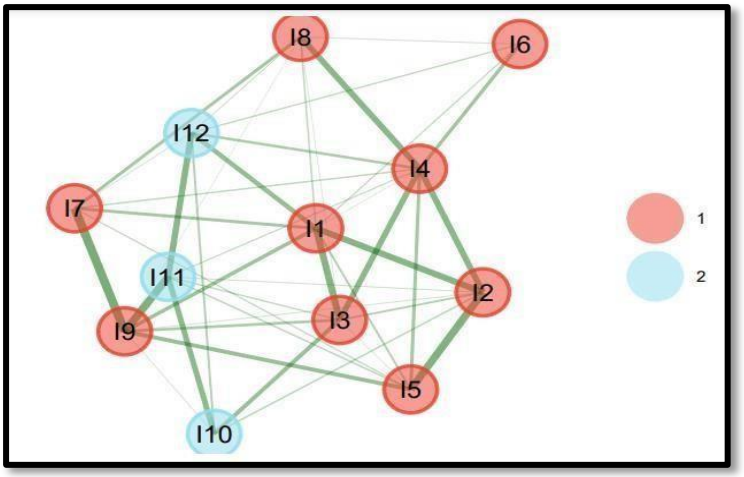


Fig. 3.19: Network Structure of the Cognitive Absorption Model

based Science Academic Flow Scale Nodes at Dimension Level at Item Level, 1 = Cognitive Absorption and 2 = Autotelic Experience Using the R/Rstudio Ver. 4.2.3 package of bootnet, the technique of exploratory graph analysis (EGA) was applied on the collected data items. The obtained network shown in Fig.1, has two

clusters, with the nine nodes forming the first cluster of Cognitive absorption and the remaining three nodes forming the second cluster of auto telic experience.

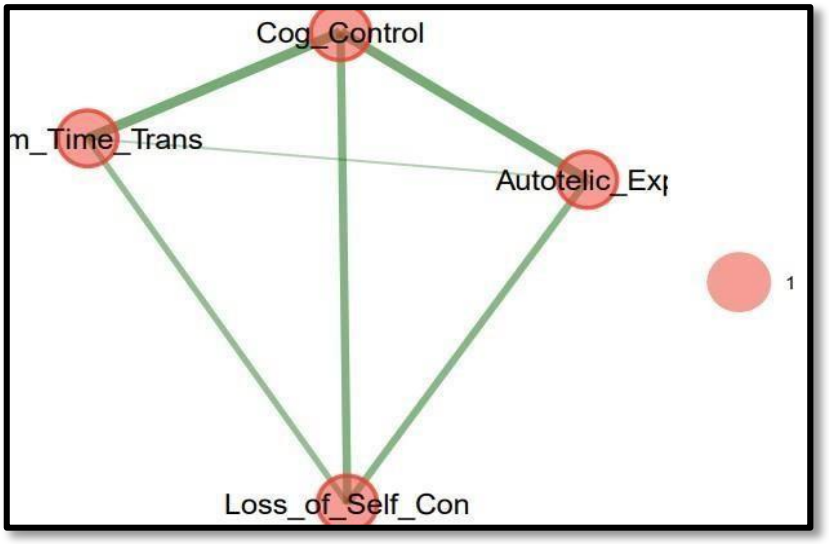


Fig. 3.20: Network Structure of the Cognitive Absorption Model based Science Academic Flow Scale Nodes at Dimension Level.

The exercise of exploratory graph analysis was again run with the data of the four dimensions of the science academic flow scale as per the Cognitive absorption model. It resulted in obtaining of a single cluster network, representing the science academic flow construct, where its dimensions as nodes of the network, were complexly related to each other, as shown in Fig.2, in contrast to the simplistic linear relationships displayed in El-Mawas and Heutte (2019) scale. The nodes of cognitive control, immersion and time transformation, loss of self-consciousness are interrelated to each other, forming cognitive absorption, and these three nodes are related to the fourth dimension of autotelic experience. However, the strength of the connection between the node immersion and time transformation, and the node autotelic experience is relatively weak.

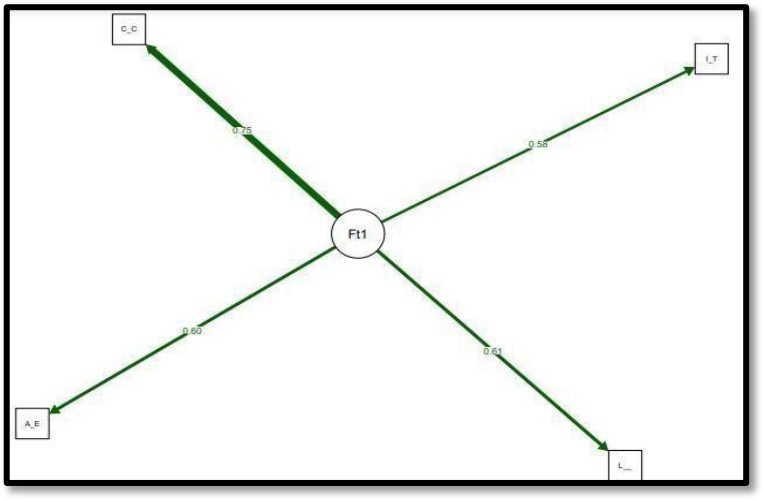


Fig.3.21: Ordinal Confirmatory Factor Analysis Structure of the Cognitive Absorption Model based Science Academic Flow Construct

Table 3.12

Goodness of Fit Estimates of the Ordinal Confirmatory Factor Analysis of the Science Academic Flow Construct Network Structure

	CFI (For Interval Data)	**Robust CFI (For Ordinal Data)**	**TLI (For Interval Data)**	**Robust TLI (For Ordinal Data)**	**RMSEA (For Interval Data)**	**Robust RMSEA (For Ordinal Data)**	**SRMR (For Interval Data)**	**SRMR Bentler (For Ordinal Data)**
Benchmark (Hu and Bentler, 1999)	>0.95	>0.95	>0.95	>0.95	<0.05	<0.05	<0.08	<0.08
Obtained Estimates From R Version 4.2.2	0.995	0.997	0.986	0.991	0.041	0.032	0.016	0.016

The obtained estimates quite satisfy their respective benchmarks as per the goodness of fit standards set by Hu and Bentler (1999). This result verifies the cognitive absorption model based science academic flow scale with its 12 nodes / items and four dimensions / clusters. The factor loadings of the nodes cognitive control, immersion and time transformation, loss of self-consciousness and auto telic experience on science academic flow construct are strong enough at 0.75, 0.58, 0.61 and 0.6 respectively

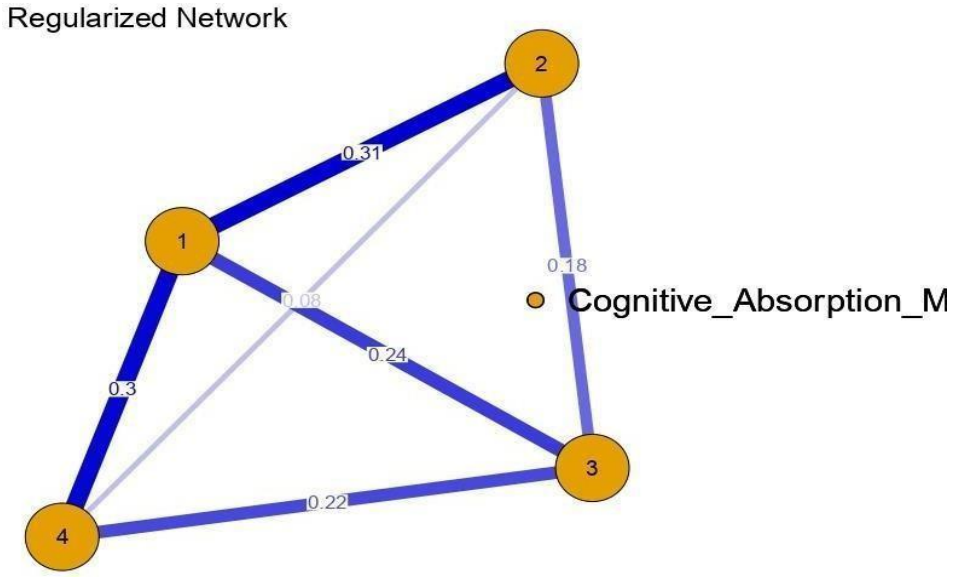


Fig.3.22: Regularized Network of Cognitive Absorption Model based Science Academic Flow Scale

Node 1 in the regularized network is cognitive control. Node 2 is immersion and time transformation. Node 3 is loss of self-consciousness and node 4 is autotelic experience. It is evident that the strength of the connection (edge) between the node 2 of immersion and time transformation, and the node 4 of autotelic experience is weak at 0.08. The strengths of the edges connecting other nodes of the Cognitive absorption modeling network are relatively stronger

Table 3.13
Loadings of the Nodes in the Network Structure

Node	**Network Loading (Partial Correlation Coefficient of the Edge)**
Cog_Control	0.505
Loss_of_Self_Con	0.379
Autotelic_Exp	0.354
Imm_Time_Trans	0.335

In order to estimate the stability of the obtained network, the package *qgraph* was used to get the measures of the centrality indices of the network.

Centrality Metrics Analysis using *bootnet* (Epskamp, Borsboom and Fried, 2018) and *qgraph* R (Epskamp et al., 2012) Packages:

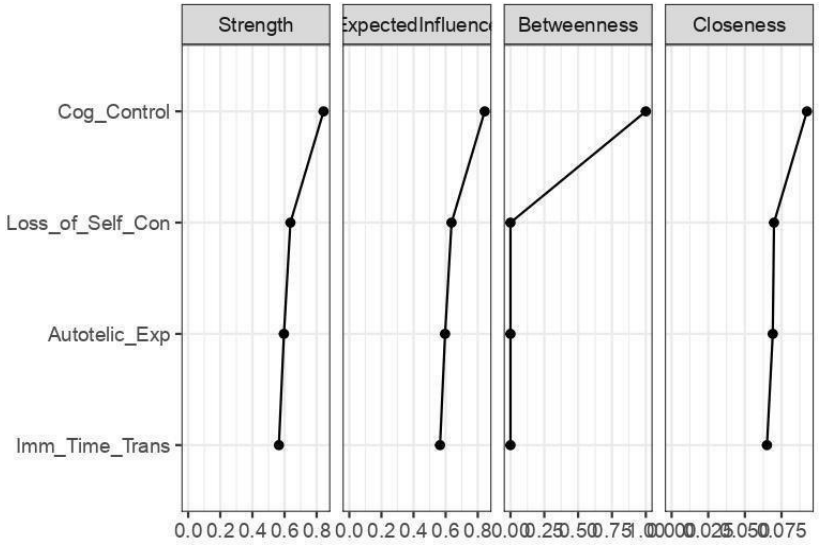


Fig.3.23: Strength, Expected Influence, Betweenness and Closeness Centrality Indices Plots of the Nodes of Cognitive Absorption Model based Science Academic Flow Scale.

The node cognitive control is the strongest node of the network, followed by the nodes of loss of self-consciousness, auto telic experience and, immersion and time transformation. Closeness wise also, this node is vital, along with expected influence and betweenness.

Table 3.14
Node Centrality Indices Estimates

	Betweenness	**Closeness**	**Strength**	**Expected Influence**
Cog_control	1	0.09	0.843	0.843
Imm_Time_Trans	0	0.065	0.565	0.565
Loss_of_Self_Con	0	0.069	0.636	0.636
Autotelic_Exp	0	0.06904	0.596	0.596

Estimation of the Accuracy of the Edges of Cognitive Absorption Model based Science Academic Flow Scale Network Structure:

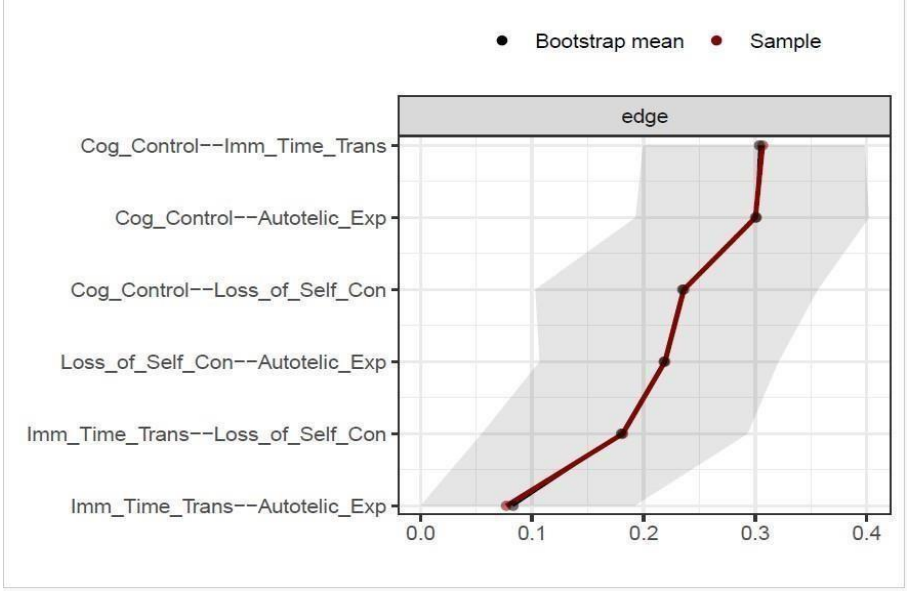


Fig.3.24: Estimation of Edge Weight Accuracy Non-Parametric Bootstrapped Confidence Interval Plot of Cognitive Absorption Model based Science Academic

3.5.2. Flow Scale Network Structure

The non-parametric bootstrapped confidence interval is estimated for determining the accuracy of the edge weights with 95 % confidence considering the ordinal data measurement level in the present study (Epskamp, Borsboom and Fried, 2018). The above figure is generated after running the bootstrap technique for 500 times and on the allocation of eight processor cores. The edge weights of the network are represented by red dots and the grey region represents the 95 % confidence interval (CI) around them. In general, lesser number of nodes and larger sample size lead to the generation of smaller and non-overlapping CIs around the edges, which make the estimation more reliable and allowing mutual comparison, like the present study CI being in and around 0.1. The edge connecting the nodes cognitive control and Immersion Time and Transformation, is the strongest edge, and edge connecting nodes Immersion Time and Transformation, and autotelic experience is the weakest edge of the network, which can be true in 95% cases.

3.5.3. Estimation of Stability of the Edges of Cognitive Absorption Model based Science Academic Flow Scale Network Structure

Estimation of edge-weight accuracy using confidence interval is mostly difficult to interpret, and hence the stability of the edges, with respect to all the four centrality indices, are conducted by estimating the correlation of these metrics in original sample and in successively reduced cases through bootstrap replication.

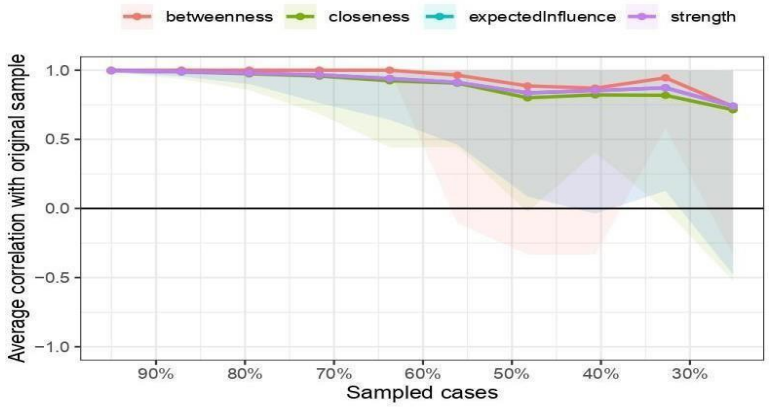


Fig.3.25: Estimation of Stability of Edges of Cognitive Absorption Model based Science Academic Flow Scale Network Structure with respect the Centrality Indices

The correlation stability CS coefficient quantitatively obtained is low at 0.363 than the benchmark of 0.5 but above the minimum value of CS coefficient at 0.25 (Epskamp, Borsboom and Fried, 2018).

Estimation of Bootstrapped Difference Test with respect to Nodes:

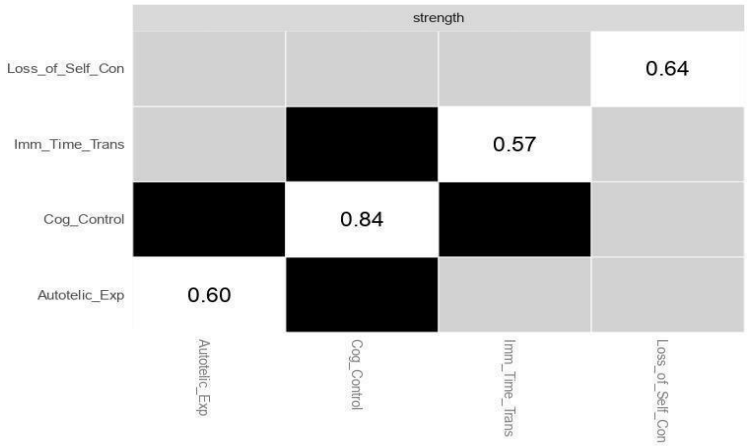


Fig.3.26: Bootstrapped difference tests (α = 0.05) between nodes of Cognitive Absorption Model based Science Academic Flow Scale Network Structure.

Nodes which do not differ significantly from each other are represented by gray boxes in the plot. The significant ones are represented by the black boxes.

Estimation of Bootstrapped Difference Test with respect to Edges:

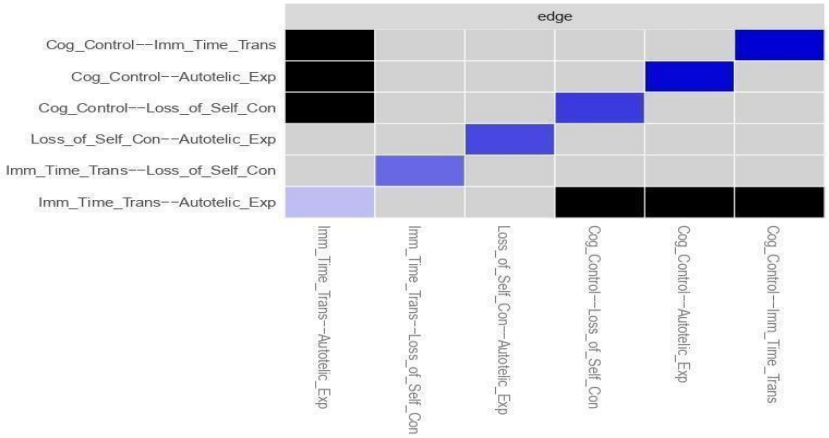


Fig.3.27: Bootstrapped difference tests (α = 0.05) between non-zero edge weights and node strength of the Cognitive Absorption Model based Science Academic Flow Scale Network Structure.

Edges which do not differ significantly from each other are represented by gray boxes in the plot. The significant ones are represented by the black boxes. Blue colored boxes represent the order of the edge-weights as displayed in figure 5 above.

Estimation of Structural Consistency of the Cognitive Absorption Model based Science Academic Flow Scale Network Structure:

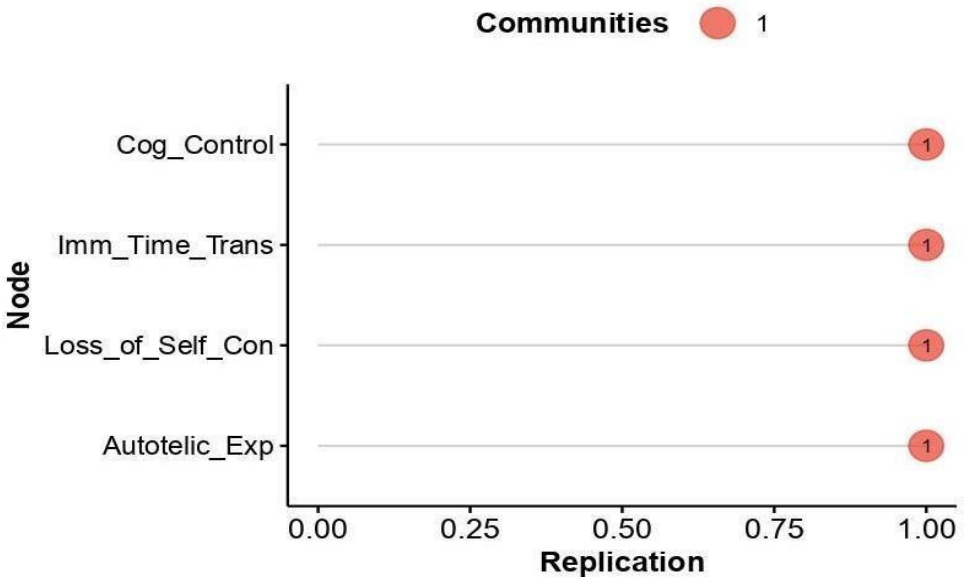


Fig.3.28: Structural Consistency Plot of Cognitive Absorption Model based Science Academic Flow Scale Network Structure

All the nodes load on same science academic flow network 100% when their consistency is tested through the replication of their original structure in multiple bootstrap-based samples, displaying very strong internal consistency. Quantitatively, the structural consistency of both the network and its individual nodes are obtained to be 1.

Conclusion:

The availability of instruments to measure novel science education variables, which are in turn based on psychologically solid theoretical underpinnings and validated through robust psychometric techniques to prove being culturally neutral, is quintessential for the progress of research in science education in India and across the world. Our present exercise is a meniscual enterprise in this direction, with a hope that the tool is accessed and vigorously tested by all the stakeholders of science education

research in the country. The robustness of the validated tools arises from the stringent following the rule of removing the nodes or items of the scales which were found to contribute little to the stability of the network of their respective clusters and networks based on the estimates of structural consistencies.

3.6 Statistical Techniques

The following statistical techniques were brought to use to analyze the collected data, and interpret the findings in concurrence with the objectives of the research study:

- Descriptive Statistics – Mean, Standard Deviation, skewness, kurtosis, and Pearson product-moment correlation
- Exploratory Factor Analysis (EFA)
- Structural Equation Modelling (SEM) - Confirmatory Factor Analysis (CFA)
- Measurement Invariance Testing
- Network Psychometrics

3.7 Conclusion

This present chapter focused on a detailed description of the methods and procedures that the investigator employed while carrying out his research activity. It served as a navigation device that guided and led the investigator to find answers to the questions he had in mind in this research activity. Further, it highlighted the tools and the statistical treatments of the data employed in the collection and analysis.

CHAPTER - IV

DATA ANALYSIS AND INTERPRETATIONS

4.1 INTRODUCTION:

This chapter discusses in detail the results obtained from the administration of the research tools on the subjects of this study as mentioned in the previous chapter and the interpretations of the results towards the attainment of the research objectives, by applying the previously listed statistical techniques on the collected data.

4.2 ANALYSIS OF THE DATA:

4.2.1 Descriptive Statistics Estimates of the Research Variables:

Under descriptive statistics estimates, the measure of central tendency, dispersion and asymmetry in the form of mean, standard deviation, skewness and kurtosis are presented of the study variables with details given below:

Table 4.1

Summary of Descriptive Statistics Estimation of the Research Variables

Variable	N	Mean	Std. Deviation	Skewness	Kurtosis
Constructivist Learning Environment	918	3.3585	0.47948	0.086	0.257
Epistemological Beliefs in Science	918	3.7454	0.44798	-0.928	3.108
Science Self Efficacy	918	3.1908	0.64435	0.153	-0.015
Science Academic Flow	918	4.6160	0.97606	-0.057	-0.276
Science Academic Achievement	918	70.30	8.156	-0.227	-0.137

The mean Constructivist learning environment score of secondary school students is found to be 3.3585, which is higher than the average score of 3 in the scale and hence implies that this independent variable of the study is satisfactorily present in the subjects of the sample. The extent of spread of the scores of this variable in the data, estimated using standard deviation, is at 0.47948. Skewness and Kurtosis in the data of this variable are found to be under limits at 0.086 and 0.257 respectively. The acceptable benchmarks of these two estimates of asymmetry measurement are from -2 to +2 and from -7 to +7 respectively (Hair et al., 2010).

The mean Epistemological beliefs in science score of secondary school students is found to be 3.7454, which is higher than the average score of 3 in the scale and hence implies that this mediatory variable is satisfactorily present in the subjects of the sample. The extent of spread of the scores of this variable in the data, estimated using standard deviation, is at 0.44798. Skewness and Kurtosis in the data of this variable are found to be under limits at -0.928 and 3.108 respectively. The acceptable benchmarks of these two estimates of asymmetry measurement are from -2 to +2 and from -7 to +7 respectively (Hair et al., 2010).

The mean Science self-efficacy score of secondary school students is found to be 3.1908, which is higher than the average score of 3 in the scale and hence implies that this mediatory variable is satisfactorily present in the subjects of the sample. The extent of spread of the scores of this variable in the data, estimated using standard deviation, is at 0.64435. Skewness and Kurtosis in the data of this variable are found to be under limits at 0.153 and -0.015 respectively. The acceptable benchmarks of these two estimates of asymmetry measurement are from - 2 to +2 and from -7 to +7 respectively (Hair et al., 2010).

The mean Science academic flow score of secondary school students is found to be 4.6160, which is higher than the average score of 4 in the scale and hence implies that this mediatory variable is satisfactorily present in the subjects of the sample. The extent of spread of the scores of this variable in the data, estimated using standard deviation, is at 0.97606. Skewness and Kurtosis in the data of this variable are found to be under limits at -0.057 and -0.276 respectively. The acceptable

benchmarks of these two estimates of asymmetry measurement are from - 2 to +2 and from -7 to +7 respectively (Hair et al., 2010).

The mean Science academic achievement score of secondary school students is found to be 70.3, which is higher than the first class marks threshold of 60 in school subjects and hence implies that this dependent variable of the study is satisfactorily present in the subjects of the sample. The extent of spread of the scores of this variable in the data, estimated using standard deviation, is at 8.156. Skewness and Kurtosis in the data of this variable are found to be under limits at -0.227 and -0.137 respectively. The acceptable benchmarks of these two estimates of asymmetry measurement are from - 2 to +2 and from -7 to +7 respectively (Hair et al., 2010).

4.2.2 Data Analysis of Objective 1:

To study the predictive role of Constructivist learning environment on Epistemological beliefs in Science of Secondary school students.

4.2.2.1 Predictive relationship of the construct Constructivist learning environment on Epistemological Beliefs – Simple Linear Regression Analysis

Ho_1: "There is no predictive relationship of the Constructivist learning environment on Epistemological Beliefs."

Table 4.2

Regression Analysis between Constructivist Learning Environment and Epistemological Beliefs

Model Summary							
Model	R	R Square	djusted R Square	imated F-Value	df	Sig.	Result Null Hypothesis (H0)
1	0.366	0.134	0.133	141.612	(1,916)	0.000	***Rejected***

a. Dependent Variable: Epistemological Beliefs in Science

b. Predictors: (Constant), Constructivist Learning Environment

Table 4.3 Coefficients

Model	Un standardized Coefficients		Stand ardized Coefficients	t	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	2.597	0.097		26.647	0.000	2.406	2.788
Constructivist Learning Environment	0.342	0.029	0.366	11.9	0.00	0.285	0.398

Interpretation: The correlation estimate, which is the pre-requisite for regression is reported first, where the Pearson correlation coefficient between Constructivist Learning Environment of the secondary school students and epistemological beliefs in science is found to be moderately strong in strength, with its magnitude R = 0.366, and the coefficient of determination R square 0.134. This indicates that 13.4% variation in epistemological beliefs in science is explained by the predictor variable constructivist learning environment for a unit change in it. The obtained estimate of correlation coefficient R is significant since the p-value = 0.000 is lesser than the level of significance $\alpha = 0.01$, under an estimated F value of 141.612 for degree of freedom df = (1,916). This significant ANOVA result hence obtained, confirms constructivist learning environment to be a useful predictor of epistemological beliefs in science in secondary school students, paving the way for further regression analysis.

From the Coefficients table, the regression equation is found to be: (Epistemological Beliefs in Science) = 2.597 + 0.342 (Constructivist Learning Environment). Here, the constant is 2.597 representing the intercept and the unstandardized regression coefficient (B) is found to be 0.342, which indicates the slope, and implies that for every unit increase in the perception of a constructivist learning environment in the classroom held by a secondary school student, a 0.342 unit increase in his or her epistemological beliefs in science is predicted. The

standardized coefficient (β) is 0.366. It means that for a one standard deviation rise in constructivist learning environment, a rise of 0.366 standard deviation can be expected in epistemological beliefs in science. The associated p-values of the constant and the unstandardized regression coefficient (B) are both equal to 0.000 indicating high level of statistical significance of the obtained data, allowing for the extension of the sample findings to the entire population.

Hence, the null hypothesis H_0, that existence of no predictive relationship of the constructivist learning environment on the epistemological beliefs in science, is ***rejected***. The independent variable constructivist learning environment predicts the dependent variable epistemological beliefs in science in secondary school students moderately in strength and statistically significantly.

The obtained prediction result between the two variables is in conjunction with Ozkal et al., (2009) study in the Turkish context with eight class students as the sample subjects. As per NEP 2020 the teacher in the classroom should be able to create a constructivist learning atmosphere to enrich the epistemological beliefs among the students.

4.2.3 Data Analysis of Objective 2:

To study the predictive role of Constructivist learning environment on Science Self-Efficacy of Secondary school students.

4.2.3.1 Predictive relationship of the construct Constructivist learning environment on Science Self-Efficacy – Simple Linear Regression Analysis

Ho_2: "There is no predictive relationship of the Constructivist learning environment on Science Self-Efficacy."

Table 4.4

Regression Analysis between Constructivist Learning Environment on Science Self-Efficacy

Model Summary							
Model	**R**	**R Square**	**djusted R Square**	**mated F-Value**	**df**	**Sig.**	**Result Null Hypothesis (H0)**

1	0.359	0.129	0.128	135.851	(1,916)	0.000	***Rejected***

c. Dependent Variable: Science Self-Efficacy

d. Predictors: (Constant), Constructivist Learning Environment

Table 4.5 Coefficients

Model	**Un standardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
1 (Constant)	1.569	0.141		11.161	0.000	1.293	1.845
Constructivist Learning Environment			0.359	11.656	0.000	0.402	0.564

Interpretation: The Pearson correlation coefficient, which is essential for conducting regression analysis, was first calculated. The correlation between the Constructivist Learning Environment (CLE) and science self-efficacy among secondary school students was found to be moderately strong, with a coefficient of R = 0.359. The corresponding coefficient of determination (R^2) is 0.129, indicating that 12.9% of the variance in science self-efficacy is explained by changes in the constructivist learning environment. This correlation was found to be statistically significant, with a p-value of 0.000, which is below the threshold of $\alpha = 0.01$. Furthermore, the F-test yielded a value of 135.851 with degrees of freedom df = (1,916), confirming that the constructivist learning environment is a significant predictor of science self-efficacy in secondary school students. These findings provide a solid foundation for the subsequent regression analysis.

From the Coefficients table, the regression equation is found to be:

(Science Self-Efficacy) = 1.569 + 0.483 (Constructivist Learning Environment).

Here, the constant is 1.569 representing the intercept and the unstandardized regression coefficient (B) is found to be 0.483, which indicates the slope, and implies that for every unit increase in the perception of the constructivist learning

environment in the classroom held by a secondary school student, a 0.483 unit increase in his or her science self-efficacy is predicted. The standardized coefficient (β) is 0.359. It means that for a one standard deviation rise in constructivist learning environment, a rise of 0.359 standard deviation can be expected in science self-efficacy. The associated p-values of the constant and the unstandardized regression coefficient (B) are both equal to 0.000 indicating high level of statistical significance of the obtained data, allowing for the extension of the sample findings to the entire population.

Hence, the null hypothesis H_0, that existence of no predictive relationship of the constructivist learning environment on the science self-efficacy, is ***rejected***. The independent variable constructivist learning environment predicts the dependent variable science self-efficacy in secondary school students moderately in strength and statistically significantly.

The obtained prediction result between the two variables is in conjunction with Alt., (2015) study with higher education students as the sample subjects and Boz and Cinder (2023) study with pre-service science teachers as subjects. A constructivist classroom leads to the upliftment of the self-efficacy among the students as indicated by the findings.

4.2.4 Data Analysis of Objective 3:

To study the predictive role of Epistemological beliefs in Science on the Science Academic Flow of Secondary school students.

4.2.4.1 Predictive relationship of the construct Epistemological Beliefs in Science on Science Academic Flow– Simple Linear Regression Analysis

Ho_3: "There is no predictive relationship of Epistemological Beliefs in Science on Science Academic Flow."

Table 4.6
Regression Analysis between Epistemological Beliefs in Science on Science Academic Flow:

Model Summary							
Model	**R**	**R Square**	**djusted R Square**	**stimated F-Value**	**df**	**Sig.**	**Result Null Hypothesis (H0)**
1	0.531	0.282	0.282	360.382	(1,916)	0.000	***Rejected***

a. Dependent Variable: Science Academic Flow

b. Predictors: (Constant), Epistemological Beliefs in Science

Table 4.7 Coefficients

Model	**Un standardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
1 (Constant)	0.280	0.230		1.217	0.224	-0.172	0.731
Epistemological Beliefs in Science	1.158	0.061	0.531	18.984	0.000	1.038	1.277

Interpretation: The correlation estimate, which is the pre-requisite for regression is reported first, where the Pearson correlation coefficient between epistemological beliefs in science of the secondary school students and science academic flow is found to be moderately strong in strength, with its magnitude R = 0.531, and the coefficient of determination R square 0.282. This indicates that 28.2% variation in science academic flow is explained by the predictor variable epistemological beliefs in science for a unit change in it.

The obtained estimate of correlation coefficient R is significant since the p-value = 0.000 is lesser than the level of significance $\alpha = 0.01$, under an estimated F value of 360.382 for degree of freedom df = (1,916). This significant ANOVA result hence obtained, confirms epistemological beliefs in science to be a useful predictor of science academic flow in secondary school students, paving the way for further regression analysis. From the Coefficients table, the regression equation is found to be: (Science Academic Flow) = 0.280 + 1.158 (Epistemological Beliefs in Science).

Here, the constant is 0.280 representing the intercept and the unstandardized regression coefficient (B) is found to be 1.158, which indicates the slope, and implies that for every unit increase in the perception of epistemological beliefs in science of a secondary school student, a 1.158 unit increase in h is o r he r science academic flow trait is predicted. The standardized coefficient (β) is 0.531. It means that for a one standard deviation rise in epistemological beliefs in science, a rise of 0.366 standard deviation can be expected in science academic flow. The associated p-values of the constant is non-significant, with p-value = 0.224 greater than the level of significance $\alpha = 0.05$. It indicates that there is not enough evidence to conclude that the intercept is different from zero. The unstandardized regression coefficient (B) is significant with p-value = 0.000 indicating high level of statistical significance of the obtained result, allowing for the extension of the sample findings to the entire population.

Hence, the null hypothesis H_0, that existence of no predictive relationship of the epistemological beliefs in science on the science academic flow, is ***rejected***. The independent variable epistemological beliefs in science predicts the dependent variable science academic flow in secondary school students, moderately in strength and statistically significantly. The study is first of its kind to the best of the investigator's knowledge and its results are hence standalone with respect the literature of science education research, at least in the Indian context.

As per the finding epistemological beliefs can become a path way to the secondary school students immerse themselves in science and experience the state of academic flow.

4.2.5 Data Analysis of Objective 4:

To study the predictive role of Science Self-Efficacy on Science Academic Flow in Secondary school students.

4.2.5.1 Predictive relationship of the construct Science Self-Efficacy on Science Academic Flow– Simple Linear Regression Analysis

Ho_4: "There is no predictive relationship of Science Self-Efficacy on Science Academic Flow."

Table 4.8

Regression Analysis between Science Self-Efficacy on Science Academic Flow:

Model Summary							
Model	**R**	**R Square**	**djusted R Square**	**mated F-Value**	**df**	**Sig.**	**Result Null pothesis (H0)**
1	0.550	0.302	0.301	396.228	(1,916)	0.000	***Rejected***

a.Dependent Variable: Science Academic Flow

b.Predictors: (Constant), Science Self-efficacy

Table 4.9 Coefficients

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95% Confidence Interval for B**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**
1 (Constant)	1.960	0.136	0.550	14.399	0.000	1.693	2.227
Science Self-Efficacy	0.832	0.042		19.905	0.000	0.750	0.914

Interpretation: The correlation estimate, which is the pre-requisite for regression is reported first, where the Pearson correlation coefficient between science self-efficacy of the secondary school students and science academic flow is found to be moderately

strong in strength, with its magnitude R = 0.550, and the coefficient of determination R square 0.302. This indicates that 30.2% variation in science academic flow is explained by the predictor variable science self-efficacy for a unit change in it. The obtained estimate of correlation coefficient R is significant since the p-value = 0.000 is lesser than the level of significance $\alpha = 0.01$, under an estimated F value of 396.228 for degree of freedom df = (1,916). This significant ANOVA result hence obtained, confirms science self-efficacy to be a useful predictor of science academic flow in secondary school students, paving the way for further regression analysis.

From the Coefficients table, the regression equation is found to be: (Science Academic Flow) = 1.960 + 0.832 (Science Self-Efficacy).

Here, the constant is 1.960 representing the intercept and the unstandardized regression coefficient (B) is found to be 0.832, which indicates the slope, and implies that for every unit increase in Science self-efficacy, a 1.960 unit increase in science academic flow is predicted. The standardized coefficient (β) is 0.550. It means that for every unit increase in the perception of science self-efficacy in the classroom held by a secondary school student, a 0.550 unit increase in his or her science academic flow is predicted. The associated p-values of the constant and the unstandardized regression coefficient (B) are both equal to 0.000 indicating high level of statistical significance of the obtained data, allowing for the extension of the sample findings to the entire population.

Hence, the null hypothesis H_0, that existence of no predictive relationship of the science self-efficacy on science academic flow, is ***rejected***. The independent variable science self-efficacy predicts the dependent variable science academic flow in secondary school students, moderately in strength and statistically significantly. The obtained prediction result between the two variables is in conjunction with Akyol and Sabasakal (2023) study on high school students where their academic flow as the dependent variable correlated significantly with academic self-efficacy in the Turkish context.

4.2.6 Data Analysis of Objective 5:

To validate Science Academic Achievement model in secondary school students

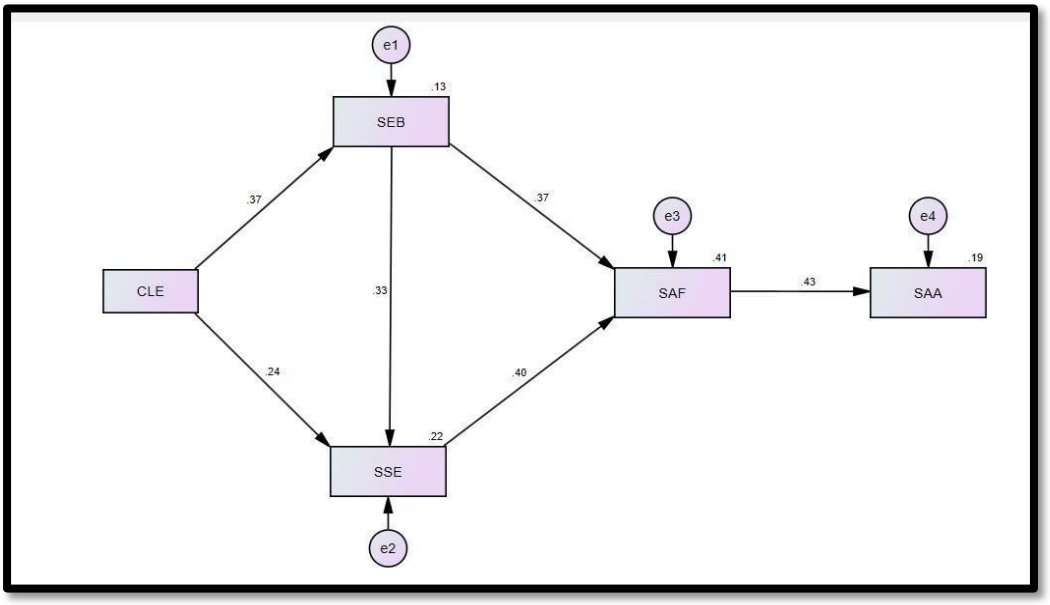


Fig. 4.1 Path Diagram of Science Academic Achievement Model

The overall fit of the hypothesized structural model was evaluated using several commonly accepted fit indices. The results are as follows:

Table 4.10

Goodness of Fit Estimates of the Science Achievement Model:

Estimates	**MIN with p-Value**	**"SRMR"**	**"TLI"**	**"CFI"**	**"RMSEA"**	**Remark**
Benchmarks	-	<0.08	0.95	0.95	0.05	-
Unconstrained Science Achievement Model	57.155; value = 0.000	0.0621	0.878	0.951	0.120	***ood Fit***

Interpretation: The Chi-Square test provided a significant result with p-value = 0.000. It suggests a discrepancy between the hypothesized model and the empirical data. However, this such a result is not uncommon owing to the

sensitivity of this estimates to large sample size. More importantly, the CFI value is 0.951 and above the benchmark of 0.95, suggesting a very good fit. The SRMR value of 0.0621 is less than its benchmark of 0.08 (Hooper, Coughlan and Mullen, 2008), indicating the hypothesized model's good fit with the obtained data.

The RMSEA value of 0.120 is higher than the recommended threshold of 0.05. The rationale behind obtaining such a high value of RMSEA for this model is that its degree of freedom is less, at df = 4, as is the case with a majority of science education models (Bailey et al., 2014; Adedokun et al., 2013; Akyol et al., 2012). Adding more regression paths between the latent constructs in a structural model, reduces its degree of freedom df (Taasoobshirazi and Wang, 2016). Moreover, RMSEA performs better for a model by having lower values, only when its degree of freedom df is large (Breivick and Olsson, 2001; Kenny and McCoach, 2003). Otherwise, this estimate has the tendency of falsely indicating poor model fit for an otherwise genuine model, when its degree of freedom df is low and even if the sample size is close to 1000 (Kline, 2010). Hence, structural equation models should observe caution while reporting the usage and the value RMSEA when the degree of freedom is less (Kenny, Kaniskan and McCoach, 2014), especially in the case of science education models.

The TFI value is 0.878 and lesser than the benchmark of 0.95. This indicates model rejection by the data. However, the low degree of freedom df of science education models also influences TLI value, where good models get rejected owing to lower values this estimates, in comparison to the CFI value for the same model (Taasoobshirazi and Wang, 2016).

Under the considerations of these statistical findings, overall, the hypothesized structural model can be deemed to show a good fit with the empirical data.

Table 4.11

Estimation of Structural Path Coefficients:

S.No.	Structural Path	β	p- value
1.	Constructivist Learning Environment -→ Epistemological Beliefs in Science	0.37	***
2.	Constructivist Learning Environment -→ Science Self-Efficacy	0.24	***
3.	Epistemological Beliefs in Science -→ Science Self-Efficacy	0.33	***
4.	Epistemological Beliefs in Science -→ Science Academic Flow	0.37	***
5.	Science Self-Efficacy -→ Science Academic Flow	0.40	***
6.	Science Academic Flow -→ Academic Achievement in Science	0.43	***

Interpretation: The results indicate that a Constructivist learning environment has a moderate predictive effect on epistemological beliefs in science, though it predicts science self-efficacy only weakly. Epistemological beliefs in science, in turn, have a moderate influence on both science self-efficacy and science academic flow. Science self-efficacy also has a moderate predictive effect on academic flow. Furthermore, science academic flow is a moderate predictor of academic achievement in science. All regression coefficients for the predictor variables in the model are significantly different from zero at the 0.001 level (two-tailed), with positive path coefficients suggesting that increases in one latent variable lead to corresponding increases in the related constructs. These findings support the proposed relationships among the constructs, demonstrating that the model is both valid and reliable in explaining their interconnections. Constructivist learning environments develops epistemological beliefs and self-efficacy beliefs in science, which make a secondary school student experience a sense of flow while studying this subject, ultimately leading to the scoring of good marks in science at secondary school level. This proposed theoretical model based on literature review, is hence

found to be supported well by empirical data also.

4.2.7 Data Analysis of Objective 6:

To test the factor structure equivalence of the Science Academic Achievement model in secondary school students across gender and batch groups.

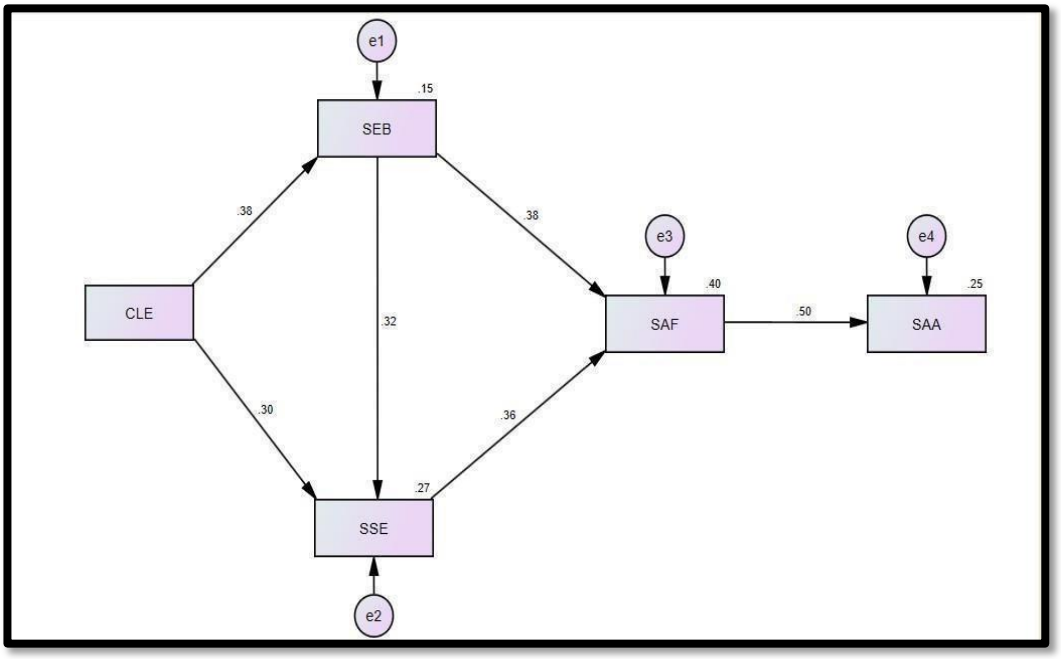


Fig. 4.2 Path Diagram of Science Academic Achievement Model during Measurement Invariance with respect to Gender

Table 4.12

Estimation of Structural Path Coefficients in Science Academic Achievement Model during Measurement Invariance with respect to Gender:

S.No.	Structural Path	β	p- value
1.	Constructivist Learning Environment -→ Epistemological Beliefs in Science	0.38	***
2.	Constructivist Learning Environment -→ Science Self-Efficacy	0.3	***
3.	Epistemological Beliefs in Science -→ Science Self-Efficacy	0.32	***
4.	Epistemological Beliefs in Science -→ Science Academic Flow	0.38	***
5.	Science Self-Efficacy -→ Science Academic Flow	0.36	***
6.	Science Academic Flow -→ Academic Achievement in Science	0.50	***

Table 4.13

Goodness of Fit Estimates – Measurement Invariance with respect to Gender

Estimates	"SRMR"	"TLI"	"CFI"	"RMSEA"	Remark	Result
Unconstrained Science Achievement Model	0.0621	0.878	0.951	0.120	**ΔCFI<= 0.01 Cheung and Rensvold Criteria (2002)**	***Invariant***
Constrained Science Achievement	0.0644	0.886	0.954	0.083		
Δ CFI	-	-	0.003	-	**Yes**	

Interpretation: The regression weight for the predictor variables in the prediction of their respective criterion variable is significantly different from zero at the 0.001 level (two-tailed). All structural path coefficients are thus statistically significant, with positive values indicating that increases in one latent construct are associated with increases in the connected latent constructs.

The goodness of fit estimates are acceptable, under the consideration that they are associated with a science education model, of lower degree of freedom. The Δ CFI difference of 0.003 between the unconstrained and constrained models is below the 0.01 threshold established by Cheung and Rensvold (2002). This indicates that the Science academic achievement model demonstrates configure measurement invariance across gender. In other words, the predictive relationships shown to exist between the variables making this model's structure, hold true not only in case of boys, but also in case of girls. The academic achievement of both boys and girls in science is dependent on the experience of flow while studying this subject, which in turn is dependent on these students' perception of their self-efficacy in science and its epistemological beliefs which primarily develop in a constructivist science classroom. It is statistically proven that the assumption that a quantitative model comprising of a host of its component science education variables, once validated, performs its primary task of measuring science academic achievement in secondary school students, exactly the same across the two levels of the demographic group gender, does not hold good.

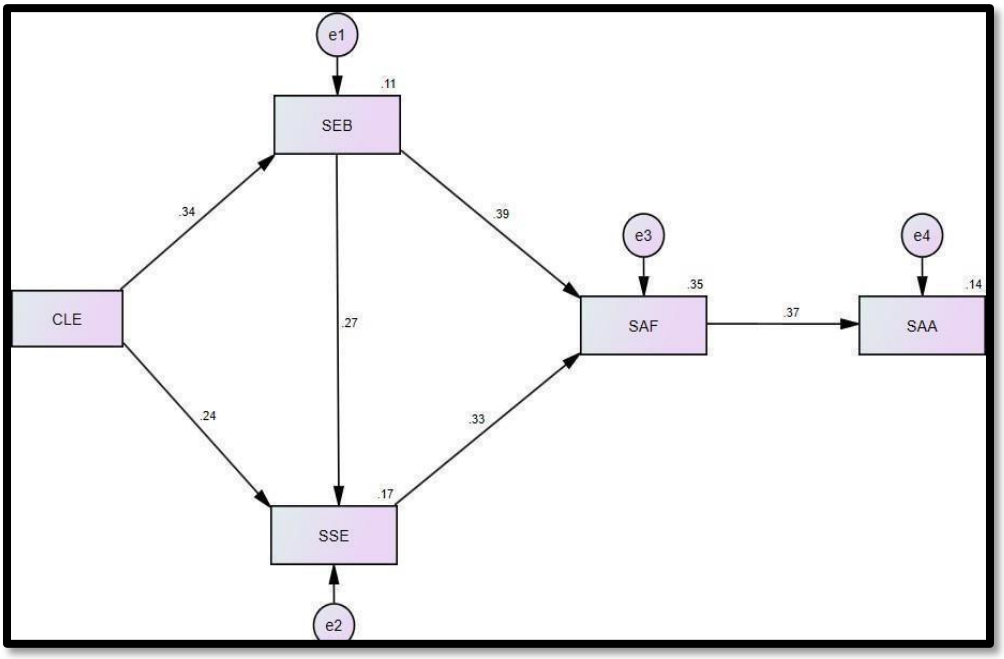


Fig. 4.3 Path Diagram of Science Academic Achievement Model during Measurement Invariance with respect to Batch

Table 4.14

Estimation of Structural Path Coefficients in Science Academic Achievement Model during Measurement Invariance with respect to Batch:

S.No	Structural Path	β	p-value
1	Constructivist Learning Environment-→ Epistemological Beliefs in Science	0.34	***
2	Constructivist Learning Environment -→ Science Self-Efficacy	0.24	***
3	Epistemological Beliefs in Science-→ Science Self-Efficacy	0.27	***
4	Epistemological Beliefs in Science -→ Science Academic Flow	0.39	***
5	Science Self-Efficacy -→ Science Academic Flow	0.33	***
6	Science Academic Flow-→ Academic Achievement in Science	0.37	***

Table 4.15

Goodness of Fit Estimates – Measurement Invariance with respect to Batch

Estimates	**"SRMR"**	**"TLI"**	**"CFI"**	**"RMSEA"**	**Remark**	**Result**
Un Constrained Science Achievement Model	0.0621	0.878	0.951	0.120	**ΔCFI<= 0.01 Cheung and Rensvold Criteria (2002)**	***Invariant***
Constrained Science Achievement	0.0538	0.864	0.946	0.09		
Δ CFI	-	-	0.005	-	**Yes**	

Interpretation: The regression weight for the predictor variables in the prediction of their respective criterion variable is significantly different from zero at the 0.001 level (two-tailed). All structural path coefficients are thus statistically significant, with positive values indicating that increases in one latent construct are associated with increases in the connected latent constructs. The goodness of fit estimates is acceptable, under the consideration that they are associated with a science education model of lower degree of freedom.

The ΔCFI difference between the unconstrained and constrained models is 0.005, which is below the threshold of 0.01 established by Cheung and Rensvold (2002). This indicates that the Science academic achievement model demonstrates configural measurement invariance across batches. In other words, the predictive relationships shown to exist between the variables making this model's structure, hold true not only in case of 9^{th} class students, but also in case of 10^{th} class students. Both 9^{th} and 10^{th} class students science academic achievement is dependent on experience of flow while studying this subject, which in turn is dependent on these students' perception of their self-efficacy in science and its epistemological beliefs which primarily develop in a constructivist science classroom. It is statistically proven that the assumption that a quantitative model comprising of a host of its component

science education variables, once validated, performs its primary task of measuring science academic achievement in secondary school students, exactly the same across the two levels of the demographic group class, does not hold good.

Therefore, the null hypothesis (H_0) that the science achievement model is measurement invariant across groups, with respect to gender and batch in the Indian context, is accepted.

4.2.8 Data Analysis of Objective 7:

To estimate the attenuation index in the reliability coefficient of the science academic achievement model variables.

Table 4.16

Estimation of Attenuation Index of Reliability of the Variables in the Science Academic Achievement Model:

Vari able	α	Ordinal α	Attenuation Index α
Constructivist Learning Environment	0.61	0.64	4.68%
Science Self- Efficacy	0.6	0.64	6.25%
Science Academic Flow	0.84	0.86	2.32%
Epistemological Beliefs in Science	0.56	0.6	6.66%

Interpretation: The attenuation index of reliability by estimates its interval and ordinal type Cronbach's alpha was conducted using RStudio software. The difference in ordinal alpha and Cronbach's alpha reliability coefficients can be clearly seen from the above table. While Cronbach's alpha underestimates the reliability of the scales, the ordinal alpha presents the actual estimations with attenuation index percentage lying between 2.32 % to 6.66%.

For constructivist learning environment variable, the attenuation in reliability when estimated using Cronbach's alpha is 4.68% less than the estimation of this psychometric property through Ordinal alpha. The drop in the reliability coefficient for Science self-efficacy variable is at 6.25% since the Cronbach's alpha estimate is

0.6 while its ordinal counterpart's estimate is 0.64.

The attenuation index is the lowest among the variables of science achievement model for science academic flow at 2.32% since its Cronbach's alpha estimate 0.84 and its ordinal alpha estimate is close enough at 0.86.

The attenuation index is the highest among the variables of science achievement model for epistemological beliefs in science variable at 6.66% since its Cronbach's alpha estimate 0.56 and its ordinal alpha estimate is close enough at 0.6. While the interval data reliability estimate for the epistemological beliefs in science variable is less than the acceptable benchmark of 0.6 (Hajjar, 2018) at 0.56 and hence not acceptable, the estimate of its ordinal counterpart is found to be acceptable at 0.6. As a result, it is apparent from these findings that estimation of Ordinal α, along with its reporting, especially when dealing with ordinal data type obtained from survey questionnaire, should be made a regular practice in research so as to not report underestimated and hence erroneous reliability estimates of adapted or constructed psychological instruments by assuming the obtained data to be of interval type.

4.2.9 Conclusion:

The present chapter conducted the statistical data analysis and discussed the interpretation of the results obtained as per the objectives of this study, along with precedence of them in the literature, if any. In the next chapter five – Conclusion, Educational Implications, Recommendations, Limitations and Suggestions for Future Research, the educational after effects of these findings, recommendations, limitations and suggestions for research in future will be discussed.

CHAPTER-V

CONCLUSIONS, EDUCATIONAL IMPLICATIONS, RECOMMENDATIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

CHAPTER-V

CONCLUSIONS, EDUCATIONAL IMPLICATIONS, RECOMMENDATIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

5.1 INTRODUCTION

The present study provides an overview of the key findings, both major and minor, and discusses their implications within the field of education. It also offers several recommendations aimed at improving the current educational landscape. Additionally, the study outlines the limitations encountered during the research and suggests potential areas for future investigation, grounded in the results presented in the previous chapter.

5.2 OVERVIEW OF THE STUDY

The investigator is a teacher and Principal of a reputed school associated with academics for the past two decades based on her professional experience at the secondary school level. The investigator wanted to explore the relationship between constructivist learning environment-based science education and certain mediators of academic achievement in science. This led to an extensive literature review exercise to learn more about the potential mediating variables. Candidate mediating variables obtained from the literature review were Epistemological beliefs in science, Science Self-efficacy, and science academic flow. The appropriate psychological instruments to measure the research variables were identified, accessed, and adopted in the Indian context. A descriptive research design followed by stratified random sampling led to data collection of intended sample subjects. The findings of the study and subsequent consequences are discussed below:

5.3 CONCLUSIONS RELATED TO STUDY FINDINGS:

The conclusive analysis of the findings as per the research objectives of the study is discussed below:

5.3 FINDINGS OF THE STUDY:

5.3.1 Objective 1: To study the predictive role of constructivist learning environment on Epistemological Beliefs in Science of Secondary school students.

- The predictive relationship of the constructivist learning environment on epistemological beliefs of science was found to be moderate in strength and statistically highly significant, indicating constructivist learning environment to be a useful predictor of epistemological beliefs in science among secondary school students.
- A unit rise in a constructivist learning environment leads to a 13.4 percent rise in epistemological beliefs. This particular result is similar to the findings of the study conducted by Cakir, 2008.

5.3.1.1 Objective 2: To study the predictive role of constructivist learning environment on Science self-efficacy in Secondary school students.

- The study reveals that a constructivist learning environment plays a crucial role in shaping secondary school students' self-efficacy in science. The relationship is statistically significant and moderately strong, indicating that as the constructivist elements in the learning environment increase, students' self-efficacy about the nature and acquisition of scientific knowledge improves accordingly. Specifically, this indicates that a 12.9% variation in science self-efficacy is explained by the predictor variable constructivist learning environment for a unit change. This finding underscores the importance of promoting constructivist practices in science education to foster a deeper understanding of scientific concepts and critical thinking skills among students. This particular result is similar to the findings of the study conducted by Alt (2015).

5.3.1.3 Objective 3: To study the predictive role of Epistemological Beliefs in Science on Academic flow in Secondary school students.

- This study reveals that the sophisticated epistemological beliefs in science are crucial for promoting academic flow. It statistically found that 28.2% variation in science academic flow is explained by the predictor variable epistemological beliefs in science for a unit change in it. Students with advanced epistemological beliefs are more likely to perceive science as a dynamic and evolving field, which ignites curiosity and a greater interest in learning. This perspective encourages them to engage deeply in science- related activities, leading to a state of academic flow where they become fully absorbed in the learning process, find it inherently rewarding, and perform at their best. This, in turn, enriches the learning experience, improves academic performance, and leads to a more profound and lasting understanding of scientific concepts among secondary school students. This particular result is similar to the findings of the study conducted by Tsai

5.3.1.4 Objective 4: To study the predictive role of Science Self Efficacy on Academic flow in Secondary school students.

- This study highlights the critical role of science self-efficacy in promoting academic flow. It was statistically determined that a 30.2% variation in science academic flow is explained by the predictor variable science self- efficacy for a unit change in it. Students with self-efficacy are more likely to see science as a dynamic and evolving field, which sparks curiosity and increases their interest in learning. This outlook motivates them to deeply engage in science-related activities, leading to a state of academic flow where they become fully immersed in the learning process. This enriched learning experience, in turn, enhances their overall academic performance. This particular result is similar to the findings of the study conducted by Rodriguez – Sanchez, et al,(2011).

5.3.1.5 Objective 5: To validate the Science Academic Achievement model in secondary school students

- The Science Academic Achievement model in secondary school students comprised of the antecedents and mediating variables like constructivist learning environment, epistemological beliefs, science self- efficacy, and academic flow was found to be valid concerning the model construct structure
- All the explanatory variables were found to predict their criterion variables statistically significantly.
- The fitness of index estimates like CFI, TLI, SRMR, and RMSCA behaved as per their statistical nature for a science education model with a low degree of freedom.

5.3.1.6 Objective 6: To test the factor structure equivalence of the Science Academic Achievement model in secondary school students across gender and batch groups.

- The Factor Structure of the Science Achievement model was found to be measurement invariant concerning gender group.
- The proposed model is found to be valid intact without any changes in construct structure in both girls and boys of secondary school level.
- The interrelationship between the variables of the study associated with science academic achievement in boys and girls is the same.
- Also, the Factor Structure of Science Achievement model was found to be measurement invariant with respect to batch group.
- The proposed model is found to be valid intact without any changes in construct structure in both 9th and 10^{th} class students of secondary school level.
- The interrelationship between the variables of the study associated with science academic achievement in 9th and 10^{th} class students are the same.

5.3.1.7 Objective 7: To estimate the attenuation index in the reliability coefficient of the science academic achievement model

- The underestimation of the reliability property of the scales of the study by Cronbach alpha was estimated quantitatively using attenuation index estimation.
- The Ordinal nature of the data obtained from survey questionnaires was considered and the associated reliability in the form of ordinal alpha for computed.
- Cronbach alpha was found to underestimate the true reliability measures of the scale compared to ordinal alpha.
- The obtained results of underestimation of the reliability of the scales or the attenuation in reliability when the obtained data is considered interval instead of treating it to be ordinal are mentioned in previous studies like Gadermann, Guhn and Zumbo (2012).

5.4 EDUCATIONAL IMPLICATIONS OF THE RESEARCH FINDINGS

- The significant prediction of Epistemological beliefs in science by a Constructivist learning environment proves the importance of employing constructivism as the pedagogical approach to teach science at the secondary school level, through the cultivation of science process skills in the students (Ramnath, 2014; Terumal and Kumar,2023; Libata , Ali and Ismail, 2023).
- Constructivist learning environment was found to predict science self- efficacy in secondary school students which further stresses the need to instruct science in the classroom of 9^{th} and 10th-class students by using the 5E model approach.
- Epistemological belief in science was found to predict the experience of academic flow in science. This finding emphasizes the need to teach science at the secondary school level using process skills, as outlined by the National Council for Educational Research and Training (NCERT) and the National Curriculum Framework (NCF 2005). This approach enables students to develop their own perspectives on the nature of science as a discipline,

which in turn can make studying science a more enjoyable activity.

- Science self-efficacy was found to be an explanatory variable for Science Academic Flow. This finding suggests that by increasing students' belief in their ability to learn science, science teachers can foster a greater appreciation of the subject among students.
- Science Academic Flow was identified as a predictor of academic achievement in science subjects among secondary school students. This result highlights the importance of promoting academic flow in science through the efforts of science teachers, administrators, and parents, both at school and at home.
- The validity of the science academic achievement model for secondary school students indicates the existence of an empirical means to estimate the predictors of strong academic performance in science at the secondary school level.
- The finding that the new model of academic achievement in science is measurement equivalent with respect to both the gender and batch of secondary school students opens up a new frontier for the science teachers to conduct quantitative research on the effectiveness of their constructivist class.
- The estimation of the attenuation index in the reliability measurement implies towards a very good psychometric practice to adapt in future by science education researchers and practitioners alike. In addition to appropriately calculating the consistency of the scale scores using ordinal alpha reliability, this study also advises education researchers to be cautious about treating survey questionnaire data as interval data, since assuming ordinal data to be interval and using Cronbach's alpha as a reliability estimate may result in underestimation of reliability due to its inherent limitations.

5.5 RECOMMENDATIONS

- Workshops must be conducted in schools to teach the in-service science teachers in the planning of lessons and delivery of science instructions in the classroom by using the 5E constructivist approach.
- The in-service teachers must be encouraged to attend seminars, refresher courses, and certifications on learning how to include science process skills as pedagogical strategies in the classroom.
- School management should make constructivism and process skill-based science pedagogy as important criteria for improving the teaching performance of their in-service staff.
- Principals of the schools along with the laboratory in charge and technical assistants must ensure that the institution has a well-maintained physical laboratory with adequate scientific instruments and hardware devices installed in the classroom for the usage of virtual lab simulations and science open wares towards the promotion of science process skills.
- In particular, all secondary school students and teachers across India must have an account in the Online Labs or Olabs platform, which is an educational initiative pioneered by Amrita Vishwa Vidyapeetham in partnership with CDAC, Mumbai, funded by the research grant provided by the Department of Information Technology, Government of India. This online platform provides a free learning resource for developing science process skills in virtual mode.
- The projects allocated to the secondary school students in science by the in-service teachers must include adequate stress on the display of science process skills and knowledge construction through social learning.
- In-service teachers must be encouraged and efficiently exposed to do science pedagogy-based research involving the measurement of important science education-based variables in secondary school students using psychological instruments available in India.
- The school library should be replenished with an adequate number of books on science process skills and constructivism-based science activities for secondary school students.

- Competitions on epistemological beliefs on science-based questions and science process skills-based activities/ projects can be regularly conducted along with National Science Day being observed in the school with the mentioned activities as the highlights of the events.
- Journals of science discussing the significance and mechanism of constructivism and science process skills must be regularly updated in the school's science clubs for the promotion of epistemological beliefs in science, self-efficacy and experience of flow while learning the subject by the students in a constructivist environment.
- ATAL labs must be established, well maintained, and promoted by the school management, utilized well by the teachers and students, and appreciated by the parents and society for their role in developing science process skills in a constructivist learning environment.
- Students must be taken on field trips to scientific institutions of repute by the school management for the development of science process skills through experiential learning which in turn can develop mediating variables of science academic achievement as per this model.
- The availability of adopted instruments of constructivist learning environment, and academic flow should be harnessed well by the research scholars, practicing in-service teachers and internship bound preservice teachers in conducting applied and action research study in science education.

5.6 LIMITATIONS:

- The cross-sectional nature of the present study offers only a snapshot of the phenomenon under study, there by neglecting the influence of several confounding and situational factors.
- The use of questionnaires as the sole means of data collection in this study is always thwarted by the possibility of social desirability bias displayed the sample subjects in spite of the provided instructions to give honest responses.
- Though there are 13 districts in the state of Andhra Pradesh, the final data collection was stopped on reaching a relatively large sample size of 918

covering only eight districts of the state.

- The study focused on selected variables. The variables of science education considering the constrains associated with model complexity. Several closely related variables found during the literature review do require appropriate addressal towards the improvement of science academic achievement in secondary school students.

5.7 SUGGESTIONS FOR FUTURE STUDIES

- The study must be extended to include other critical variables associated with science education to increase the model's robustness.
- The model can be tested on secondary school students belonging to other boards of education in multiple cultural contexts to increase its construct validity further through replications in fresh learning conditions.
- Future studies can test the measurement invariance property of the model across other pertinent groups like types of schools, localities, and school boards.
- The measurement invariance property of the model needs to be extended to metric invariance, scalar invariance, and residual invariance to complete the higher key of measurement invariance testing.
- Mixed method study must be taken up in future involving the interviews of students and teachers on the perceptions these stakeholders have on the effectiveness of science process skills in learning the subject in constructivist learning environment.
- Future studies must validate the effectiveness of the present model of science academic achievement by incorporating science process skills and extending the theoretical underpinning of the study to cognitive apprenticeship.
- Future research must take up experimental studies to test various interventions to promote the critical variables of epistemological beliefs and flow in the context of science education in secondary school students.
- Since academia and industry are intimately related to other in the 21 st century, the instrumentality of the present model of science academic achievement in furthering science career related research must be explored in

the forthcoming studies.

5.8 CONCLUSION

The National Curriculum Framework (NCF) 2005 was a landmark document that changed the pedagogical landscape of the country by introducing a constructivist learning environment in the classrooms. The present study quantitatively modeled and documented the predictive role of this vital academic variable on certain equally important mediatory variables pertaining to science education, ultimately associating the model to the very critical academic criterion variable, science academic achievement in secondary school students. The robustness and the measurement invariance capabilities of the research model are hoped to be instrumental in furthering the quality of science education and its research in the country.

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QUESTIONNAIRES

CONSTRUCTIVISTIC LEARNING ENVIRONMENT SCALE (CLES)

(Tylor&Fraser(1991)adopted byNik,Faser&Led(2003)

1. I learn about the world outside of school.
   Almost Always / Often / Some-times / Seldom / Almost Never
2. My learning starts with problems about the world outside of school.
   Almost Always / Often / Some-times / Seldom / Almost Never
3. I learn how science can be a part of my out-of-school life.
   Almost Always / Often / Some-times / Seldom / Almost Never
4. I get a better understanding of the world outside of school.
   Almost Always / Often / Some-times / Seldom / Almost Never
5. I learn interesting things about the world outside of school.
   Almost Always / Often / Some-times / Seldom / Almost Never
6. What I learn has nothing to do with my out-of-school life.
   Almost Always / Often / Some-times / Seldom / Almost Never
7. I learn that science cannot provide perfect answers to problems.
   Almost Always / Often / Some-times / Seldom / Almost Never
8. I learn that science has changed over time.
   Almost Always / Often / Some-times / Seldom / Almost Never
9. I learn that science is influenced by people's values and opinions.
   Almost Always / Often / Some-times / Seldom / Almost Never
10. I learn about the different sciences used by people in other cultures.
    Almost Always / Often / Some-times / Seldom / Almost Neve
11. I learn that modern science is different from the science of long ago.
    Almost Always / Often / Some-times / Seldom / Almost Never
12. I learn that science is about inventing theories
    Almost Always / Often / Some-times / Seldom / Almost Never
13. It's OK to ask the teacher "why do we have to learn this?"
    Almost Always / Often / Some-times / Seldom / Almost Never
14. It's OK to question the way I'm being taught.
    Almost Always / Often / Some-times / Seldom / Almost Never

15. It’s OK to complain about activities that are confusing.
    Almost Always / Often / Some-times / Seldom / Almost Never
16. It’s OK to complain about anything that prevents me from learning.
    Almost Always / Often / Some-times / Seldom / Almost Never
17. It’s OK to express my opinion.
    Almost Always / Often / Some-times / Seldom / Almost Never
18. It’s OK to speak up for my rights.
    Almost Always / Often / Some-times / Seldom / Almost Never
19. I help the teacher to plan what I’m going to learn.
    Almost Always / Often / Some-times / Seldom / Almost Never
20. I help the teacher to decide how well I am learning.
    Almost Always / Often / Some-times / Seldom / Almost Never
21. I help the teacher to decide which activities are best for me.
    Almost Always / Often / Some-times / Seldom / Almost Never
22. I help the teacher to decide how much time I spend on activities.
    Almost Always / Often / Some-times / Seldom / Almost Never
23. I help the teacher to decide which activities I do.
    Almost Always / Often / Some-times / Seldom / Almost Never
24. I help the teacher to assess my learning.
    Almost Always / Often / Some-times / Seldom / Almost Never
25. I get the chance to talk to other students.
    Almost Always / Often / Some-times / Seldom / Almost Never
26. I talk with other students about how to solve problems.
    Almost Always / Often / Some-times / Seldom / Almost Never
27. I explain my ideas to other students.
    Almost Always / Often / Some-times / Seldom / Almost Never
28. I ask other students to explain my ideas.
    Almost Always / Often / Some-times / Seldom / Almost Never
29. Other students ask me to explain my ideas.
    Almost Always / Often / Some-times / Seldom / Almost Never
30. Other students explain their ideas to me.
    Almost Always / Often / Some-times / Seldom / Almost Never

Epistemological Beliefs in Science Scale(EBSS)(Hofer&Pintrch(1997)adopted by Anne(2004)

1. Everybody has to believe what scientists say.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

2. In science, you have to believe what the science books say about stuff.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

3. Whatever the teacher says in science class is true.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

4. If you read something in a science book, you can be sure it's true.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

5. Only scientists know for sure what is true in science.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

6. All questions in science have one right answer.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

7. The most important part of doing science is coming up with the right answer.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

8. Scientists pretty much know everything about science; there is not much more to know.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

9. Scientific knowledge is always true.
   Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

10. Once scientists have a result from an experiment, that is the only answer.
    Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

11. Scientists always agree about what is true in science.
    Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

12. Some ideas in science today are different than what scientists used to think.
    Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

13. The ideas in science books sometimes change.
    Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

14. There are some questions that even scientists cannot answer.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

15. Ideas in science sometimes change.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

16. New discoveries can change what scientists think is true.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

17. Sometimes scientists change their minds about what is true in science.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

18. Ideas about science experiments come from being curious and thinking about how things work.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

19. In science, there can be more than one way for scientists to test their ideas.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

20. One important part of science is doing experiments to come up with new ideas about how things work.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

21. It is good to try experiments more than once to make sure of your findings.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

22. Good ideas in science can come from anybody, not just from scientists.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

23. A good way to know if something is true is to do an experiment.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

24. Good answers are based on evidence from many different experiments.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

25. Ideas in science can come from your own questions and experiments.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

26. It is good to have an idea before you start an experiment.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Science Self-Efficacy Scale Glynn and Koballa (2006) adapted by Biswal and Chakraborty (2024) in the Indian context.

1. Using scientific principles to explain common phenomena in an experiment or daily life.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily.

2. Calculating and comparing unknown variables according to the given data, variables and other information by using certain science laws.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

3. Interpreting the purpose of a specific operation in science experiments.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

4. Predicting an experimental phenomenon based on scientific principles.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

5. Using scientific principles to make simple judgments about properties of or changes in Matter.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

SCIENCE ACADEMIC FLOW SCALE

The scholar has adopted Edu Flow Scale of JEAN HEUTTE (2021) and converted into Science Academic Flow tool statements to be validated for the secondary school students in A.P.

1. I trust my ability to meet the high demands of the science classroom situations.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

2. I feel completely in control of my actions during science theory and practical classes
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

3. At each step, I know exactly what I have to do during science classes.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

4. I am wholly absorbed in what I am doing during a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

5. I am deeply focused on what I am doing during a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

6. I lose track of time in a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

7. I don't care about what others may think of me as a science student.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

8. I am not concerned about the judgment of others of me as a science student.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

9. I am not worried about what others might think of me for choosing science as a career.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

10. I have the feeling I am living a very exciting experience while learning science.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

11 Science activities bring me a sense of well – being.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

12.When I talk about science activities, I feel such a deep emotion that I want to share it with others.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

FINAL TOOL

Q1 - CLES - I learn about the world outside of the school.
Almost Never / Seldom / Some-times / Often / Almost Always

Q2 - CLES - I get a better understanding of the world outside of the school.
Almost Never / Seldom / Some-times / Often / Almost Always

Q3 - CLES - I learn interesting things about the world outside of the school.
Almost Never / Seldom / Some-times / Often / Almost Always
Q4 – CLES - It's OK to ask the teacher "why do we have to learn this?"
Almost Never / Seldom / Some-times / Often / Almost Always

Q5 – CLES - It's OK to question the way I'm being taught.
Almost Never / Seldom / Some-times / Often / Almost Always

Q6 – CLES - It's OK to complain about activities that are confusing.
Almost Never / Seldom / Some-times / Often / Almost Always

Q7 -- CLES - It's OK to complain about anything that prevents me from learning.
Almost Never / Seldom / Some-times / Often / Almost Always

Q8 -- CLES - I help the teacher to plan what I'm going to learn.
Almost Never / Seldom / Some-times / Often / Almost Always

Q9 -- CLES - I help the teacher to decide how well I'm learning.
Almost Never / Seldom / Some-times / Often / Almost Always

Q10 – CLES -I help the teacher to decide how much time I spend on activities.
Almost Never / Seldom / Some-times / Often / Almost Always

Q11 – CLES -I help the teacher to decide how much time I spend on activities.
Almost Never / Seldom / Some-times / Often / Almost Always

Q12 – CLES - I help the teacher to decide which activities I do.
Almost Never / Seldom / Some-times / Often / Almost Always

Q13 – CLES - I help the teacher to asses my learning.
Almost Never / Seldom / Some-times / Often / Almost Always

Q14 – CLES - I get the chance to talk to other students.
Almost Never / Seldom / Some-times / Often / Almost Always

Q15 – CLES - I talk with other students about how to solve problems.
Almost Never / Seldom / Some-times / Often / Almost Always

Q16 – CLES - I explain my ideas to other students.
Almost Never / Seldom / Some-times / Often / Almost Always

Q17 – CLES - I ask other students to explain my ideas.
Almost Never / Seldom / Some-times / Often / Almost Always

Q18 – CLES - Other students ask me to explain my ideas.
Almost Never / Seldom / Some-times / Often / Almost Always

Q19 – CLES - Other students explain their ideas to me.
Almost Never / Seldom / Some-times / Often / Almost Always

Q20 –EBS – Everybody has to believe what scientists say.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

Q21 –EBS – In science, you have to believe what the science books say about stuff.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

Q22 –EBS – Whatever the teacher says in science class is true.
Strongly agree / Disagree / Neutral / Agree / Strongly agree.

Q23 –EBS – If you read something in a science book, you can be sure it's true.
Strongly disagree / Disagree / Neutral / agree / Strongly agree

Q24 –EBS – The most important part of doing science is coming up with the right answer.

Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q25 –EBS –Scientific knowledge is always true.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q26 –EBS –Scientists always agree about what is true in science.
Strongly agree / Disagree / Neutral / Agree / Strongly agree

Q27 –EBS –Some ides in science today are different than what scientists used to think.

Strongly disagree / Disagree / Neutral / Agree / strongly agree

Q28 –EBS –The ideas in science books sometimes change.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q29 –EBS –Ideas in science sometimes change.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q30 –EBS –Sometimes scientists change their minds about what is true in science.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q31 –EBS–In science there can be more than one way for scientists to test their ideas.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q32 –EBS – One important part of science is doing experiments to come up with new ideas about How things work.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q33 –EBS – It is good to try experiments more than once to make sure of your feelings.

Strongly disagree / Disagree / Neutral / Agree / Strongly agree

Q34 –EBS – Good ideas in science can come from anybody, not just from scientists.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

Q35 –EBS– Ideas in science can come from your own questions and experiments.
Strongly disagree / Disagree / Neutral / Agree / Strongly agree.

Q36 –SSES – Using scientific principles to explain common phenomena in an experiment or daily life.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily.

Q37 –SSES –Calculating and comparing unknown variables according to the given data, variables and other information by using certain science laws.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

Q38 –SSES –Interpreting the purpose of a specific operation in science experiments.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

Q39 –SSES–Predicting an experimental phenomenon based on scientific principles.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

Q40 –SSES –Using scientific principles to make simple judgments about properties of or changes in Matter.
I couldn't do this at all/I couldn't do this/May be I could do this/I could do this/ I could do this easily

Q41-EDUF- I trust my ability to meet the high demands of the science classroom situations.

Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q42–EDUF- I feel completely in control of my actions during science theory and practical classes
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q43–EDUF - At each step, I know exactly what I have to do during science classes.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q44- EDUF-I am wholly absorbed in what I am doing during a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q45 EDUF -- I am deeply focused on what I am doing during a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q46 –EDUF - I lose track of time in a science class.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q47 –EDUF- I don't care about what others may think of me as a science student.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q48 – EDUF - I am not concerned about the judgment of others of me as a science student.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q49 - EDUF - I am not worried about what others might think of me for choosing science as a career.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q50 – EDUF- I have the feeling I am living a very exciting experience while learning science.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q51 – EDUF - Science activities bring me a sense of well – being.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

Q 52 - EDUF -When I talk about science activities, I feel such a deep emotion that I want to share it with others.
Strongly disagree / Disagree / Somewhat disagree / Neutral / Somewhat agree / Agree / Totally agree

SCOPUS PUBLICATIONS

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Validation of Cognitive Absorption Model Based Science Academic Flow Scale in the Indian Context: A Network Psychometrics Approach Analysis

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ABSTRACT

The present study was conducted to validate the Cognitive absorption model (El-Mawas and Heutte, 2019) based Science Academic Flow Scale in the Indian context. The sample of the study comprised of 342 (213 Girls and 129 Boys) secondary school students belonging to grades 9^{th} and 10^{th} of a school in the Andhra Pradesh state of India. Considering the ordinal level of the data obtained in this cross-sectional survey design study, the novel approach of Network Psychometrics was chosen to validate the four factors structure of the construct flow particularly in science academic context. RStudio/R Ver 4.2.3 was used for conducting the statistical analysis. Exploratory graph analysis (EGA) performed at the item/node level, using the function *bootnet*, revealed the nine nodes of Cognitive absorption form a cluster and the remaining three nodes of autotelic experience form another cluster. The network existing between the four dimensions/clusters of science academic flow was explored. The ordinal confirmatory factor analysis results displayed excellent estimates of robust goodness of fit indices. Structural consistency exercise revealed all four clusters being part of a single network of science academic flow. The regularized network of the model was obtained using the function *bootnet*. It was followed by obtaining of the centrality indices, edge weight confidence interval and correlation stability of the network using *qgraph* function. Implications of the study with respect to school education and psychometric practices are discussed.

Keywords: *Cognitive Absorption Modeling, Exploratory Graph Analysis (EGA), Network Psychometrics, Ordinal Confirmatory Factor Analysis, Science Academic Flow, Science Academic Flow Scale, Structural Consistency*

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Research paper

Addressing The Issues of Low Degrees of Freedom and Associated Poor Validation Estimates of Science Education Models: An Advocacy for The Application of Confirmatory Network Analysis

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Abstract

Generally, science education models have a low degree of freedom df, and this psychometric aspect negatively impacts the overall goodness of fit estimates obtained on conducting CB-SEM-based Confirmatory Factor Analysis (CFA) on the hypothesized latent models using the Maximum Likelihood (ML) estimator. To address this issue, the state-of-the-art Confirmatory Network Analysis (CNA) approach is advocated, which uses the adjacency matrix in estimation and treats the data type of the data collected using survey questionnaires as ordinal using the appropriate Diagonally Weighted Least Squares (DWLS) estimator to provide the proper scaled goodness of fit estimates of the network. In the present study, the goodness of fit estimates of a science education model involving the perception of 918 secondary school students of India on their science constructivist learning environment, epistemological beliefs in science, science self-efficacy, science academic flow, and science academic achievement were found from the traditional latent variable modeling and the latest network perspectives. Data analysis was conducted using SPSS AMOS Ver 23.0, several packages of R and through generated using ChatGPT Ver. 5. The scaled goodness of fit estimates of confirmatory network analysis produced a better picture of the reality over confirmatory factor analysis, and provided deeper insights on the interactions among the studied variables as were graphically established by the differences in the Bland-Altman plots of the CFI, TLI, RMSEA and SRMR estimates of the two approaches. Educational and psychometric implications of the study are discussed.

Keywords: *Bland-Altman Plots; Confirmatory Network Analysis; Confirmatory Factor Analysis; Degree of Freedom; Science Education Models*

1. Introduction

Science education plays a significant role in the development of problem-solving skills, critical thinking, and creativity among adolescents at the secondary school level, which cast their ramifications on the development of society, its economic progress, while observing the essence of sustainable development goals [8]. The goal of science education is to be instrumental in developing adolescents into adults who can creatively and scientifically solve the issues of the societies in which they will dwell in the future [43]. For meeting this mandate, the field must be supported by research-driven findings, which come under the purview of science education research. It tries to gain insights into the ways in which the subject of science can be learned by the students and taught optimally by the teachers. Its approach is multi-disciplinary and grounded in other fields like educational psychology, statistics, and data science.

Researchers in the field of science education research most often try to test the relationships among multiple science education-related traits in the sample subjects by proposing hypothesized models driven by theory and involving representation of the traits as operationally measurable variables, to statistically substantiate the proposed models with empirical data [34]. The statistical approach found to be most appropriate for this purpose is called the Structural equation modeling [32]. A special case of structural equation modeling called the Confirmatory factor analysis (CFA) forms the statistical technique, which is applied on the obtained data to test the validity of any proposed theory based model using several statistical software and formulae or estimators [11], most prominent and quite developed of whom is the covariance-based SEM (CB-SEM) via maximum likelihood estimator [31],[33],[28] using software like SPSS AMOS [3].

To perform the covariance-based structural equation modeling (CB-SEM), a researcher gathers the data of each of the variables (p) whose relationships are to be studied. In the first stage of the CB-SEM approach, called model specification, the software used to carry out the statistical analysis is specified, including the number of variables involved in the model, their status as being the predictor or the predicted, and relationships existing among them, as guided by a theory, graphically, which form the path diagram of the model. In the second stage,

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PAPER PRESENTATIONS AND CERTIFICATIONS



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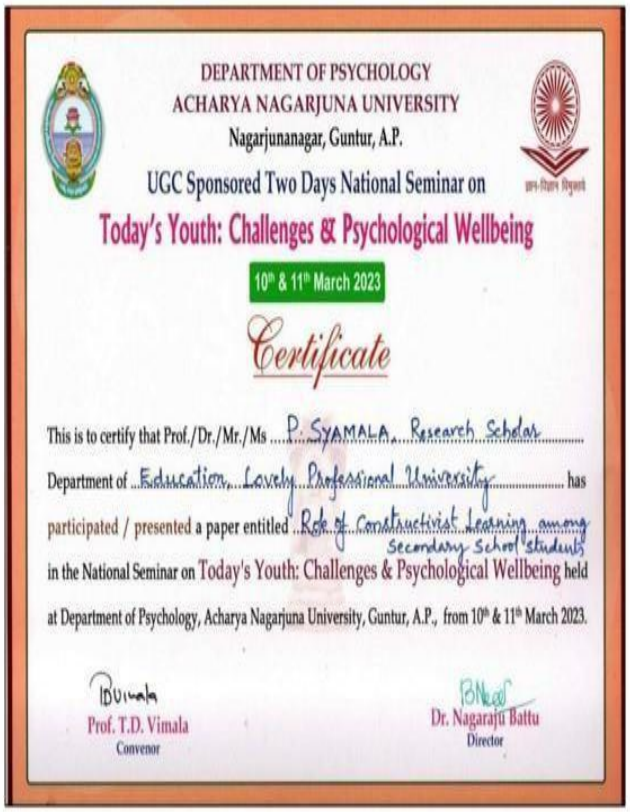
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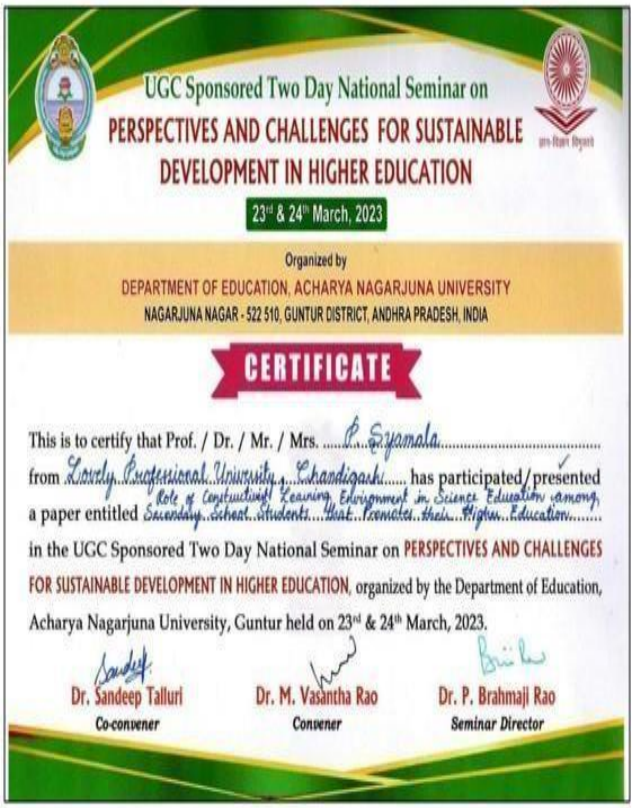
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Dr. Nagaraju Battu
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UGC Sponsored Two Day National Seminar on
PERSPECTIVES AND CHALLENGES FOR SUSTAINABLE DEVELOPMENT IN HIGHER EDUCATION
23rd & 24th March, 2023

Organized by
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NAGARJUNA NAGAR - 522 510, GUNTUR DISTRICT, ANDHRA PRADESH, INDIA

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This is to certify that Prof. / Dr. / Mr. / Mrs. P. Syamala
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in the UGC Sponsored Two Day National Seminar on PERSPECTIVES AND CHALLENGES FOR SUSTAINABLE DEVELOPMENT IN HIGHER EDUCATION, organized by the Department of Education, Acharya Nagarjuna University, Guntur held on 23rd & 24th March, 2023.

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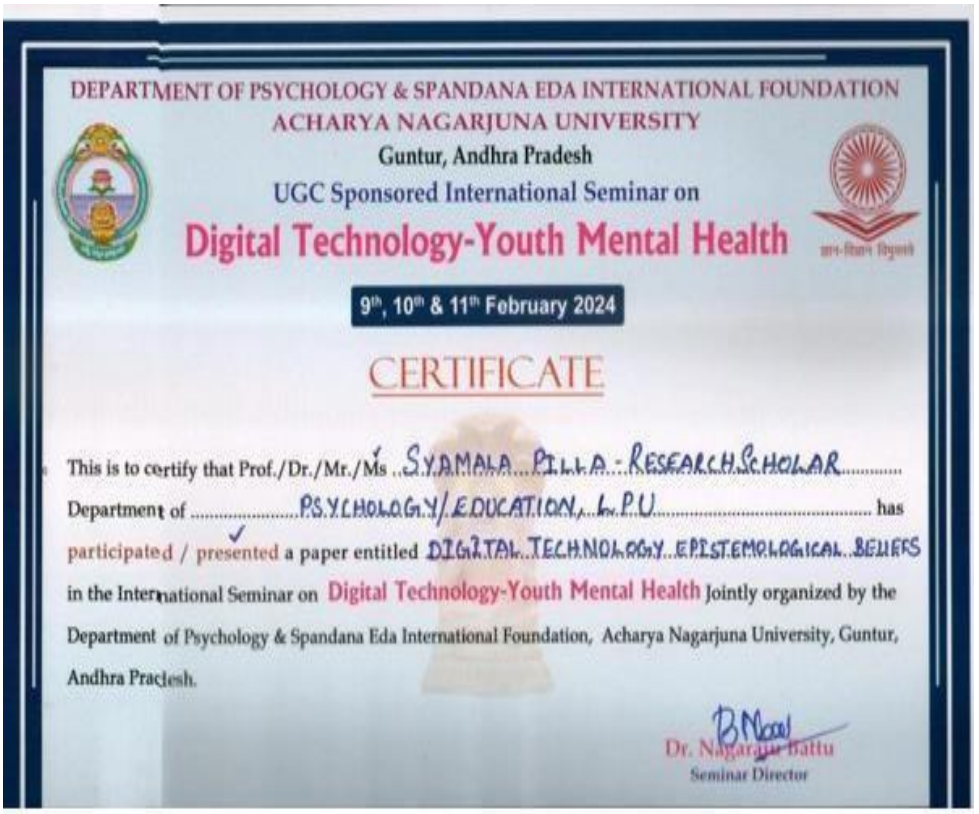
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DEPARTMENT OF PSYCHOLOGY & SPANDANA EDA INTERNATIONAL FOUNDATION
ACHARYA NAGARJUNA UNIVERSITY
Guntur, Andhra Pradesh
UGC Sponsored International Seminar on

Digital Technology-Youth Mental Health

9th, 10th & 11th February 2024

CERTIFICATE

This is to certify that Prof./Dr./Mr./Ms SYAMALA PILLA - RESEARCH SCHOLAR
Department of PSYCHOLOGY/EDUCATION, L.P.U. has
participated / presented a paper entitled DIGITAL TECHNOLOGY EPISTEMOLOGICAL BELIEFS
in the International Seminar on Digital Technology-Youth Mental Health Jointly organized by the Department of Psychology & Spandana Eda International Foundation, Acharya Nagarjuna University, Guntur, Andhra Pradesh.

Dr. Nagaraju Battu
Seminar Director