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Experiential Learning in Science for Developing Higher Order Thinking Skills (HOTS) & Scientific Temper: A Literature Review

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ABSTRACT

The quality teaching learning depends on how students are actively engaged in the learning process. Science classes should always create a spark among students and motivate them to think critically and design creatively. This review paper synthesizes findings from 51 research studies that includes 30 international studies and 21 national studies on experiential learning. The study specifically explores the impact of experiential learning on the development of HOTS, Scientific temper among the secondary students in science. Some selective studies are also taken from other subjects. The study has structured around five essential themes emerged from the reviewed literatures; the concept of experiential learning, its impact on the effectiveness of science teaching learning, its effectiveness in the development of HOTS as well as scientific temper among students & its effectiveness in other subjects. The critical analysis reveals positive outcomes in the science learning following experiential learning approach though there are significant obstacles in implementing this approach in all schools and for all students, The study establishes a foundation for understanding how direct, hands-on engagement with scientific concepts can lead to improved critical thinking and scientific curiosity, compared to traditional rote learning. The study concludes that experiential learning has a positive effect on the achievement of science in secondary stage and suggests for developing comprehensive strategy and lesson plan that can lead higher order thinking Skill and scientific temper development. Further studies need to be carried out on the effectiveness of experiential learning on the development of HOTS in aspects like creativity and evaluation as well as on Scientific temper in aspects like respect for evidence, honesty & integrity, perseverance, and scepticism among students as very few studies are there in these areas.

Keywords: Experiential learning, Science, Higher Order Thinking Skills, Scientific temper, Secondary students

INTRODUCTION

21st century education system demands holistic development i.e. the development of 3H (Heart, Hand, and Head). The prevailing education system mostly focusses on cognitive development leaving the affective and psychomotor aspects aside. This leads to uneven development of a child. This may be due to traditional teacher-centred method of teaching. Thus, the need of the hour is the change of pedagogical approach i.e. from teacher centred to learner centred approach. Experiential learning (EL) is one such learner centred approach. Kolb (1984) in his *book Experiential Learning: Experience as the Source of Learning and Development*. emphasizes on active participation and reflection on the learning process over the product. It focusses on environment where learning can reflect on their experiences and apply them into real life contexts. As per the experiential learning model of Kolb, the learning theory works in four stages— concrete experience, reflective observation, abstract conceptualization, and active experimentation.

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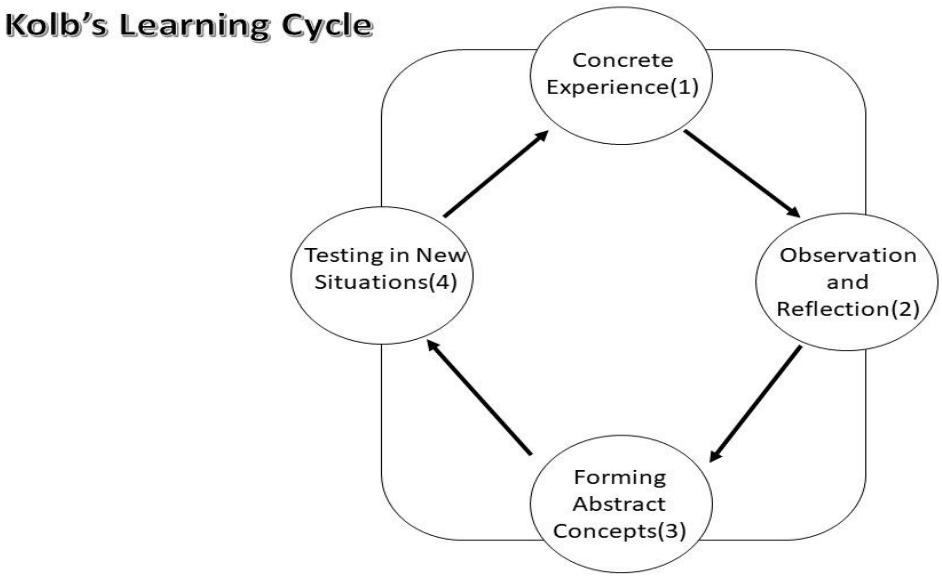

The first two stages of the cycle involve grasping an experience, the second two focus on transforming the experience. Kolb argues that effective learning is seen as the learner goes through the cycle, and the speciality of this model is that the learner can enter the cycle at any time. NEP (2020) framework in Part-I chapter 4 *Curriculum and Pedagogy in Schools: Learning Should be Holistic, Integrated, Enjoyable, and Engaging*, under sub clause 4.6 writes "In all stages, experiential learning will be adopted, including hands-on learning, arts-integrated and sports-integrated education, story-telling-based pedagogy, among others, as standard pedagogy within each subject, and with explorations of relations among different subjects. The NEP (2020) document further emphasizes on experiential learning under sub clause 4.5, where it writes "reduce curriculum content to enhance experiential learning and critical thinking." Bloom's taxonomy (1956) describes that Higher-order thinking skills (HOTS) include analysis, synthesis, evaluation, problem-solving, critical thinking, and creativity, that involve complex cognitive processes beyond simple memorization. HOTS represent higher levels of thinking where individuals apply, connect, and generate new ideas from existing knowledge, rather than just recalling facts. These transferable skills are crucial for lifelong learning, critical thinking, and navigating complex situations in real life. Experiential learning fosters critical thinking and Deep learning concludes Koulouris (2024). Scientific temper is a rational and questioning attitude towards life and problems, characterized by open-mindedness, a reliance on evidence-based reasoning, and a willingness to revise beliefs considering new information. It involves applying scientific methods such as questioning, hypothesizing, testing, and analysing to make informed choices and solve problems as mentioned by Nehru (1946) in his book *The Discovery of India*. According to the Position Paper of National Focus Group on 'Teaching of Science' (p.11) one of the aims of Science Education is to cultivate scientific temper, objectivity, critical thinking and freedom from fear and prejudice. The concept of scientific temper is crucial for societal progress by promoting critical thinking and rejecting superstition and irrational beliefs. It includes aspects like rationality, critical thinking, open-mindedness, curiosity, scepticism, respect for evidence, objectivity, honesty & integrity, perseverance etc. Chakraborty, et al. (2024) studying on Scientific temper: towards an alternate model of science-society relationships argues that scientific temper is fostered through a process-oriented, reflexive approach that is cultivated through direct engagement, rather than a top-down deficit model. Students studying in classes 9 to 12 and aged between 14 to 18 are generally considered as secondary level students as per NEP (2020). The Science Council, UK (2009) defined Science as a discipline that seeks to understand the natural and social world through systematic observation, experimentation, and the creation of testable hypotheses and predictions. It comprises of organized knowledge and a process of discovery, with major branches including the natural, social, and formal sciences. Raina (2019) highlighted that improving Science learning can be improved through Experiential hands-on activities.

The above discussion reveals that experiential learning pedagogy is indispensable in class room teaching learning interactions as it plays a vital role in the development of basic concepts in science along with HOTS & scientific temper among secondary science students.

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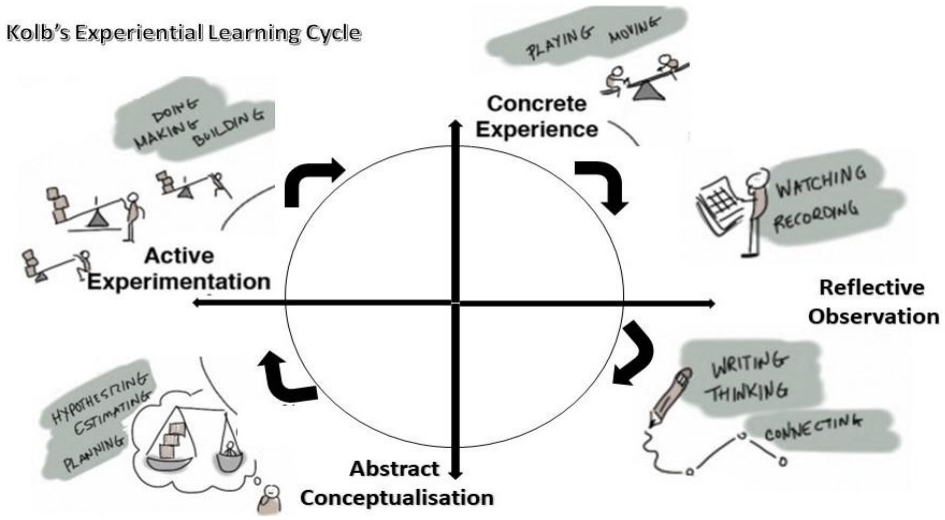
Historical and Conceptual Background of Experiential Learning

Experiential learning's history starts from ancient times, where Aristotle emphasized on “learning by doing" in 350 BC, and continues to modern educational theory championed by John Dewey in the early 20th century, and later synthesized into David Kolb's cyclical model in 1984. The concept gained significant momentum in the 1970s, recognized as a distinct field with the establishment of the Association for Experiential Education (AEE). Today, it is a widely adopted approach in the field of educational pedagogy for fostering active engagement, skill development, and the transformation of experience into knowledge across diverse educational and professional settings. Experiential learning, as defined by Kolb (1984), is the sort of learning which is attained through utilizing experiences specifically in sustaining the teaching-learning procedure. Experiential learning theory (ELT), as Kolb (1984) acknowledged, a most pertinent theory as it gives pure basics for learning to occur in natural settings. As per Kolb (1984), “Learning is the process whereby knowledge is created through the transformation of experience” (p. 38). Learning, according to Kolb (1984), (p.31), “involves the integrated functioning of the total organism – thinking, feeling, perceiving, and behaving”. A theory consisted of experiential learning may take all mentioned elements into account for processing information into meaningful channels based on students’ previous understanding. Moreover, Kolb’s experiential learning theory (ELT) (1984) emphasize the transformation of learning as a long-lasting process, and this postulate depicted the significant value of the knowledge provided in the classrooms may also be connected to the field of work and other life routines outside the educational settings. Several models have been proposed by various educationists on Experiential learning theory, out of that the significant theories are 1. Kurt Lewin’s Model of experiential Learning 2. John Dewey’s Model of Experiential Learning 3. Jean Piaget’s Model of Experiential Learning 4. Carl Roger’s Model of Experiential Learning 5. Maria Montessori’s Model of Experiential Learning 6. David Kolb’s Model of Experiential Learning. Out of these models the present class room pedagogies mostly follow David Kolb’s Experiential Learning Model. This review paper mostly focusses on David Kolb’s model of experiential Learning. Kolb's Model (1984) of Experiential Learning follows a cyclical process of acquiring knowledge through experience, transforming it by doing reflection on it, forming concept, and doing experimentation, and finally applying it in new ways.



It is useful in providing a structured framework for creating effective, active learning experiences that enhance skill development, promote continuous improvement, fosters reflection and self-awareness, improves motivation & Engagement and increase knowledge retention across educational and professional settings. This model provides a continuous cycle, allowing for the repetition of the process with new tasks and skills, thereby supporting long-term individual and organizational growth.

So, it can be said that experiential learning is simply learning through reflection on doing. It follows a four-stage cyclical model of learning and gives maximum emphasis on reflection and experience.

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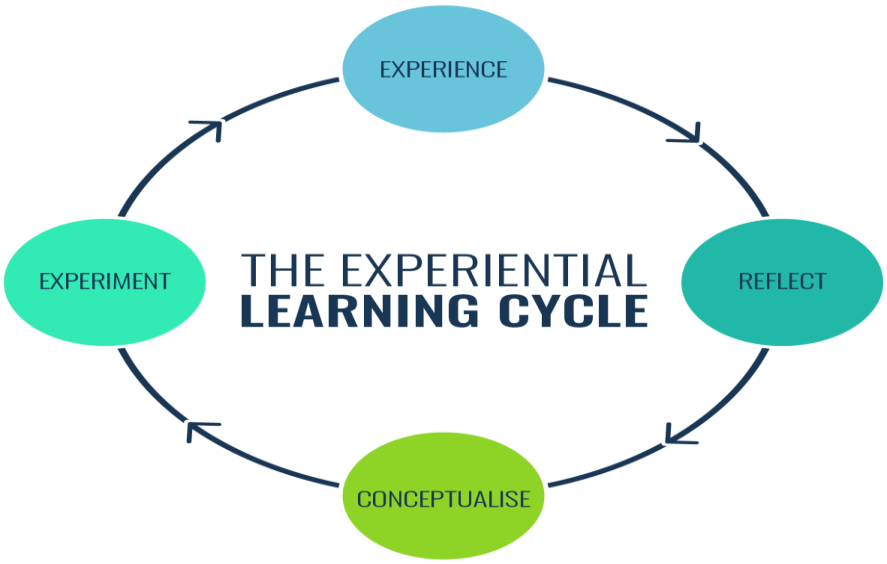
Experiential Learning and Science

Experiential learning is crucial in science as it helps students understand concepts through hands-on activities, promotes deeper retention than traditional lectures, fosters critical thinking, problem-solving, and creativity by linking theoretical knowledge to real-world applications.



This "learning by doing" approach also builds important life skills like teamwork and communication, making learning more engaging, relevant, and memorable for students. Research highlights several findings and practices of experiential learning in science classes, including study by Raina (2019) on Improving Science learning through Experiential hands-on activities revealed that there was significant difference in the scholastic achievement of the students and significant effects on student knowledge gain for those who followed experiential hands-on activities. Rani & Kumar (2023) studying on Experiential learning in school education: Perspectives and challenges, highlights the significance of experiential learning, challenges in the effective implementation of experiential learning in the teaching-learning process, suggestive measures to overcome these challenges and concludes that though several initiatives have been taken by Govt. of India to promote the implementation of experiential learning in school education, still it takes sincere attention in this regard . study by Appa, (2018) on effectiveness of Experiential learning approach on learning attainment attitude towards science and science process skills at upper primary level concluded that there is significant improvement in promoting the attitude towards science among the students of upper primary by following experiential learning approach and the experimental group showed a prolonged understanding of the subject matter, and positive attitude towards learning. Study by Thota & Gowri (2020) on Experiential Learning: An Analysis of impact on academic achievement among students of Grade 12, concludes that there is a significantly positive impact of student's handmade model as outcome-based learning on the academic performance in subject Chemistry at Senior Secondary School level and the learners of experimental group show surprisingly better improvement than that of control group. Garibaldis et al. (2018)studying on the application of the experiential learning approach in science learning to improve critical thinking in elementary school students concludes that the application of the Experiential Learning approach can improve students' critical thinking skills in learning science in grade 5.The article by Ranasinghe et al. (2019) studying on the Influence of Experiential Learning Models on curiosity and learning achievement in elementary School Science concludes that there is an influence of the experiential learning model on curiosity and science learning achievement. study by Sharma & Singh (2023) to investigate the effect of experiential learning technique on achievement in science of IX grade students revealed that the achievement in science of group exposed to experiential learning technique was significantly better than that of group taught through traditional technique. Haryanto et al. (2019) studying on the application of the experiential learning model to improve science learning outcomes with hot themes and their transfer in elementary schools' remarks that the Experiential Learning model implemented using the Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation steps can improve science learning outcomes on the theme of Heat and Transfer in class V of Elementary School. Fauzi et al. (2019)

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studying on Improvement of student learning outcomes using experiential learning models on the concept of light in science concluded that the experiential learning model can improve student learning outcomes, especially in science learning. Scott et al (2023) on Examining How Experiential Learning Impacts Performance in an Introductory Animal Science Course recommended practitioners to use experiential learning to complement traditional lectures and to increase knowledge and practical skills. Imro'ah (2022) studying on efforts to increase understanding of the concept of simple electric circuits with experiential learning models in class VI concludes that experiential learning is a model of the teaching and learning process that activates learners to build knowledge and skills through direct experience. Article by Yuliana et al (2025) on effectiveness of experiential learning on students' understanding of science and technology concluded that the experiential learning model is very effective for developing the understanding of science and technology .Study by Joshua et al (2023) on the effectiveness of experiential learning approach on students' academic achievement in Biology in Secondary Schools concluded that experiential learning approach is an effective method of teaching a science subject and teachers engage students in this approach and motivate them to pursue science. Study by Mund (2024) on effectiveness of experiential learning on Integrated Science Process Skills among Secondary School Students revealed that the students usually have a low level of integrated science process skills and when the experiential learning program adapted from Kolb's learning cycle model was incorporated, the integrated science process skills of the learners improved. Study by Devi (2024) on Effectiveness of Multiple Intelligence Theory Oriented Experiential Learning Approach on Development of 21st Century Skills and Learning Outcome in Science concludes that the experiential learning approach centred on the multiple intelligence theory had a good impact on scientific creativity thinking abilities, critical thinking abilities, and learning outcomes. Rukhsana et al (2021) studying on effect of experiential learning on Students motivation and interest at elementary level in the subject of General Science concludes that experiential learning was effective in teaching science at elementary grade. Nguyen et al (2023) researching on Kolb's experiential learning in STEM Education: A theoretical and empirical study with ninth grade students indicates that a moderate relationship between experiential learning stages and problem-solving abilities with concrete experience having the strongest effect. Study by Yinka et al(2025)on perception of the Experiential learning approach: benefits, impacts and strategies concludes that the experiential learning technique is seen by undergraduate students as a very successful way to improve academic achievement and the acquisition of practical skills . Article by Geyser et al (2020) on the use of experiential learning as a teaching strategy in life sciences describes that use of experiential learning cycle maximizes the time and manner of learning in the life sciences class room. Julinda et al (2022) concludes that experiential learning model improves learning outcomes in the subject science in class Kumar (2022) studying on effectiveness of experiential learning pedagogy on science process skills, scientific attitude, and achievement in science of secondary School tribal students in Kerala concluded that the pedagogical module has significant effect in enhancing the scientific attitude, science process skills, and achievement in science. Jannah & Sofiya (2023) researching on implementation of experiential learning model to improve science process skills proves that learning using the experiential learning model can make students understand the material in depth, which is taught through the search process carried out by students. Study by Falloon (2019) on using simulations to teach young students science concepts: An experiential learning theoretical analysis, concludes that simulations can be effective for introducing young students to simple physical science concepts, and for providing them with opportunities to engage in higher order thinking process. Article by Susiloningsih et al (2023) on experiential learning model in science learning: Systematic literature review, indicates that there is an influence of the experiential learning model on science learning in elementary schools .Hwang (2019) on the study from reflective observation to active learning: A mobile experiential learning approach for environmental science education, concludes that learners who learned through experiential learning approach showed higher problem-solving competence than those who learned with the conventional situated mobile learning approach.

From the above discussion, it can be concluded that experiential learning is quite useful in science learning particularly at secondary level. It paves the way for academic achievement and enhances the learning outcomes side by side making science learning joyful and engaging.

Limitations of Experiential learning

There are challenges from inadequate infrastructure and resources, teacher training and capacity building, curriculum alignment, assessment and evaluation, equity and access, community engagement, and partnerships. Seerat (2014), and Rani & Shivani (2021), reported that experiential learning is difficult to use in a limited given

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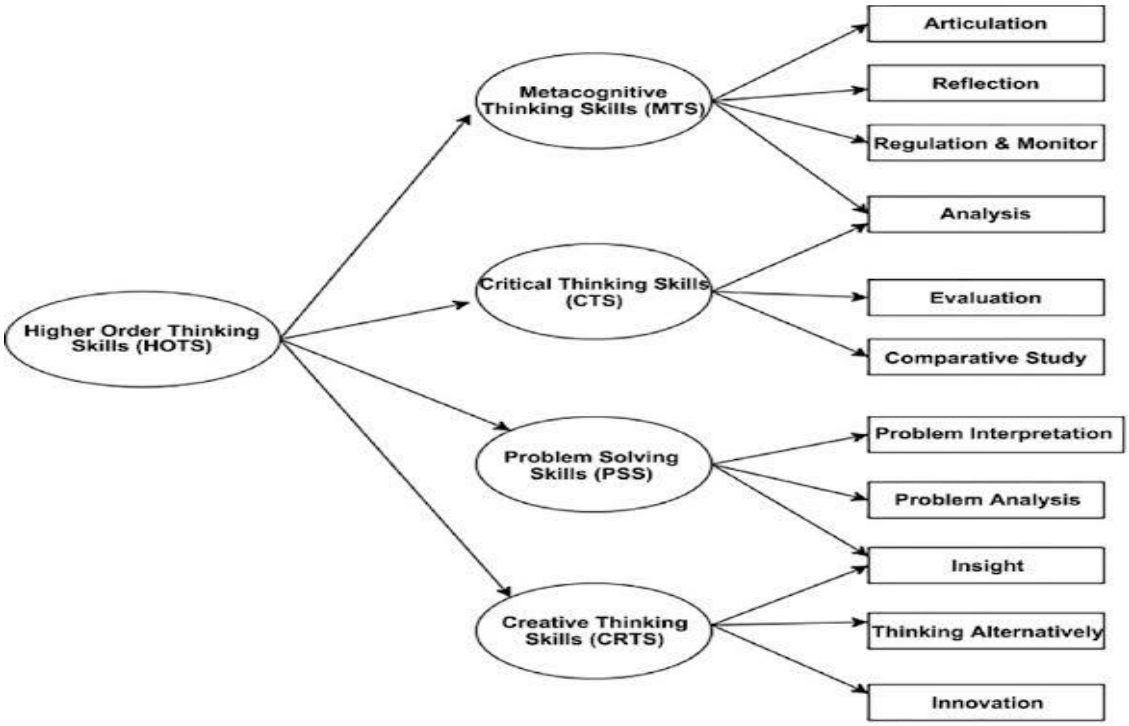
time. Giving practical experiences and having students' reflections on their experience, need time to design and implement. Nooghabi et al (2011) remarks that the lack of facilities for carrying out practical work, lack of space for outdoor and indoor activities, and even no proper furniture, laboratories, and other basic equipment act as a hurdle to implementing experiential learning. Difficulties in accessing experiential learning opportunities for teachers to implement particularly in rural areas are very challenging because of the lack of basic resources and facilities reports McDougal (2014).Nooghabi et al and Rani & Shivani (2021) emphasizes that the lack of teacher's knowledge about the latest skills, devices, innovations, and skills for practicum/practical tasks and field visits, and any other experiential activity is a barrier in using experiential learning. Reddipalli and Rajesh Babu (2018) highlighted that not all units are suitable to design based on experiential learning in terms of the teacher's expertise. Singh & Shakir (2019) and Hossain (2021) remarks that providing ample opportunities to teachers for their self-development and updating their knowledge and skills to the innovations will facilitate experiential learning. Nooghabi et al (2011) & Mc Dougal (2014) highlights that lack of flexibility in the time schedule, rigid rules, and regulations, and less coordination with community, villages, etc. also act as a barrier for the smooth implementation of experiential learning in school.

From the above discussion, it can be concluded that several challenges are faced in implementing experiential learning in true sense in class room transactions. Inspite of that experiential learning is useful in science learning and it adds flavour to the education at secondary level.

Impact of experiential learning on development of HOTS

Experiential learning and HOTS are interconnected concepts that emphasize learning through active engagement and Critical Thinking, analysis and problem solving. The AI overview research findings suggests that Students learn by doing and engaging in hands on activities and reflecting on their experiences. HOTS enable students to think critically, analyse complex situations, and solve problems effectively. Analysing information, evaluating arguments, synthesizing ideas, and developing innovative solutions are examples of HOTS.



The findings further reveals that the content and opportunities for students to practice and develop HOTS. By actively engaging in activities, students are naturally challenged to think critically, analyse information, and solve problems. Study by Senapati &Selvam (2025) reveals that the there is strong effect of experiential learning coupled with thinking-based learning (TBL) pedagogy in developing higher-order thinking skills among students. Indah (2020) concludes that discovery Learning Model Increases the Critical Thinking Skill and HOTS among Students of class XI. Pamunkeys &Widia Stuti (2019) studying on 21st Century Learning: Experiential Learning to Enhance Critical Thinking in Vocational Education finds that the experiential learning in vocational

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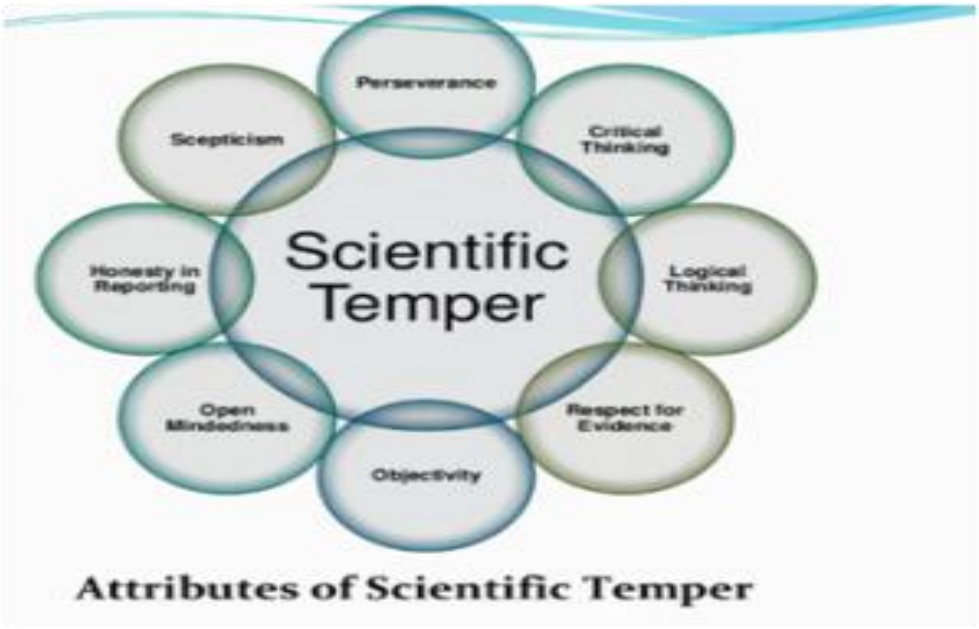
education is effective in developing critical thinking among students. Artika & Nurmaliah (2023) concludes that the habituation of HOTS-based science questions can effectively improve students' critical thinking. Mertayasa et. al (2024) finds that the students engaged in experiential learning show increased cognitive activity, more comprehensive participation, and high motivation to develop critical thinking skills. Koulouris (2024) studying on Experiential learning fosters critical thinking and deep learning concludes that, through experiential learning students are no longer passively engaged with lecture materials but are actively observing, analysing, and participating through field education. Researches by Ranjan (2024) on how experiential learning helps in developing critical thinking and problem-solving skills concludes that Experiential learning effectively develops critical thinking and problem-solving skills by engaging students in active, reflective, and collaborative learning processes.

From the above discussion, it can be concluded that experiential learning develops critical thinking. Very few studies are there that are focussing on the effectiveness of experiential learning on the development of HOTS, though some studies are carried on certain aspects of HOTS like analysis, problem solving and critical thinking still further research need to be carried out in other aspects like creativity and evaluation.

Impact of experiential learning on development of Scientific temper

Experiential learning develops scientific temper by replacing rote memorization with hands-on activities that foster a scientific method of questioning, experimenting, and reflecting. Both are intertwined; experiential learning provides the practical, engaging activities that build the critical thinking and analytical skills essential for a scientific temper.



This approach is more effective than traditional learning for building interest in science and creating a mindset of curiosity and rational inquiry. Some studies on experiential learning and scientific temper reveals that Experiential learning has impact on the development of scientific temper among the students. Some remarks that aspects like critical thinking and scepticism towards superstitions gets improved when students do hands on activities and engage themselves in Experiential learning. Chakraborty et al (2024) studying on Scientific temper: towards an alternate model of science-society relationships argues that scientific temper is fostered through a process-oriented, reflexive approach that is cultivated through direct engagement, rather than a top-down deficit model. DPS Warangal in its Blog post (2024) on the topic how to develop scientific temperament in students Cites curiosity and critical thinking, which are developed through experiential learning, as fundamental to scientific temper. KVS RO Jabalpur, Blog post (2024) on developing scientific temperament highlights that experiential, inquiry-based methods like experimentation, observation, and communication are essential for cultivating scientific temper. Shiv Nadar School, Blog post (2021) describes that a scientific temper from early childhood by encouraging curiosity, critical thinking, and a "hands-on, minds-on" approach involving experiential learning activities build confidence in the scientific process, reinforcing a scientific temperament.

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ResearchGate (2021) on development of scientific temper through the Teaching of Science at Secondary Schools Reviews various pedagogies that can help develop scientific temper, which includes healthy scepticism, rationality, and open-mindedness. The study notes that methods involving learner participation and real-world experience foster scientific temper. Kumar & Sharma (2019) studying on "Developing Scientific Temper in School Students" found that project-based learning and inquiry-based science education significantly correlate with higher levels of scientific temper. Das & Gupta (2021) studying on the topic Role of Science Museums in Fostering Scientific Temper Concluded that interactive exhibits and hands-on activities in science museums are effective in stimulating curiosity and a questioning attitude. Patel (2020) studying on effectiveness of workshops on Promoting Scientific Temper concludes that training on scientific temper concepts and pedagogical strategies led to positive changes in the scientific temper of students along with improved classroom practices and students' attitudes.

From the above discussion, it can be concluded that experiential learning develops scientific temper. Very few studies are there on the impact of experiential learning for the development of scientific temper among students. some studies are carried on certain aspects of scientific temper like open mindedness, rationality, and curiosity, still further research need to be carried out on other aspects like Respect for evidence, Honesty & integrity, perseverance, and scepticism of scientific temper.

Experiential Learning & other Subjects

The effect of experiential learning on achievement in other subjects is also studied by taking some limited number of studies. Gugale (2023) on the study effectiveness of experiential learning in History among CBSE Secondary School students concludes that Experiential learning is effective for the understanding and concept clearance of History for CBSE Secondary School students as students developed interest in the subject History and their learning outcomes were improved. Karthiyayeni and Geethalakshmi (2025) studied on effectiveness of experiential learning in developing attitude towards learning social science Among 9th Standard Students concluded that attitude plays an important role as prerequisite in learning social science. Development of the attitude of learning social science lies in the hands of parents, teachers, and students as well along with various methods, The study also reveals that there is no significant difference between experimental group and control group in attitude across and within different groups about their gender. Villarroel et al (2020) studying on experiential learning in higher education describes that by following the phases and modes of experiential learning, the students´ had a positive perception about the quality of their learning. Specifically, they valued the opportunity to apply their knowledge, learn in greater depth, remembering it better, as well as being able to make a concrete contribution, from the discipline, to solve a real problem. Kong (2021) on the role of Experiential learning on students' motivation and class room engagement reports that the learners are encouraged to think logically, find solutions, and take appropriate action in relevant situations. The learners enthusiastically participate in mental, emotional, and social interactions during the learning procedure within experiential learning. study by Yakun et al (2022) On experiential learning: A view of the literature writes that the learning experience is conducted by teachers in school to help students understand more about the subject concept during teaching and learning. The study reveals that the learning theory introduced by Kolb helps more in the education system to understand the environment and learning process. Study by Chopra & Lakshmi (2022) on effect of experiential learning strategies on learning outcomes and interpersonal skills of senior secondary students in relation to learning approaches revealed significant difference in learning outcomes and interpersonal skills of experimental group in comparison to control group due to intervention of experiential learning strategies and experimental group scored better in both dependent variables. Ramesh (2025) on Scientific Temper in Indian Education System - A Historical Perspective Provides a historical perspective on scientific temper in India, emphasizing its importance for promoting rational inquiry and evidence-based decision-making notes that education is a key vehicle for promoting scientific temper in students.

From the above discussion, it can be concluded that experiential learning has impact on other subjects as well. The experiential learning cycle can be followed in other subjects for the development of HOTS as well as interpersonal skills.

Recommendations for Future Research

Further research needs to be carried out on various aspects of scientific temper like creativity, evaluative thinking, integrity aspects etc. so that the detailed and comprehensive ideas can be gathered on the usefulness of experiential learning.

CONCLUSIONS

Most of the studies concludes that experiential learning has a positive effect on the achievement of science in secondary stage but there is no mention whether such approach is developing higher order thinking skills or not. Some studies categorically remark that experiential learning approach is essential for scientific temperament but no such specific study is found that highlights whether experiential learning is effective or not in developing scientific temper among secondary students. Almost no studies are found that gives a comparative analysis between experiential learning and traditional pedagogies in similar contexts. Very few studies are there that are focussing on the effectiveness of experiential learning on the development of HOTS as well as Scientific temper among students and most of them are silent whether the experiential learning approach is developing all aspects of higher order thinking skills or not. Though some studies are carried on certain aspects of HOTS like analysis, problem solving and critical thinking, still further research need to be carried out on other aspects like creativity and evaluation of HOTS, similarly in scientific temper some studies are carried on certain aspects like open mindedness, rationality, and curiosity, still further research need to be carried out on other aspects like Respect for evidence, Honesty & integrity, perseverance, and scepticism. As experiential learning is an emerging pedagogy, further research must be carried on how experiential learning is effective in developing higher order thinking skills as well as scientific temper among secondary students in science.

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