

Developing 21st Century Competencies through Experiential Learning in Science: An Integrative Review

Anuradha Dhiman¹, Dr. Rajinder Singh²

¹Research Scholar, Department of Education, Central University of Himachal Pradesh

²Associate Professor, Department of Education, Central University of Himachal Pradesh

ABSTRACT

The demands of the contemporary era have reshaped the objectives of school education that is shifting the focus from the mere acquisition of content to the holistic development of 21st century competencies such as critical thinking, problem solving, collaboration and creativity or shifting from conventional methods to experiential learning method which is beneficial for developing these competencies among students in science. In this context, the leading principles of Experiential Learning emphasize the importance of learning by doing, reflection and real-world participation, which have gained a lot of pedagogical attention. This research uses the integrative literature review method by analyzing search results from the Scopus, Erics, Web of Science and Google Scholar databases. The aim of present integrative review is to assess the existing national and international research on the effect of experiential learning approach on 21st century competencies in science among school students. The main focus of the review is to synthesize empirical studies, conceptual papers and policy documents based on pedagogical methods such as experiential learning, lab experimentation, simulations, field visits and so on. The analysis reveals that experiential learning improves learning outcomes, increases the interest of students and enhances the 21st century competencies. Furthermore, the review highlights the integration of experiential learning approach with constructivist and other learning theories. Experiential Learning on one hand is very much effective but on other hand it confronts various challenges such as insufficient time, inadequate resources, assessment process, lack of quality teachers. The study highlights that effective adoption of Experiential Learning in science requires curriculum restructuring, professional development of teachers and strong policy support. The review concludes that the integration of Experiential Learning can play a crucial role in developing 21st century competencies among students which make them capable to meet global challenges.

Keywords: Experiential Learning, 21st Century Competencies, Science Education, School Students, Integrative Review, Pedagogical Methods.

INTRODUCTION

Education is the conscious, methodical, and ongoing endeavour to impart, elicit, or obtain knowledge, values, attitudes, abilities, or sensibilities, as well as any learning that emerges from the activity. It is universally recognized as one of the most powerful tools for individual transformation, societal upliftment, and the progression of communities. It equips people with the knowledge, skills, and critical thinking abilities necessary for both individual achievement and civic engagement. Within the sphere of learning,

education is often viewed as a methodical voyage of imparting and receiving knowledge, yet it also embodies the dynamic interchange of culture, ethics, and heritage. Education is one of the more tangible sources of knowledge and information through which our intellect, capacity to reason are improved and in order for everyone to gain information and prosper in life, numerous government schools have been established (Sharma and Ankit, 2023).

A quality education will facilitate us to express our opinions and views that improves our chances of being heard and taken seriously. But, the conventional teaching methodologies, which frequently emphasize rote learning and passive engagement, fail to captivate students in a manner that nurtures critical thinking, creativity, and problem-solving abilities essential for thriving in the dynamic landscape of the 21st century. Tackling these issues demands thorough policy reforms that champion equitable educational access, mitigate structural inequalities, and inspire innovative teaching techniques that underscore active, student-centered learning. The integration of technology into education has revolutionized methods of learning, enabled personalized educational journeys and linked students with resources via online platforms, virtual classrooms, and interactive tools. This digital transformation reveals new possibilities for educators to address the diverse needs of the students, making education more inclusive and flexible. To prepare a golden generation which is ready to face the challenges of 21st century, education is an important indicator. Knowledge is deep-rooted treasure and education aids in its manifestation as the perfection that already exists within an individual. Knowledge is the condition of knowing something with familiarity gained through experience or association. In general, knowledge is shared in schools, colleges, universities and other institutions where a teacher plays a vital role in providing guidance, knowledge and inspiration, and student acts as a passive learner instead of his active participation or engagement. But for effective learning, active engagement of mind is very essential because actively engaged learners who are provided with opportunities are more probable to achieve effective learning outcomes. Active engagement in learning is crucial for cognitive development as the learners attempt to express their thoughts in the best possible manner.

EXPERIENTIAL LEARNING IN SCIENCE

Experiential learning is learning by doing and reflecting, where real-world activities become the foundation for deeper understanding and skill development. It is a key pedagogical innovation emphasized in the National Education Policy (NEP) 2020, promoting student-centered education through hands-on experiences. Experiential Learning is an approach that focus on creative and hand on experiences in the field of education and is capable of developing self-belief, positive attitude, decision making and problem-solving skills (Singh et al. 2025). Students who participate in experiential learning have the chance to learn at their own speed and gain real-world knowledge that connects to their experiences. Experiential learning is very much beneficial in science because it permits the students to actively engage themselves with the scientific concepts through experiments, hands on activities which results in deeper understanding and increased knowledge retention. More over the confidence of the students to handle science experiments in the laboratories show significant improvements through this approach. And then the questioning and problem -solving skills of the students are developed due to the effective realization of the concepts in laboratories (Erdem et al. 2014). Despite these advantages, challenges remain in effectively implementing experiential learning to develop 21st-century competencies in science education. Existing literature reveals gaps in standardized frameworks, teacher preparedness, and resource allocation, which hinder consistent application and assessment of these pedagogies (Utomo et al., 2025) (Ashari, 2024) (Ansari, 2025)

21ST CENTURY COMPETENCIES

21st century competencies encompass substantive knowledge, ICT skills, conceptual understanding, cognitive and metacognitive abilities, as well as personal and interpersonal skills. These competencies are essential for adapting to new learning expectations in the information age, as recognized globally (Su, 2023). Foster and Piacentini (2023) defined 21st Century Competencies as the skills, knowledge and attitudes that are necessary to be successful for engaging in the 21st century global knowledge economy to participate in a diverse society to adapt to change and uncertainty. Broadly, 21st century competencies are divided into six categories namely Cognitive, Interpersonal, Intrapersonal, Metacognitive, Civic and citizenship and ICT and digital. The competencies such as critical thinking, problem solving and creativity and innovation are cognitive competencies and collaboration competency comes under interpersonal category. To integrate these competencies into different curriculum areas and to help teachers to develop teaching methodologies and to improve learning environment, education systems all over the world are exploring the ways to make education system more effective for student's development. Experiential Learning is one of the ways that will help in student's development. The increasing needs of 21st century must be addressed immediately with an emphasis on the type of teaching and learning strategy that works best in today's classroom. The main aim of the education is to develop the innate potentials present within an individual which is possible only through experiential learning in which learner gains knowledge through direct experience. The study is structured to first determine whether experiential learning significantly enhances 21st-century competencies in science education. It then explores the specific pedagogical strategies that operationalize experiential learning and contribute to improved learning outcomes. Finally, it identifies institutional challenges that may hinder its effective implementation. Together, these objectives provide a comprehensive understanding of effects, process, and practical feasibility, thereby offering both empirical evidence and actionable insights for curriculum reform and classroom practice.

RATIONALE OF THE STUDY

The body of existing literature is still fragmented, with limited integrative synthesis, inconsistent frameworks, and implementation challenges related to teacher preparation, resources, and assessment practices, despite the fact that numerous national and international studies highlight the potential of experiential strategies—such as laboratory experimentation, simulations, and field-based activities in enhancing student interest and learning outcomes. To establish a thorough understanding of how experiential learning helps schoolchildren develop 21st-century science competencies, an integrative review is necessary to methodically analyze, compare, and consolidate empirical findings, conceptual perspectives, and policy insights. This review also identifies research gaps, practical constraints, and future directions for curriculum reform, teacher professional development, and evidence-based pedagogical planning.

RESEARCH OBJECTIVES

1. To assess the effects of the experiential learning approach on the development of 21st-century competencies among school students in science.
2. To examine various pedagogical methods within the experiential learning framework, and their effectiveness in improving learning outcomes.
3. To identify the challenges which hinder the effective implementation of experiential learning in science classrooms.

METHODOLOGY

Search Strategy

This study was carried out through the review of literature of the papers established. The pre- defined key terms such as “Experiential Learning, 21st Century Competencies, Science Education” related articles were employed to identify related articles in different databases such as Scopus, Erics, Web of Science and Google Scholar. Bibliographic mining was conducted to systematically analyze existing literature related to experiential learning in science and 21st century competencies.

Eligibility criteria

The following inclusion and exclusion criteria have been chosen to identify the relevant studies:

Inclusion Criteria	Exclusion Criteria
Full-text articles published in English between the year 2010 and 2025.	Studies that were not published in English.
Research that focus on keywords such as experiential learning, 21 st century competencies and science education,	Research that does not focus on keywords such as experiential learning, 21 st century competencies and science education and with zero citation.
Studies that carried out to develop 21 st century competencies through experiential learning in science.	Studies not focusing on science education

Data collection procedure

To assess the eligibility for inclusion, the author reviewed the titles and abstracts of all studies. After reviewing the full text of all identified studies, a final decision was made on each of the independent studies.

Data extraction

Data has been extracted from the selected papers using a tabular data collecting form. The form comprised author’s name, year of publication, name of journal, findings, pedagogical methods and challenges.

Author & Year	Journal Name	Findings	Pedagogical Method	Challenges
Vila et al. (2012)	Management Decision	Proactive and problem-based learning methods are the most effective classroom practices for developing innovation-related competencies for the workplace.	Proactive and Problem-Based Learning (PBL)	Future research must address trade-offs between diverse resources and outcomes, specifically regarding relative costs versus value to society.
Voogt and Roblin (2012)	Journal of Curriculum Studies	Reported global alignment on 21 st -century competences (collaboration,	Framework Integration (requiring "new teaching	Implementation requires drastic changes to national curricula, including restructuring, new teaching methods, and extensive

		communication, ICT literacy) but noted that curriculum intentions often diverge from actual practice.	methods")	teacher development.
Sevli et al. (2013)	Procedia - Social and Behavioral Sciences	Learning-by-doing via artistic activities (such as drawing and circuits) achieved high success in helping children understand basic scientific principles.	Learning-by-doing via Artistic Activities (e.g., drawing, circuits)	The success rate of these activities depends heavily on whether the scientific knowledge was previously known to the students from their daily lives.
Nath (2016)	Literacy Information and Computer Education Journal (LICEJ)	Instructional programmes on experiential learning increase student interest in science and improve reflective thinking and science process skills.	Instructional Programmes on Experiential Learning / Inquiry-based	Both students and teachers must invest significant time and effort for personal intellectual development to reach successful project goals.
Simmons (2017)	Virginia Tech (Doctoral Dissertation)	Exemplary STEM experiential learning requires hands-on real-world tasks, student ownership, and active industry advisory communities.	STEM Experiential Learning (Hands-on, real-world tasks)	Key challenges include the need for adequate funding, small class sizes, and the necessity of improving perceptions of technical (CTE) programs.
García-Carmona et al. (2018)	International Journal of Science and Mathematics Education	Prospective teachers often hold traditional, "cookbook" views of experimental activities rather than more effective inquiry-based pedagogical valuations.	Inquiry-based Labs / Experimental Activities	Many prospective teachers lack prior science backgrounds and view inquiry-based labs as requiring excessive time, expensive materials, and specific laboratory spaces.
Subramanian and Singaravelu (2018)	Review of Research	Found that experiential learning is significantly more effective than conventional methods for teaching science to student-teachers.	Experiential learning	Traditional, conventional teaching methods were found to be less fruitful for enhancing knowledge among student-teachers.
Halimatus sa'diah,	ACEIVE 2019 (EAI)	Project Based Learning (PjBL) models	Project-Based	Obstacles include the unavailability of learning

and Mursid(2019)		significantly improve students' science process skills compared to conventional learning methods.	Learning (PjBL)	facilities and the high amount of preparation time required for teachers to implement the model.
Hébert and Jenson (2020)	Canadian Journal of Learning and Technology	Demonstrated that sandbox games like Minecraft help teachers support 21st-century competencies like communication and collaboration.	Game based learning	Competency development is heavily dependent on teachers' pedagogical decisions and how they scaffold activities within the game.
Shivam and Bhattacharjee (2022)	IUT Journal of Advanced Research and Development	Identified a significant difference in experiential learning and critical thinking between high and low achievers, but no significant difference between genders.	Experiential learnings	A lack of time and the heavy engagement of faculty members in other duties often prevented the completion of educational activities.
Ramaila and Molwele (2022)	International Journal of Higher Education	Concluded that technology integration promotes 21st-century skills and creates exciting learning environments that boost academic achievement.	Technology Integration	Coherent development of these skills remains a strategic imperative that requires the adoption of innovative pedagogical strategies.
Thornhill-Milleret al. (2023)	Journal of Intelligence	Proposed the "Crea-Critical-Collab-ication" model, highlighting that the 4Cs are interrelated and should be taught and assessed together for future employability.	"Crea-Critical-Collab-ication" Model	Assessing "soft" skills is complex and lacks large-scale psychometric measures, necessitating major shifts in pedagogical techniques.
Novitasari and Subekti(2024)	Jurnal Pajar MIPA	Experiential learning models effectively improve science process skills and foster a cooperative attitude (gotong	Experiential Learning Models	Negative impacts of globalization and differences in individual personality or learning styles can cause tension and difficulty in student cooperation.

		royong) among students.		
Rahmadini and Utama (2025)	Proceedings Series of Educational Studies	Found that experiential learning increases student interest and understanding in science, specifically when supported by teacher collaboration.	Experiential learning	Major obstacles include limited resources, teacher unpreparedness, and students' difficulty in developing initial ideas.

Analysis as per Key Themes of the Study

Objective 1:

Theme: “Development of 21st century competencies through experiential learning”.

The related literature shows how experiential learning contributes to the enhancement of 21st century competencies among school students in science. Exploration of real-world problems, experimentation, and inquiry-based activities are all promoted by experiential learning. Students develop their analytical reasoning and evidence-based thinking skills through observation, hypothesis formation, data analysis, and interpretation. According to Nath (2016) Students identify their own learning progress, question their findings, and develop more proficient inquiry skills over time. They gain the ability to recognize issues, test solutions, and assess results through practical exercises and real-world scientific challenges. Adaptive thinking and decision-making abilities are encouraged through experiential approaches. Working together, communication, and peer engagement are necessary for group-based initiatives, simulations, and experiments. Students acquire cooperative learning practices, shared responsibility, and interpersonal skills. Hebert and Jenson (2020) demonstrated the role of digital games like Minecraft which is learning through activity in fostering collaboration. Experiential learning promotes experimentation, model-building, project management, and the development of alternative solutions. Divergent thinking and creative application of scientific topics are encouraged in students through experiential learning.

The experiential learning approach positively correlates with improved engagement and competency development. Students exposed to such methods tend to demonstrate higher-order thinking skills compared to those taught through traditional lecture-based methods or conventional methods according to Subramanian & Singaravelu (2018). Activities involving "learning by doing" (e.g., building circuits or parachutes) led to high success rates in understanding basic natural science principles among elementary students (Sevli et al., 2013). According to Novitasari & Subekti (2024), Experiential learning models effectively foster a mutually cooperative attitude, empathy, and a sense of responsibility among students which is one of the competencies among 21st century competencies. And these competencies are very much necessary for future employability Thornhill-Miller, B. et al. (2023)

Objective 2:

Theme: “Effectiveness of Pedagogical Methods within Experiential Learning”.

This research paper explores specific instructional strategies such as laboratory experimentation, simulations and technology-based learning, field visits and real-world exposure, and their impact on learning outcomes. All these methods improve conceptual clarity by direct observation of objects, improves

retention of concepts, enhances motivation and encourage curiosity and a long- term interest in science courses.

Among the various methods, laboratory activities and simulations show strong effectiveness in improving academic performance of students, while field visits significantly enhance student interest and contextual understanding when they really observe the things. According to Ramaila and Molwele (2022) technology integration creates exciting learning environments that boost academic achievement. All these instructional strategies yield the most impactful results.

Objective 3:

Theme 3: “Challenges and Barriers to Implementation”.

This research paper identifies that there may be structural and systemic obstacles in implementing experiential learning effectively. There may be time constraints means, generally in school curriculum time is fix for every class which limits the opportunities for extended practical activities. Also, there is pressure on teacher to complete the syllabus which affects the depth of experiential tasks. According to Rahmadini & Utama (2025), inadequate resources and infrastructure such as lack of well - equipped laboratories, insufficient materials, technological tools, funding etc create hindrance for implementing experiential learning in classrooms. In some schools due to large strength, some students either do not get sufficient time to do hands on practice. The learning of student mainly depends on teacher and the teaching method which he or she opts in school but due to limited training in experiential pedagogies and inadequate resources, teacher finds it difficult to implement or sometimes they do not want to change their pattern of conventional method to experiential method which hinder its implementation Voogt & Roblin (2012). The research also suggests the need for professional development programmes for teachers.

DISCUSSION

Experiential learning plays a crucial role to overcome the challenges of 21st century. Although previous research studies have suggested development of competencies through experiential learning. The findings indicate that students exposed to experiential learning strategies demonstrated significantly higher gains in competencies such as critical thinking, collaboration, problem solving and creativity as compared to traditional method. The findings are consistent with previous research that highlights experiential learning as effective method for improving academic achievement and skill development in science education. Studies have also reported that experiential learning increases student’s interest and understanding in science. Also, when teachers taught through games such as sand box, mine craft or activities help to increase competencies among students.

In conclusion, the study provides empirical support for integrating experiential learning which is a transformative pedagogical approach that significantly enhances 21st-century competencies in science education compared to traditional, rote-based methods. The research highlights three primary areas: the development of core competencies, the efficacy of specific instructional strategies, and the systemic barriers to implementation.

IMPLICATIONS

The experiential learning cycle proposed by David Kolb and aligned with competency-oriented reforms such as the National Education Policy 2020, the following implications provide practical directions for strengthening experiential learning (EL) in science classrooms.

1. The main aim of experiential learning is to enable learners to acquire knowledge, skills, attitudes, and competencies through direct experience, reflection, and active application, rather than through passive listening or rote memorization so, it is very important to integrate experiential activities systematically so that students can able to think critically, solve problems collaborately and create new ideas.
2. Experiential learning enhances conceptual understanding and metacognitive skills so teachers should include reflective discussions, and peer feedback sessions after each experiential activity.
3. For developing competencies among students, teachers should be provided with regular training programs on implementing experiential learning in science and also school should provide low-cost and locally accessible materials to conduct meaningful experiential activities.
4. For effective learning in science, experiential learning plays a very important role so, curriculum frameworks should clearly integrate 21st-century competencies into science learning and this can also be done by providing incentives to those teachers who effectively implement experiential strategies in classroom and by providing extended time period for laboratories work.

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