Asian Journal of Applied Science and Technology (AJAST)
Volume 9, Issue 1, Pages 89-106, January-March 2025

Advancing Science Education: A Comprehensive Review of Pedagogical Innovations from 2010-2023

Sheetal Prajapati*

Research Scholar, Department of Education, Central University of Rajasthan, India.
*Corresponding Author Email: sheetaldna@gnail.com**

DOI: https://doi.org/10.38177/ajast.2025.9109

Article Received: 06 January 2025 *Article Accepted: 09 March 2025* *Article Published: 17 March 2025*

ABSTRACT

This paper aims to investigate different strategies in teaching of science through which learning becomes joyful for the learners. To make learning joyful, teachers need to change their teaching styles according to the need of learners. This review paper shows how different pedagogical strategies help learners to enhance their learning skills and how other teaching-learning techniques in science provide several essential benefits in learners' lives in the present scenario. Many studies have been conducted on teaching science at the school level. This study aims to reveal the research themes and trends by analyzing the 45 articles from different journals conducted in which only 24 studies were found for school level, i.e., primary, elementary, secondary, and senior secondary level in the area of science teaching, which contributes to the enhancement of skills required in 21st century. In this study, the researcher reviewed the scientific papers on different teaching-learning strategies published from 2010 onwards. The paper also aims for the future perspective on science teaching. The paper suggests some pedagogical interventions that help in enhancing skills required for 21st-century learners, and these skills help to cope with stress, which leads to depression and not performing well in their life due to stress. So, teachers need to organize and implement such activities that help out with this issue because when learners feel too much burden or pressure on them, they feel mentally ill. Pedagogical tools can address these issues and play an essential role in reducing these issues to make learning more effective and enjoyable, pedagogical interventions are necessary, particularly those who seek some challenges like academic stress, fear of failure which ultimately results to depression, anxiety, and more psychological issues among the learners. Among these, art-integrated learning emerges as a powerful tool to foster holistic education and emotional well-being. This paper aims to explore the integration of art with various disciplines and highlights the benefits of Art-Integrated Learning as an innovative pedagogical approach/ tool in classroom settings. While numerous studies on this subject have been conducted globally, relatively few conducted in India. The concept of art integration is well-established internationally, with early work by Ives and Pond (1980) demonstrating a relationship between the arts and cognitive development. For art integration to be effective, teachers must adhere to the PAOR (Plan, Act, Observe, Reflect) framework, ensuring structured implementation. However, integrating art into education presents unique challenges in the current digital age, where technology dominates yet falls short in imparting values. To instill values and enhance learning outcomes, educators must adopt diverse pedagogical strategies tailored to real-world contexts.

Keywords: Science teaching; Pedagogical strategies; Science; 21st Century learners; 21st Century skills; Innovate pedagogical tools; Challenges; Values; Learning Outcomes; School level.

1. Introduction

The foundational question here is, "Why do we need to bring change in teaching strategies?" because learning science and mathematics is complicated and challenging for learners, it becomes necessary to improve the teaching strategies used by science and mathematics teachers. Understanding science and mathematics is perceived as complex and hard to grasp; this becomes a reason to refrain from studying these subjects at higher grades (11th and 12th grades). Furthermore, the learners, society, and nation's needs change over time, but with these considerations, teachers have to reflect on their teaching strategies; if there is a sense of dissatisfaction, they have to look up different teaching approaches (Cutting & Kelly, 2015). So, by looking for these considerations, a few strategies for teaching science at school levels detour this mindset of learners. In continuation, when a teacher uses or applies various approaches in the teaching-learning process, this leads to many questions. Still, the question is regarding the assessment of learners: "How will they assess the learning, and what appropriate tool they can use for the assessment of learners" (Cutting & Kelly, 2015)? Science education in early childhood focuses on being critical, having the courage to explore, and making systematic observations (Ravanis, 2017). This review paper mainly focused on teaching science and pedagogical practices adopted by teachers up to the secondary school education level. The information and knowledge of science play an important role in everyone's life (Kayode O. et al., 2020).

Nowadays, science has evolved too much compared to ancient times. Now, science and technology are closely associated with each other, and these two are essential vehicles for the development of our country. The U.K. government took the initiative to make a New National Curriculum for England (2013), which came into existence with the idea that there is no relation between vast content and the development of something new. They are now focusing on "less content and more time in doing seems to be an approach to create something new." In the U.K., teachers bring change in design and approaches to teaching Science (The National Curriculum in England, 2013). During teaching-learning, teachers make use of comedy as an effective tool in the academic curriculum to bring out joyful classroom learning (Schouela, 2022).

1.1. Research Questions

1. How have pedagogical practices in science education evolved since 2010?

2. In what ways have these evolving pedagogical practices benefited 21st-century learners?

3. Do these pedagogical practices address only the cognitive domain, or do they also incorporate the affective and psychomotor domains of learning?

4. What are the contemporary pedagogical approaches being implemented in science teaching today?

Most of the research in science teaching shows that constructivist learning model is one of the successful models for providing meaningful learning experiences to learners in science classrooms. Pedagogical practices offer scope for a learner to learn "how to learn." Science education is a vital curriculum component (Singh, 2015). Samuel and Ogunkola (2013) highlighted the role of a teacher in instructional practices, stating that learning science through role play plus brainstorming is a practical teaching approach (Teppo et al., 2021).

2. Literature Review

This paper focuses on trends in science teaching at different levels, majorly from sixth to tenth standard. This paper focuses on how other pedagogical practices exist and whether the pedagogical approach influences the learner's attitude toward science. Creative teaching has the potential to inspire deep learning, using activities and stimulating contexts that can capture the imagination of children (Cutting & Kelly, 2015). From 10 years back, teachers were following one-way teaching-learning process. So, considering this, the paper focuses on different pedagogical practices used at different levels in science teaching.

Table 1. Summary of the Studies

Year	Author	Title of the Study	Pedagogy Used	Major Findings
2010	Burkey DD, Anastasio DD, and Suresh A	"Improving student attitudes toward the capstone laboratory course using gamification"	Gamification	Gamification develops mental skills, makes science learning fun, develops social skills, provokes enthusiasm to learn, and positively impacts. academic achievement.
2010	Lawson	"Teaching Inquiry Science in Middle and Secondary	Inquiry-Based Pedagogy	Inquiry-based pedagogy has positively impacted learners'

		Schools"		attitudes towards science, achievement in science, skills, and understanding level in science.
2010	Duffy, T. M., & Raymer, P. L.	"A practical guide and a constructivist rationale for inquiry-based learning"	Inquiry-Based Learning	Learners could solve the problem in multiple ways, reflecting their ideas.
2012	Tan, A.-L., & Wong, H.-M.	"Did not Get Expected Answer, Rectify It.': Teaching science content in an elementary science classroom using hands-on activities"	Hands-on activities	Hands-on activities develop a sense of observation and make an alignment between the science activities chosen and the teaching purposes.
2013	Samuel, D. F., & Ogunkola, B. J.	"St. Lucian Elementary School Teachers' Applicability Beliefs and Beliefs about Science Teaching and Learning: Relevance to Their Level of Inquiry-Based Instructional Practices in Science"	Inquiry-Based Instructions (IBI)	IBI was not an effective teaching-learning method at the primary level; two reasons are inadequate facilities and resources in the school and not receiving social support from stakeholders, which is highly responsible for the low level of IBI at primary schools.
2013	Sterling, D. R.	"How Does Leadership Matter? Developing and Teaching a Definition of Hands-On Science, a Prerequisite for Effective Inquiry Teaching"	Hands-on activities	Hands-on activities using accurate teaching material result in more significant learning and higher achievement in science.
2014	Dhanapal, S., Kanapathy, R., & Mastan, J.	"A study to understand the role of visual arts in the teaching and learning of science"	Visual art as Pedagogy	Arts in science teaching leads to development academically, socially, emotionally, behaviourally.
2014	William W. Cobern, David Schuster, Betty Adams, Brandy Ann Skjold, Ebru Zeynep Muğaloğlu, Amy Bentz & Kelly Sparks	"Pedagogy of Science Teaching Tests: Formative assessments of science teaching orientations"	Didactic direct, Active direct, Guided inquiry, and Open Inquiry	The open inquiry method of teaching is better than other methods because in this teaching-learning method, students actively explore ideas, and the teacher only facilitates the learners.
2015	Dicheva, D., Dichev, C., Agre, G., & Angelova, G.	"Gamification in education: A systematic mapping study"	Gamification as a teaching technique	Positive impact on learning, participation, and build a sense of healthy competition among the learners.
2016	Wiggins, B. E	"An overview and study on the use of games, simulations, and gamification in higher education"	Game-Based Teaching	Gamification helps build a conducive classroom environment and healthy competition among the learners and encourages participation in the activities.

2017	Aaron Chia Yuan Hung	"A Critique and Défense of Gamification"	Game-Based Learning	It enhances participation, develops social skills, and healthy competition among the learners.
2018	Avikasari, A., Rukayah, R., & Indriayu, M.	"The Influence of Science Literacy-Based Teaching Material Towards Science Achievement"	Literacy-Based Teaching	Literacy-based material increases achievement, improves understanding of science concepts, affects scientific attitude, and improves the ability to use science and technology.
2018	Yildirim & Sensoy,	"The Effect of Science Teaching Enriched with Technological Applications on the Science Achievements of 7th-Grade Students"	Technology-Based Teaching	Technology-based teaching brings a positive change in the academic achievement of learners in science.
2018	Romli, S., Abdurrahman, & Riyadi, B.	"Designing students' worksheets based on an open-ended approach to foster students' creative thinking skills"	Worksheet based teaching	Worksheet-based teaching enhances information processing skills, and learners can demonstrate their knowledge.
2018	Kalogiannakis, M., Ampartzaki, M., Papadakis, S., & Skaraki, E.	"Teaching natural science concepts to young children with mobile devices and hands-on activities. A case study"	Hands-on activities and Mobile learning	ICT with appropriate hands-on activities is a practical approach to science teaching and also develops an interdisciplinary approach to science and technology.
2019	Asrizal, Amran, A., Ananda, A., & Festiyed	"Effects of science student worksheet of motion in daily life theme in adaptive, contextual teaching model on academic achievement of students"	Worksheets as a contextual teaching model	Worksheets provide an opportunity to enhance information processing skills and also demonstrate their knowledge.
2019	Halvorsen, H.-P., Tretjakova, R., Timmerberg, J., Thiriet, J. M., & Mylvaganam, S.	"STEAM for STEM - Include "Art" in STEM (Science, Technology, Engineering and Mathematics)"	Integrate Art with STEM	Integrate art with different courses, which leads to high engagement, attendance, and better academic performance of students.
2019	Hunkins, M. M.	"The Art of Science: An Exploration of Art Integration in a Science Classroom"	Art-Integration	Art integration in science grows learners as scientists and artists, generates ideas through creativity, helps strengthen cognitive skills, can express learning, develops curiosity, reflects on viewpoints, and learns diverse ways to interact.
2021	Teppo, M., Soobard, R., &	"Grade 6 & 9 Student and Teacher Perceptions of	Role-Play & Conventional	The lecture method has less variability in learners'

	Rannikmäe, M.	Teaching and Learning Approaches about Student Perceived Interest/Enjoyment Towards Science Learning"	Teaching Approaches	responses, and role play has the highest variability in the reactions of grade 6 and 9 learners. Still, teachers preferred the lecture method as the findings of the study.
2021	Lozano, O. R., & Solbes, J.	"Promoting Inquiry-Based Learning through Entertaining Science Activities"	Inquiry-Based Learning	Role-playing, using toys and games, and demonstration experiments positively impact arousing interest, improvement in the science-learning process, and scientific inquiry skills among the Learners.
2021	Demirhan, E., & Şahin, F.	"The Effects of Different Kinds of Hands-on Modeling Activities on the Academic Achievement, Problem-Solving Skills, and Scientific Creativity of Prospective Science Teachers"	Hands-on modelling activities	Model-based teaching and model-based inquiry should be used to develop an understanding of fundamental laws, investigate laws & also enable learners to understand the relationship between various disciplines.
2022	Witchayada Nawanidbumrung, Sara Samiphak, Noriyuki Inoue	"The Impact of Pre-service Teachers' Pedagogical Beliefs on Teaching Science as Inquiry: A Silent Antagonist for Effective Inquiry-Based Science Lessons"	Inquiry-Based Teaching	It provides real-world opportunities that reflect their educational beliefs.
2022	Ali Alqarni, Monira Alabdan	"Exploring teachers' perspectives on using gamification in teaching Science in Saudi Arabia"	Gamification as a Pedagogy	This strategy in teaching science positively impacts all three domains: cognitive, affective, and psychomotor.
2022	Ogegbo & Ramnarain	"A systematic review of computational thinking in science classrooms"	Model-Based Pedagogy	Model-based pedagogy incorporates computational thinking skills among learners.

Table 1 presents a summary of the studies included in this review. The findings highlight that game-based learning, hands-on activities, and art-integrated learning are widely adopted pedagogical approaches in science education. These methods foster essential 21st-century skills and promote active participation in classroom activities, preparing students to become productive and responsible members of society.

3. Comprehensive Review of Selected Research

Ogegbo & Ramnarain, 2022 reviewed 23 studies highlighting different strategies and assessment practices that can be used to promote integrating computational thinking specifically with science. Modeling-based pedagogy is a key that incorporates computational thinking skills among learners (Ogegbo & Ramnarain, 2022). An experimental study was conducted to study the effect of an inquiry-based approach and its positive impact on attitude toward science, achievement in science, skills & understanding level is better than the conventional method of teaching

(Lawson, 2010). Using different pedagogies in science leads to developing a scientific outlook rather than memorizing the facts, principles, laws, & theories, which also changes learners' attitudes toward science. Cobern et al. (2014) assessed these pedagogical strategies in science, i.e., didactic direct, active direct, guided inquiry, and open inquiry. To know the orientation of teachers in science teaching. The open inquiry method of teaching is better than other methods because in this teaching-learning method, students actively explore ideas, and the teacher only facilitates the learners. Ali Alqarni and Monira Alabdan (2022) are interested in knowing the perception of teachers using games in science teaching. They focus on three areas: importance, uses, and obstacles regarding gamification in science teaching. They found that gamification is essential in developing mental skills, making science learning fun, developing social skills, provoking enthusiasm to learn, and positively impacting academic achievement (Burkey et al., 2013). However, they moderately use gamification in teaching science because they are facing obstacles such as administration-related (proper internet connection, lack of equipment, adequate training, resource room, classroom size) and teacher—related (burden of content completion, student-teacher ratio, lack of technical knowledge and skills, lack of awareness of modern methods of teaching science) (Curriculum and Instruction Department, Umm Al-Qura University, Makkah, Saudi Arabia, et al., 2022). Game-based learning enhances learners' involvement, and effectiveness of game-based leaning increased (Dichev and Dicheva, 2017; Filgona et al., 2020; and Smiderle et al., 2020).

Avikasari et al. (2018) found that literacy-based material increases achievement in science of fourth-grade learners, i.e., the selection of learning resources is also a cause behind learners' academic achievement, improves understanding of science concepts, affects scientific attitude, and improves the ability to use science and technology. Technological applications also enrich science teaching for seventh-grade students. They found a significant difference with $t(81)= -4.64$; $p<.05$, who receive technology-enriched science teaching. They also conducted a follow-up test and found that the achievement of the experimental group was higher than that of the control group. Interactive technologies were used as a pedagogical tool to teach science at the school level. It positively changes learners' academic achievement in science particularly (Benli et al., 2012; Sensoy & Yildirim, 2017; Ogreten & Ulucinar Sagir, 2013). To bridge the gap between science's actual and ideal conditions Asrizal et al. (2019) conducted a study, they use learners' worksheets of integrated science teaching by integrating literacy in the adaptive, contextual teaching model to fill this gap. Worksheets provide an opportunity to enhance information processing skills and also demonstrate their knowledge (Romli et al.; B., 2018). They explore the importance of contextual learning, such as making it easy for learners to connect with the real world, making teaching meaningful, and developing literacy skills required for their learning and daily lives. This contextual teaching model has positively impacted learners' knowledge, attitude, and literacy aspects. The perception of both learners and teachers is important in teaching-learning process. According to Teppo et al. 2021, the perception of learners has less variability for lecture method in learners' responses, and role play has the highest variability in the responses of grade 6 and 9 learners, but it is the least used approach in science teaching. The current situation needs a role-play teaching method, but teachers preferred the lecture method according to the findings of this study.

Solbes explored hands-on activities in teaching science with the help of entertaining activities in formal education (Solbes et al., 2008; Robles et al., 2015). The studies shows that learners believe science and mathematics are

boring subjects that can only be filled by entertaining activities (Lozano & Solbes, 2021). Lozano & Solbes (2021) but it is essential to identify the significant concerns towards science learning, arouse interest in science learning, improve the science-learning process, and improve scientific inquiry skills among the students. Lozano and Solbes mentioned that role-playing, using toys and games, and demonstration experiments positively impact the concerns discussed above regarding science teaching. Bravo et al. (2021) highlight the importance of storytelling and drama in science teaching through a robot as an educator (McCarthy, 2004). Content presented through a story has a deep understanding, and learners imitate the actions done by the robot, improve narrative skills, and help in retention. Robot storytelling activity enriches creativity among learners (Angel-Fernandez et al., 2018).

Samuel & Ogunkola (2013) explores Inquiry-Based Instructions (IBI) develop thinking skills, reasoning skills, and understanding of the processes in science. At the primary level, IBI was not an effective teaching-learning method; for this, one of the reasons is inadequate facilities of resources in the school and the need to receive social support from stakeholders, which is highly responsible for the low level of IBI at primary schools. Learners engage in searching for the solution to a problem that will reflect ideas (Duffy and Raymer, 2010). The government of the United States has launched i3 (Investing in Innovation) program in 2013 and VISTA was one of the science teaching and achievement programs, especially for learners with high needs. In science, using appropriate materials in teaching-learning has a more significant amount of learning, leading to higher achievement. To achieve significant amount of learning in science, teachers are using hands-on activities, they need to be more aware of the alignment between the science activities chosen and the teaching purposes that they aim to achieve, develop a sense of observation that happens in the classrooms offers invaluable insights into how science is enacted in schools (Tan & Wong 2012). Nowadays, teachers are using art-related activities that help learners to grow as scientists. There is a connection between arts and various types of development (Hunkins, 2019). Integrating arts into science provides a foundation for assisting & visualizing information in new ways and developing creative thinking abilities by engaging the learners in activities. Art integration offers a new way of acquiring knowledge and enhancing skills. Hunkins (2019) explores art integration in science through a qualitative approach in which he found that activities can be used to grow learners as scientists and artists, generate ideas through creativity, help in strengthening cognitive skills, express their learning, develop curiosity, reflect on their viewpoints, & learn diverse ways to interact (Mcdougall et al., 2011). This study shows that visual art positively impacts the learners' learning abilities (Gelineau, 2011). Integrating science with visual arts benefits learners in the 21st century (Dhanapal et al., 2014; Alberts, 2010). Dhanapal (2014) found that art elements in science teaching led to academic, social, emotional, and behavioral development. Gardner and other psychological researchers reveal that "artistic involvement is a mind-building experience" (1989, cited in Dobbs, 1998:9). With this thought, nowadays, schools, institutions, and universities organize cultural programs to prove the importance of arts for the development of an individual (Dhanapal et al., 2014). Visual art can be integrated into teaching-learning with all subjects and levels. Visual arts may allow learners to think, discover, connect, and enhance conceptual understanding (Alberts, 2010; Mohalik & Basu, 2020). Integration of arts with different elements of courses can reduce gender inequality. Before the integration of arts in STEAM, a low percentage of female students' enrolment was observed, which led to gender inequality, but STEAM studies enhance gender balance on national, regional, and international levels, for this

gamification is introduced to integrate art with different courses which leads to high engagement, attendance, better academic performance of female students (Halvorsen et al., 2019, Aaron Chia Yuan Hung, 2017). Some studies revealed the positive impact of gamification on learners' learning and participation and build a sense of healthy competition among the learners (Dicheva et al., 2015; Nah et al., 2014; Wiggins, 2016).

In today's education landscape, technology plays a crucial role in science teaching. Kalogiannakis et al. (2018) emphasized that children aged 5-7 can grasp concepts like gravity effectively through hands-on activities combined with mobile learning. Integrating ICT with well-designed hands-on activities provides a practical approach to teaching science while fostering an interdisciplinary connection between science and technology.

4. Research Methodology

A systematic literature review uses an unbiased and thorough research approach to assess the existing research in science teaching from 2010 to 2023. This research summarizes the results of studies on different pedagogical practices in science and come up with an emerging trend. A critical analysis is being made based on studies conducted in teaching science up to the secondary level only because science education provides a foundation to look at the world from different lenses (National Curriculum for England, 2013).

4.1. Source of Data

To conduct a literature review aligned with the objectives of this paper, five databases were selected to address the research questions. The selection process involved identifying relevant studies from these databases, as summarized in Table 2, which outlines the inclusion and exclusion criteria for the detailed review. These repositories were utilized to explore various pedagogical approaches in science education at the school level from 2010 to 2023. Research papers were manually filtered, and the most relevant studies in the field were chosen for inclusion in this review article.

Table 2. Inclusion Exclusion Criteria for the Selection of Studies

Criteria Based on	Inclusion	Exclusion
Document Type	Refereed Journals, Peer-reviewed Journals, Conference Proceedings, Thesis	Research reports, Thesis, Dissertations, Seminar Proceedings
Database	ERIC, Research Gate, WoS, Scopus, Taylor & Francis	Other Databases
Language	English	Other Language
Level of Education	Primary, Elementary, and Secondary levels of education	Beyond Secondary
Year	2010- 30th April 2023	Before 2010
Keywords	Teaching of Science	The teaching of English, Hindi, Social Science, and Mathematics

Table 2 outlines the inclusion and exclusion criteria for study selection. Included document types were refereed journals, peer-reviewed journals, and conference proceedings, while other research reports, theses, dissertations, and seminar proceedings were excluded. The review focused solely on studies in the English language and on

school education, ranging from primary to secondary levels; higher education was excluded as the research questions specifically addressed school-level science education. Additionally, this review is limited to the teaching of science, excluding other subjects such as English, Hindi, Social Science, and Mathematics, in line with the framed research questions.

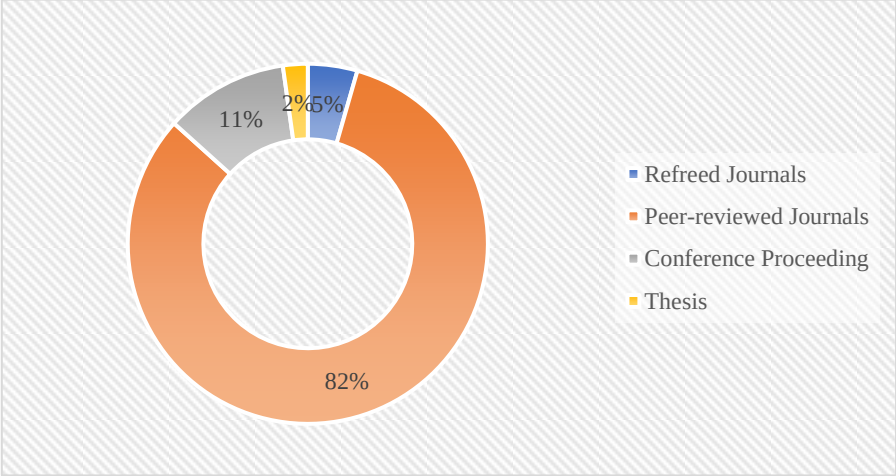

Figure 1. Distribution of Selected Studies

Figure 1 shows the percentage of distribution of studies taken from refereed journals, peer-reviewed journals, conference proceedings, and thesis included in this review paper. This figure shows that 82% of research papers are from peer-reviewed journals, 11% are conference proceedings, 5% of studies are from refereed journals, and 2% of results are from the thesis.

Table 3. Proportion of Databases

Name of Databases	**N (total number of studies)**	**Percentage**
ERIC	9	20%
Research gate	5	11.11%
WoS	3	6.67%
Google Scholar	8	17.78%
Taylor & Francis	8	17.78%
Springer	2	4.44%
IEEE	2	4.44%
Academia	2	4.44%
Science Gate	1	2.22%
IOP Science	1	2.22%
Indian Journal	2	4.44%
Wiley	2	4.44%
Total	**45**	**100%**

Table 3 shows the distribution of studies according to the databases, which also shows the inclusion and exclusion criteria for selecting studies. The research from (ERIC, Google Scholar, and Taylor & Francis) these databases

contributed good work in science teaching, giving rise to the new pedagogical tools implemented in the classroom from primary to secondary level.

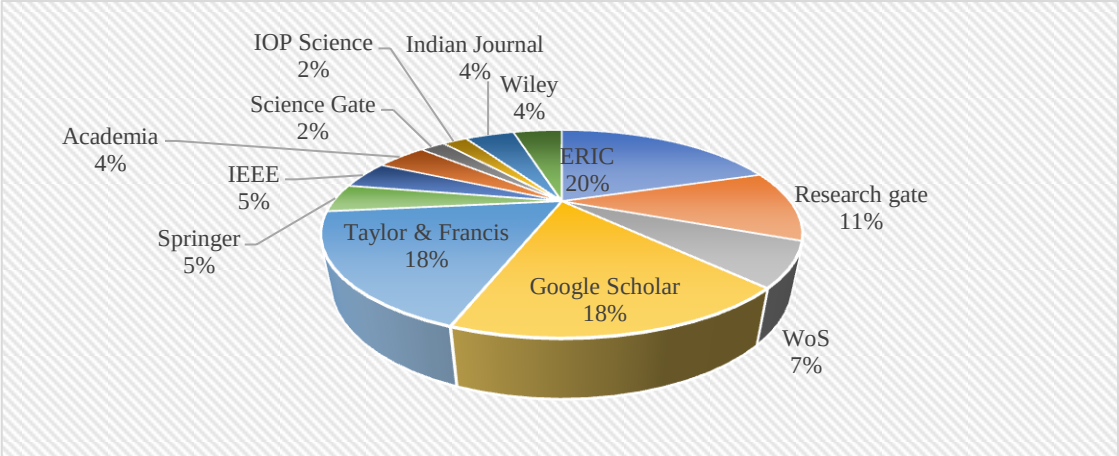

Figure 2. Databases and Their Percentage Contributions

Figure 2 shows the percentage of distribution of studies according to the repositories included in this study. The significant studies were found in ERIC, Google Scholar, and Taylor & Francis. These databases are rich in teaching science. The findings of these databases show that hands-on activities, gamification, art-integrated learning, and inquiry-based teaching are the most relevant pedagogical practices that should be practiced in the actual classroom setting. These strategies have a positive impact on learners' academic achievement, and they are also able to acquire the skills that are required for 21st-century learners.

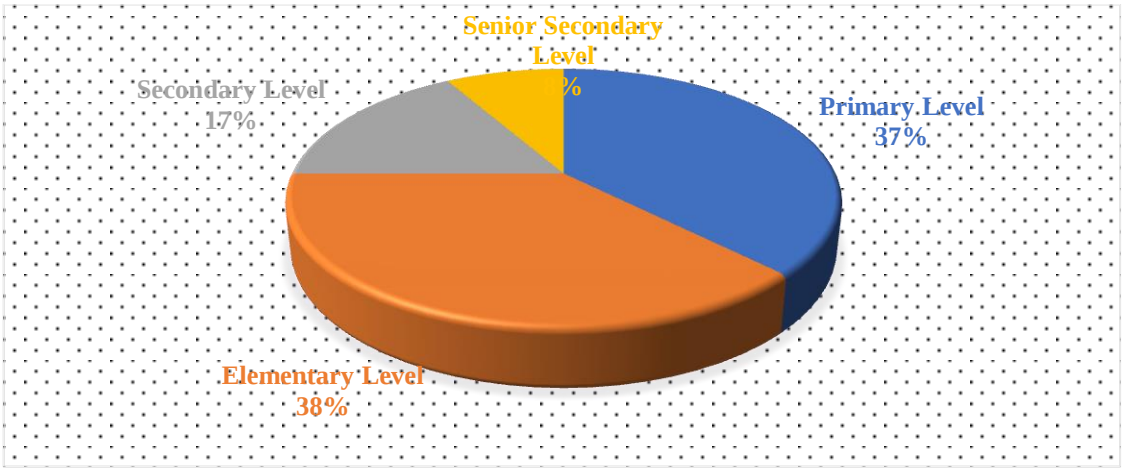

Figure 3. Distribution of Studies across Four Educational Levels

Figure 3 the above figure shows that most of the studies are conducted on the elementary level consists of 38%, 37% at the primary level, 17% at the secondary level, and 8% at the senior secondary level. The findings show that it is easier to engage the students of elementary-level in different activities because they are more curious to know the concepts, facts than secondary and senior secondary-level students.

5. Findings of the Study

Science is an emerging field through which the body of knowledge expands and explores new domains of experience. For this, there should be a change in pedagogical practices in science teaching and now focuses more on

the application of science. It has been found that pedagogical practices are changing daily because the needs are also changing. That is why policymakers develop education policies to cater the needs of learners, society, and the nation. In India, we have only two National Education Policies. In 1968, the first education policy came into existence, after that, this policy was revised in 1986. the second policy is the National Education Policy 2020, which will be implemented in the upcoming years, and states are still working in the direction provided by NEP 2020. Science involves various interconnected steps, including observation, making a hypothesis, deduction of consequences, and verification of different scientific theories to arrive at the principles, laws, and ideas for upgrading scientific concepts. To add something new to science education, school teachers are doing various practices because it develops a base to understand the higher concepts in higher education. In teaching science, this review paper found that different pedagogies help learners to stay motivated, develop skills such as thinking skills, scientific inquiry skills, observation skills, reasoning skills, social skills, scientific attitude, information processing skills (Tan & Wong, 2012, Benli, Kayabasi & Sarikaya 2012; Burkey et al., 2013, Sterling, 2013, Ogreten & Ulucinar Sagir 2013, Samuel & Ogunkola, 2013, Cobern et al. 2014, Romli, S., Sensoy & Yildirim 2017, Abdurrahman, & Riyadi, B. 2018, Yildirim & Sensoy, 2018, Avikasari et al., 2018, Asrizal et al. 2019, Ogegbo & Ramnarain, 2022).

Hands-on activities, gamification, and art-integrated learning in science at a different level in school education are the practices that are being implemented and found to have positive results in enhancing creative thinking skills, cognitive skills, reflective skills, social skills, emotional skills, high engagement, freedom to think, discover and then build a connection between the concepts, create a sense of healthy competition between the learners & generate curiosity (Alberts, 2010; Dhanapal, 2010; Mcdougall et al., 2011; Gelineau, 2011; Dhanapal et al., 2014; Nah et al., 2014; Dicheva et al., 2015; Wiggins, 2016; Kalogiannakis et al., 2018; Angel-Fernandez et al., 2018; Hunkins, 2019; Halvorsen et al., 2019; Hunkins, 2019; Mohalik & Basu, 2020, Ali Alqarni, Monira Alabdan, 2022, Umm Al-Qura University, Makkah, Saudi Arabia et al., 2022). The significant change through art integration in science is that it reduces gender inequality at regional, national, and international levels (Halvorsen et al., 2019; Aaron et al., 2017). These are the only pedagogical practices that have proven beneficial for 21st-century learners because, in this century, all learners need 21st-century skills for their betterment, which are also required to work at the workplace. Pedagogical practices like gamification, hands-on activities, and art-integrated learning emphasize cognitive, affective, and conative domains. Other pedagogical practices emphasize more on the cognitive domain and less on the affective and conative domains.

6. From the Perspective of Future Teachers

Demirhan and Şahin, 2021 discussed that model-based teaching and model-based inquiry should be used to develop an understanding of fundamental laws, investigate laws, and enable learners to understand the relationship between various disciplines. So, teachers must know meta-modeling, in which teachers can only guide the learners to construct models. Demirhan & Şahin, 2021 proposed an expressive model (also known as a hands-on model) used to develop models expressing ideas about a particular phenomenon. The prospective teachers believe that modeling teaching is essential in academics, creativity, and problem-solving skills. Studies also shows that modeling teaching-learning positively influences learners' academic achievement (Arslan, 2013a; Bamberger and Davis,

2013; Devetak et al., 2010; Turk and Kalkan, 2017). According to the perception of learners and teachers, working with textbooks or workbooks is the most used practice in teaching science, but only up to the elementary level (Teppo et al., 2021).

Cheng et al., 2016 explored the correlation between perceptions, attitudes, and instructional practices found to be low correlation and a moderate correlation between instructional practices and philosophy. A strong correlation is needed between perception, mood, and instructional approaches because this leads to open-mindedness, a sense of respect for the evidence in science, and patience among secondary school teachers (Nooraida Yakob et al., 2015; Cruz, 2022). Science teaching should provide real-world opportunities that reflect their educational beliefs and get suitable support to transform their confidence in delivering inquiry-based lessons (Human et al., Faculty of Human Sciences, Waseda University, Tokorozawa, Japan, et al., 2022).

7. Limitations of the Study

The majority of the papers included in this review were from peer-reviewed journals focusing on science teaching using various pedagogical tools in classroom settings, as illustrated in Figure 1. A limitation of this review is that it relies on major repositories such as ERIC, Google Scholar, and Taylor & Francis for sourcing materials related to science teaching, as shown in Table 2 and Figure 2. The selected studies on science teaching at the school level from 2010 to 2023 are included. This review focuses solely on the K-12 level, as depicted in Figure 3, and concentrates specifically on science education, examining different pedagogical strategies and the changes observed over the past decade. Most of the studies included are quantitative in nature, as they involve interventions for school students, while a smaller number are qualitative or mixed-method studies.

8. Discussion & Conclusion

Nowadays, science plays a remarkable role in technology. So, it is essential to focus on science teaching from the primary school level because, at that stage, children are curious to know everything; for example, they ask questions like how the stars formed, why they blink, why the sun rises, and sets, how colors are visible to us, etc., this leads to increase the scientific temper, and it promotes in-depth understanding of science. But it is the duty as well as the responsibility of a science teacher to maintain the interest of the learners by providing the answers to their questions and help to develop imagination and thinking towards science. To achieve the goal of science education, innovative pedagogical strategies are to be implemented through which learners can actively participate in various activities & these activities aim to achieve the learning outcomes (Wieman, 2014).

Memorization-based teaching methods widen the gap between science teaching and practical implications, which creates a negative mindset toward science. That's why there is a need to apply innovative pedagogical practices more focused on application. That will reduce the gap, and many studies prove that gamification, art-based learning, inquiry-based learning, and hands-on activities promote the actual teaching & learning of science. In the educational process, implementing entertaining activities at early stages could be more motivating for the learners (Lozano & Solbes, 2021). Drama & storytelling is a multisensory approach that can be used in science education through robots. The drama and storytelling approach allows one to discuss, explore & express thoughts (Bravo et al., 2021). All these activities lie in one umbrella term, i.e., hands-on activities in which learners perform,

experience, express in their own words, understand deeply, are motivated to do more tasks, enhance creativity, dare to know, etc. These activities help learners to learn, understand abstract concepts, and change their attitude toward science and learning. Teaching science through traditional methods is being criticized by Dewey (Samuel & Ogunkola, 2013). There is a need to focus on innovative teaching practices that can be used in teaching science and mathematics because, generally, learners perceive that these two subjects are too difficult to understand. Some innovative pedagogical approaches that are generally used in science teaching are mentioned in this study. For example, inquiry-based teaching is highly recommended by alleged international organizations, researchers, practitioners, and educators. A blended approach, flipped classroom approach, hands-on activities, dance, drama, storytelling, model-based pedagogy, games & toys, art-based learning, computational thinking approach, etc., are beneficial to secondary-level students.

To advance science education, future efforts should focus on integrating innovative teaching methods that foster curiosity, creativity, and critical thinking among students. Embracing interdisciplinary approaches, such as art-integrated pedagogy and role-play activities, can make complex scientific concepts more relatable and engaging. Leveraging digital tools and technologies, including virtual simulations and interactive platforms, can enhance experiential learning and promote self-directed exploration. Professional development programs for educators should prioritize building competencies in adaptive instructional strategies and digital literacy to meet the diverse needs of learners. Additionally, fostering collaborative learning environments and emphasizing life skills like problem-solving and decision-making will prepare students for real-world challenges, ensuring science education remains relevant and impactful.

"Science is not just for rote memorization; it is something to experience. John Dewey also emphasized 'Learning by Doing' to promote experiential learning, especially in science teaching (Williams, 2017)."

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not–for–profit sectors.

Competing Interests Statement

The author declares no competing financial, professional, or personal interests.

Consent for publication

The author declares that she consented to the publication of this study.

Authors' contributions

Author's independent contribution.

References

[1] Alberts, R. (2010). Discovering Science through Art-Based Activities. Learning Disabilities: A Multidisciplinary Journal, 16(2): 79–80.

[2] Albreiki, B., Zaki, N., & Alashwal, H. (2021). A Systematic Literature Review of Student' Performance Prediction Using Machine Learning Techniques. Education Sciences, 11(9): 552. https://doi.org/10.3390/educsci11090552.

[3] Alokozaya, W.J. (2022). Students' perception of alternative assessment: A qualitative meta-analysis. International Journal of Curriculum and Instruction (IJCI), 14(2): 1419–1441.

[4] Angel-Fernandez, J.M., & Vincze, M. (2018). Introducing storytelling to educational robotic activities. In Proceedings of the 2018 IEEE Global Engineering Education Conference (EDUCON), Canary Islands, Spain, Pages 608–615.

[5] Arslan, A. (2013a). The effects of modeling-based science and technology teaching on understanding, memorization, creativity and mental models of primary school students. Master Thesis, Akdeniz University.

[6] Asrizal, Amran, A., Ananda, A., & Festiyed (2019). Effects of science student worksheet of motion in daily life theme in adaptive contextual teaching model on academic achievement of students. Journal of Physics: Conference Series, 1185: 012093. https://doi.org/10.1088/1742-6596/1185/1/012093.

[7] Avikasari, A., Rukayah, R., & Indriayu, M. (2018). The Influence of Science Literacy-Based Teaching Material Towards Science Achievement. International Journal of Evaluation and Research in Education (IJERE), 7(3): 182. https://doi.org/10.11591/ijere.v7i3.14033.

[8] Bamberger, Y.M., & Davis, E.A. (2013). Middle-school science students' scientific modelling performances across content areas and within a learning progression. International Journal of Science Education, 35(2): 213–238. https://doi.org/10.1080/09500693.2011.624133.

[9] Benli, E., Kayabasi, Y., & Sarikaya, M. (2012). The effect of supported science education to the science achievement, the permanence of knowledge and the attitudes toward science of 7th grade students. Gazi University Journal of Gazi Educational Faculty, 32(3): 733–760.

[10] Bravo, F.A., Hurtado, J.A., & González, E. (2021). Using Robots with Storytelling and Drama Activities in Science Education. Education Sciences, 11(7): 329. https://doi.org/10.3390/educsci11070329.

[11] Brown, S.C. (1962). The Teaching of Science. Science, 138(3541): 703–705. https://doi.org/10.1126/science.138.3541.703.

[12] Burkey, D.D., Anastasio, D.D., & Suresh, A. (2013). Improving student attitudes toward the capstone laboratory course using gamification. In the 2013 ASEE Annual Conference and Exposition, Atlanta, USA.

[13] Castro-Gil, R., & Correa, D. (2021). Transparency in previous literature reviews about blended learning in higher education. Education and Information Technologies, 26(3): 3399–3426. https://doi.org/10.1007/s10639-020-10406-x.

[14] Cheng, P.Y., Talib, O., & Othman, A. (2016). Science Teaching: Perceptions, Attitudes and Instructional Practices. Journal Pendidikan Sains & Matematik Malaysia, 6(2): 2232–0393.

[15] Cobern, W.W., Schuster, D., Adams, B., Skjold, B.A., Muğaloğlu, E.Z., Bentz, A., & Sparks, K. (2014). Pedagogy of Science Teaching Tests: Formative assessments of science teaching orientations. International Journal of Science Education, 36(13): 2265–2288. https://doi.org/10.1080/09500693.2014.918672.

[16] Cruz, R.C. (2022). The Scientific Attitude of Science Teachers and Their Students. International Journal of Academic Multidisciplinary Research (IJAMR), 6(2): 2643–9670.

[17] Curriculum and Instruction Department, Umm Al-Qura University, Makkah, Saudi Arabia, Alqarni, A., Alabdan, M., & Curriculum and Instruction Department, Umm Al-Qura University, Makkah, Saudi Arabia (2022). Exploring teachers' perspectives on using gamification in teaching Science in Saudi Arabia. International Journal of Advanced and Applied Sciences, 9(9): 41–52. https://doi.org/10.21833/ijaas.2022.09.006.

[18] Cutting, R., & Kelly, O. (2015). Creative Teaching in Primary Science. In Creative Teaching in Primary Science, Pages 28–41, SAGE Publications Ltd. https://doi.org/10.4135/9781473910195.

[19] Demirhan, E., & Şahin, F. (2021). The Effects of Different Kinds of Hands-on Modeling Activities on the Academic Achievement, Problem-Solving Skills, and Scientific Creativity of Prospective Science Teachers. Research in Science Education, 51(s2): 1015–1033. https://doi.org/10.1007/s11165-019-09874-0.

[20] Devetak, I., Hajzeri, M., Glažar, A.S., & Vogrinec, J. (2010). The influence of different models on 15-years old students' understanding of the solid state of matter. Acta Chimica Slovenica, 57: 904–511.

[21] Dhanapal, S., Kanapathy, R., & Mastan, J. (2014). A study to understand the role of visual arts in the teaching and learning of science. Asia-Pacific Forum on Science Learning and Teaching, 15(2).

[22] Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. Educational Technology & Society, 18(3): 75–88. doi: 10.1109/educon.2014.6826129.

[23] Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. International Journal of Educational Technology in Higher Education, 14(1): 1–36. https://doi.org/10.1186/s41239-017-0042-5.

[24] Dobbs, S. (1998). Learning in and Through Art: A Guide to Discipline-Based Art Education. CA: Getty Pub.

[25] Duffy, T.M., & Raymer, P.L. (2010). A practical guide and a constructivist rationale for inquiry-based learning. Educational Technology, 46(3): 3–13.

[26] Filgona, J., Sakiyo, J., Gwany, D.M., & Okoronka, A.U. (2020). Motivation in learning. Asian Journal of Education and Social Studies, 10(4): 16–37. https://doi.org/10.9734/ajess/2020/v10i430273.

[27] Gelineau, R.P. (2011). Integrating the Arts across the Elementary School Curriculum. United States of America: Wadsworth, Cengage Learning.

[28] Güler Yıldız, T., Öztürk, N., İlhan İyi, T., Aşkar, N., Banko Bal, Ç., Karabekmez, S., & Höl, Ş. (2021). Education for sustainability in early childhood education: A systematic review. Environmental Education Research, 27(6): 796–820. https://doi.org/10.1080/13504622.2021.1896680.

[29] Gurcan, F., & Cagiltay, N.E. (2023). Research trends on distance learning: A text mining-based literature review from 2008 to 2018. Interactive Learning Environments, 31(2): 1007–1028. https://doi.org/10.1080/10494820.2020.1815795.

[30] Halvorsen, H.P., Tretjakova, R., Timmerberg, J., Thiriet, J.M., & Mylvaganam, S. (2019). STEAM for STEM - Include "Art" in STEM (Science, Technology, Engineering and Mathematics). 2019 29th Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE), Pages 1–7. https://doi.org/10.1109/eaeeie46886.2019.9000460.

[31] Nawanidbumrung, W., & Samiphak, S. (2022). The Impact of Pre-service Teachers' Pedagogical Beliefs on Teaching Science as Inquiry: A Silent Antagonist for Effective Inquiry-Based Science Lessons. Science Education International, 33(1): 112–121. https://doi.org/10.33828/sei.v33.i1.12.

[32] Hung, A.C.Y. (2017). A Critique and Defense of Gamification. Journal of Interactive Online Learning, 15(1): 1541–4914.

[33] Hunkins, M.M. (2019). The Art of Science; An Exploration of Art Integration in a Science Classroom. The Art of Science, 5: 16.

[34] Kalogiannakis, M., Ampartzaki, M., Papadakis, S., & Skaraki, E. (2018). Teaching natural science concepts to young children with mobile devices and hands-on activities. A case study. Int. J. Teaching and Case Studies, 9(2): 171–183.

[35] Karacan, C.G., & Akoğlu, K. (2021). Educational Augmented Reality Technology for Language Learning and Teaching: A Comprehensive Review. Shanlax International Journal of Education, 9(2): 68–79. https://doi.org/10.34293/education.v9i2.3715.

[36] Kayode, O.O., Ogundokun, R.O., Mohammed, R.E., & Olorundare, A.S. (2020). Review of Innovative Teaching Strategies in Senior Secondary Schools Sciences. i-manager's Journal of Educational Technology, 17(1): 56–65. https://doi.org/10.26634/jet.17.1.17018.

[37] Lawson, A.E., (2010). Teaching Inquiry Science in Middle and Secondary Schools. Thousand Oaks, California: Sage Publications.

[38] Lozano, O.R., & Solbes, J. (2021). Promoting Inquiry Based Learning through Entertaining Science Activities. International Journal of Research in Education and Science, 7(4): 1117–1135. https://doi.org/10.46328/ijres.2390.

[39] Mcdougall, M., Bever, B., & Seper, R. (2011). Art as a Way of Knowing. San Francisco: Exploratorium, Pages 1–33.

[40] McCarthy, K.F. (Eds.) (2004). Gifts of the muse: Reframing the debate about the benefits of the arts. RAND Research in the Arts.

[41] Mohalik, R., & Basu, M. (2020). Effectiveness of Arts Integrated Learning (AIL) in Developing Conceptual Understanding in Geography at Elementary Level. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3674340.

[42] Nah, F.F.H., Zeng, Q., Telaprolu, V.R., Ayyappa, A.P., & Eschenbrenner, B. (2014). Gamification of education: A review of literature. In F.F.H. Nah (Eds.), Proceedings of 1st International Conference on Human-Computer Interaction in Business, Pages 401–409, Crete, Greece: LNCS Springer.

[43] NCERT (2006). Chemistry: Textbook for class XI 2 Parts. National Council of Education Research and Training.

[44] Nooraida Yakob, Hashimah Mohd Yunus & Chan Yi May (2015). Knowledge and Practices in Teaching Socio-scientific Issues among Malaysian Primary School Science Teachers. US-China Education Review A., 5(9): 634–640. https://doi.org/10.17265/2161-623x/2015.09a.006.

[45] Ogegbo, A.A., & Ramnarain, U. (2022). A systematic review of computational thinking in science classrooms. Studies in Science Education, 58(2): 203–230. https://doi.org/10.1080/03057267.2021.1963580.

[46] Ogreten, B., & Ulucinar, S.S. (2013). The effect of interactive teaching on academic success and technology course for 4th grades. Journal of Western Anatolia Educational Sciences, 4(3): 1–18.

[47] Ravanis, K. (2017). Early childhood science education: state of the art and perspectives. Journal of Baltic Science Education, 16(3): 284–288.

[48] Riley, S. (2012). Shake the Sketch: An Arts Integration Workbook. U.S. Copyright.

[49] Robles, A., Solbes, J., Cantó, J., & Lozano, O.R. (2015). Actitudes de los estudiantes hacia la ciencia escolar en el primer ciclo de la Enseñanza Secundaria Obligatoria. Revista Electrónica de Enseñanza de las Ciencias, 14(3): 361–376.

[50] Romli, S., Abdurrahman & Riyadi, B. (2018). Designing students' worksheet based on openended approach to foster students' creative thinking skills. IOP Conf. Series: Journal of Physics: Conf. Series, 948: 1–6.

[51] Samuel, D.F., & Ogunkola, B.J. (2013). St. Lucian Elementary School Teachers' Applicability Beliefs and Beliefs about Science Teaching and Learning: Relevance to Their Level of Inquiry-Based Instructional Practices in Science. International Education Studies, 6(7): 48. https://doi.org/10.5539/ies.v6n7p48.

[52] Schouela, J.M. (2022). Learning through Laughter: The Integration of Comedy into the Academic Curriculum. Learning Landscapes, 15(1): 311–322. https://doi.org/10.36510/learnland.v15i1.1062.

[53] Sensoy, O., & Yildirim, H.I. (2017). The effect of information technologies and applications in the science courses on students' academic achievement levels. Paper presented at the International Association of Educational Researchers (ULEAD), Canakkale, Pages 143.

[54] Singh, S. (2015). Constructivist approaches for teaching and learning of science. International Journal in Management and Social Science, 3(12): 164–176, 2321–1784.

[55] Smiderle, R., Rigo, S.J., Marques, L.B., Peçanha de Miranda Coelho, J.A., & Jaques, P.A. (2020). The impact of gamification on students' learning, engagement and behavior based on their personality traits. Smart Learning Environments, 7(1): 1–11. https://doi.org/10.1186/s40561-019-0098-x.

[56] Solbes, J., Lozano, O.R., & García-Molina, R. (2008). Juegos, juguetes y pequeñas experiencias tecnocientíficos en la enseñanza aprendizaje de la física y química y la tecnología. Investigación en la escuela, 65: 71–88. https://doi.org/10.12795/ie.2008.i65.07.

[57] Sterling, D.R. (2013). How Does Leadership Matter? Developing and Teaching a Definition of Hands-On Science, a Prerequisite for Effective Inquiry Teaching. The Journal of Mathematics and Science: Collaborative Explorations, 13: 79–92.

[58] Tan, A.L., & Wong, H.M. (2012). 'Didn't Get Expected Answer, Rectify It.': Teaching science content in an elementary science classroom using hands-on activities. International Journal of Science Education, 34(2): 197–222. https://doi.org/10.1080/09500693.2011.565378.

[59] Teppo, M., Soobard, R., & Rannikmäe, M. (2021). Grade 6 & 9 Student and Teacher Perceptions of Teaching and Learning Approaches in Relation to Student Perceived Interest/Enjoyment Towards Science Learning. Journal of Baltic Science Education, 20(1): 119–133. https://doi.org/10.33225/jbse/21.20.119.

[60] Turk, C., & Kalkan, H. (2017). The effect of teaching astronomy with models on students' achievements and attitudes. Journal of Current Researches on Educational Studies, 7(2): 185–204. https://doi.org/10.26579/jocures-7.2.12.

[61] U.K. Government (2013). National Curriculum for England: Key stages 1 and 2 framework documents. Department of Education. http://www.gov.uk/dfe/nationalcurriculum.

[62] Wieman, C.E. (2014). Large-scale comparison of science teaching methods sends clear message. Proceedings of the National Academy of Sciences, 111(23): 8319–8320. https://doi.org/10.1073/pnas.1407304111.

[63] Wiggins, B.E. (2016). An overview and study on the use of games, simulations, and gamification in higher education. International Journal of Game-Based Learning, 6(1): 18–29. doi: 10.4018/ijgbl.2016010102.

[64] Williams, M. K. (2017). John Dewey in the 21st century.

[65] Yildirim, H.I., & Sensoy, O. (2018). The Effect of Science Teaching Enriched with Technological Applications on the Science Achievements of 7th Grade Students. Journal of Education and Training Studies, 6(9): 53. https://doi.org/10.11114/jets.v6i9.3363.

Website Links

[1] https://www.imanagerpublications.com/article/17018.

[2] https://books.google.co.in/books?hl=hi&lr=&id=vRO8EAAAQBAJ&oi=fnd&pg=PT8&dq=art+integrated+learning&ots=YZ3KYdG-jH&sig=ei-oTBLWyRkv_W3JiZQ0wdBWiQg#v=onepage&q=art%20integrated%20learning&f=false.