encyclopedia

MDPI

Review

Narrative Approaches in Science Education: From Conceptual Understanding to Applications in Chemistry and Gamification

Gregorio Jiménez-Valverde

EduCiTS Innovation and EMA Research Groups, IRE-Faculty of Education, Universitat de Barcelona, 08035 Barcelona, Spain; gregojimenez@ub.edu

Abstract

Narrative methods are increasingly recognized in science teaching for their potential to deepen conceptual understanding and foster meaningful connections to scientific content. This review explores their educational significance by examining three main formats—historical narratives, realistic fiction, and science fiction or fantasy—highlighting how each can render complex scientific principles more accessible and memorable. Special attention is given to chemistry education, a field where abstract, multilevel concepts often pose significant challenges for students. Furthermore, the review explores the integration of narratives into gamified environments, examining how storytelling functions as both a motivational engine and a cognitive scaffold to support deeper learning in science. Finally, the review proposes directions for future research, underscoring the need for empirically grounded narrative resources that balance imaginative appeal with scientific accuracy across diverse educational settings.

Keywords: narrative-based learning; science education; chemistry teaching; storytelling; motivation; gamification; scientific literacy; cognitive load; narrative-centered learning environment

check for updates

Academic Editor: Victoria Samanidou

Received: 23 June 2025
Revised: 19 July 2025
Accepted: 5 August 2025
Published: 8 August 2025

Citation: Jiménez-Valverde, G. Narrative Approaches in Science Education: From Conceptual Understanding to Applications in Chemistry and Gamification. *Encyclopedia* **2025**, *5*, 116. https://doi.org/10.3390/encyclopedia5030116

1. Introduction

In recent years, storytelling and narrative methods have become increasingly prominent in science education, reflecting a growing interest in making scientific knowledge more accessible, engaging, and personally meaningful for students [1]. Although the terms "story" and "narrative" are often used interchangeably, this review adopts a common distinction: a "story" generally refers to the chronological sequence of events, while a "narrative" encompasses how these events are organized, presented, and interpreted for an audience [2,3].

A robust body of educational research now highlights the pedagogical value of narrative-based instruction across diverse learning environments, from traditional classrooms to those shaped by digital technologies [4,5]. Research indicates that narrative approaches can deepen conceptual understanding and stimulate critical thinking and creativity, while also capturing attention to enhance knowledge retention and facilitate the transfer of learning across these varied settings [6–8].

Science education—and chemistry in particular—poses unique challenges that make narrative integration especially valuable. By their nature, scientific disciplines frequently address phenomena that lie beyond direct human perception and rely on abstract, specialized language, which can create a sense of distance between students and scientific content [9]. Chemistry, specifically, often introduces multi-level abstract concepts that are difficult for students to visualize or connect to their everyday experience [10]. Compounding these cognitive hurdles, many students report negative attitudes or a sense of detachment toward science, which can further hinder their learning and motivation [11,12]. Narrative frameworks offer a promising way to address both the cognitive and affective dimensions of this problem, humanizing scientific content to provide emotional resonance and support meaningful engagement [13].

Despite these advantages, the use of narrative in science education has also drawn criticism. Some question whether fictional elements risk introducing misconceptions or undermining scientific rigor, while others contend that narrative structures are essential for making science relevant and accessible to foster deeper understanding [14]. This ongoing debate highlights a fundamental tension between optimizing student engagement and maintaining scientific rigor. This underscores the need for a nuanced examination of narrative approaches, one that carefully considers their strengths, limitations, and appropriate applications within the science classroom.

This review responds to this debate by critically examining the principal narrative formats employed in science education—historical (authentic) narratives, realistic fiction, and science fiction or fantasy—and exploring their pedagogical applications, with a particular focus on chemistry teaching and gamified educational environments Rather than a systematic review, this review adopts a narrative and integrative approach. The referenced studies were selected based on the following criteria: empirical and theoretical contributions published in peer-reviewed journals or scholarly books between 1986 and 2025; direct relevance to the central themes of narrative in science education (with special emphasis on chemistry and gamification); and availability in English or Spanish. The literature was identified via targeted keyword searches in major academic databases (e.g., Web of Science, Scopus, Google Scholar) and backward citation tracking. By synthesizing the research found, this review aims to clarify the educational significance of narrative in science education, illuminate unresolved questions in the field, and offer evidence-based recommendations for future research and classroom practice.

This review ultimately argues that narrative approaches—when carefully designed and thoughtfully embedded within the curriculum—can play a transformative role in science education, promoting conceptual understanding, motivation, and scientific literacy. However, as the author will demonstrate, further empirical investigation is needed to develop narrative resources that effectively balance imaginative appeal with scientific accuracy, and to validate their effectiveness across diverse educational settings.

2. Theoretical Background: Narratives in Science Education

Narrative is increasingly recognized not only as a fundamental mode of human thought but as a core process through which individuals interpret experience, organize knowledge, and construct meaning [15,16]. Educational theorists draw a distinction between the “narrative” and “paradigmatic” modes of cognition: while the latter emphasizes logic, abstraction, and decontextualized fact, the narrative mode privileges temporal sequence, agency, and the construction of meaning through story [16,17]. This duality has shaped science education, where the dominance of expository discourse often sidelines narrative, despite its natural alignment with how learners make sense of complex phenomena.

In educational contexts, narrative-based approaches have become prominent as educators seek effective strategies to address persistent challenges related to motivation, engagement, and the retention of scientific knowledge. Far from being a mere stylistic device, narrative functions as a powerful cognitive scaffold—supporting the integration of new information with prior understanding and shaping both personal and social identity within learning communities [18,19].

A substantial body of research in psychology and education documents both the cognitive and affective power of narrative. Narratives not only provide coherent structures for organizing complex or abstract ideas, but also activate mental schemas, foster emotional engagement, and enhance memory [20–22]. Neuroimaging studies confirm that narrative processing recruits associative brain networks encompassing language, emotion, and action-planning [23,24]. Stories' inherent sensitivity to change, surprise, and resolution resonates with learners' curiosity and innate drive for sense-making, acting as a catalyst for scientific inquiry [25–27]. These features are particularly valuable for students who struggle with traditional expository texts or who may otherwise remain disengaged [28].

Some theorists even suggest that scientific explanation itself is a narrative endeavor, as both aim to provide coherence, establish causal sequences, and make sense of phenomena [29]. Within science education, narrative approaches address key disciplinary barriers. Science is frequently presented as a body of decontextualized facts, which can impede students' ability to connect content with personal experience or recognize the human dimensions of scientific practice [30]. Embedding scientific information within stories not only bridges this gap—making science more relevant and building trust—but also creates a sense of community and belonging, helping students see themselves as participants in scientific practice [9,31]. Moreover, narratives can serve a metacognitive function, supporting reflection on the Nature of Science (NoS), model-based reasoning, and fostering the critical thinking and perspective-taking skills essential for navigating scientific controversies [32,33].

Empirical support for narrative-based instruction is robust and extends across diverse settings. Studies consistently show that it enhances conceptual understanding, intrinsic motivation, and classroom engagement [34,35]. Critically, these positive outcomes are not limited to formal schooling; research has validated their effectiveness in informal learning environments, such as museums and science centers, where narrative-rich experiences boost both motivation and comprehension [36,37].

This trend is reflected in the development of pedagogical resources designed to embed narrative in science teaching. University textbooks now increasingly integrate stories and case studies to improve preservice science teacher education [38]. In parallel, a structured collection of stories designed to support scientific inquiry and dialog in primary science classrooms is presented in [39]. These narrative resources help children connect new concepts to familiar experiences and serve as effective entry points for both hands-on exploration and reflective classroom discussion.

The evolution of this approach is evident in narrative-centered learning environments (NCLEs), where students are immersed in story-driven problem-solving [40,41]. By positioning learners as co-constructors of knowledge, these environments increase students' situational interest —a state of heightened attention and positive emotion—and promote sustained learning, especially when combined with inquiry-based methods [42,43]. The expansion of digital education has further amplified this potential, enabling collaborative and personalized experiences. For example, digital storytelling has been found to foster associative and divergent thinking—cognitive skills essential for creative problem-solving in science [4,5].

Despite these advantages, two types of challenges complicate implementation: practical barriers for educators—such as limited training, confidence, and resources [44]—and conceptual concerns regarding scientific rigor, authenticity, and the risk of introducing misconceptions through fiction [42]. Language barriers, students' limited prior knowledge, and managing engagement during narrative-based activities add further complexity [45]. Overcoming these obstacles requires thoughtful instructional design, ongoing reflection, and targeted professional development, as well as access to high-quality narrative materials and collaborative networks.

In summary, the theoretical and empirical literature confirm the value of narrative in making science education more engaging, accessible, and relevant. Narrative not only supports memory and conceptual change, but also builds trust, community, and motivation—key prerequisites for inclusive and effective science learning. Building on this foundation, a systematic examination of the primary narrative formats employed in science teaching is necessary to understand their distinctive functions and classroom applications. The following section undertakes this analysis.

3. Main Narrative Formats in Science Education

The diversity of narrative forms used in science education reflects both the richness of storytelling as a pedagogical tool and the multifaceted nature of scientific understanding. These formats vary in their degree of factual grounding, imaginative scope, and connection to students' lived experiences. For clarity and analytical depth, this section adopts the classification used in a recent systematic review [46], which distinguishes three principal narrative types frequently employed in science learning environments: authentic scenarios, realistic fiction, and science fiction or fantasy.

3.1. Authentic Scenarios

Authentic scenarios, rooted in real historical events or natural phenomena, hold a privileged place in science education. By design, they connect scientific content to its broader historical, social, and cultural context, humanizing the discipline and countering perceptions of it as abstract or impersonal [47]. Classic examples range from the story of Rosalind Franklin's contribution to discovering the structure of DNA and Ignaz Semmelweis's investigation of puerperal fever to historical controversies like the Galvani–Volta debate [48–50]. Another compelling pedagogical approach leveraging authentic narratives is the "Storyline Approach" [51], which creates immersive learning experiences based on historical episodes and scientific discoveries. Specialized teaching resources such as The Story Behind the Science and the Project StoryTelling further provide educators with structured guides for implementing these narratives [52–54].

The pedagogical power of these scenarios lies in their ability to serve as "gateways" to scientific learning. By highlighting the personal and social dimensions of science—including the struggles, failures, and perseverance of scientists—these stories spark curiosity and foster emotional connections that support deeper learning, retention, and self-efficacy [55–57]. Such use of storytelling has been credited with transforming science from a sterile collection of facts into a meaningful human endeavor, capable of inciting wonder and appreciation for discovery, and enabling students to integrate complex concepts into a coherent, dynamic story—like the evolutionary history of life—rather than viewing them as isolated facts [50,58].

However, the pedagogical impact of authentic narratives is critically dependent on their selection and framing, particularly for cultivating a nuanced understanding of the NoS. Critics caution against perpetuating the "lone genius" stereotype or presenting heroic, decontextualized accounts that can reinforce a simplistic view of science [59,60]. A growing body of classroom-based research validates these concerns while highlighting the benefits of a more contextualized approach. Students who engage with contextualized and explicitly reflective historical narratives develop a more informed understanding of the NoS, becoming less prone to associate science exclusively with empirical experimentation and more likely to acknowledge the essential role of creativity, imagination, and inference in scientific inquiry [61]. Similarly, narratives centered on figures like Ernest Rutherford have been shown to help middle-school students engage explicitly with the tentativeness of knowledge, the social context of discovery, and the human dimensions of empirical model-building [62]. Diversifying the range of narratives in science education by incorporating stories of scientists from underrepresented backgrounds has also been identified as a powerful way to humanize science, expand students' sense of scientific identity, and promote inclusivity in the classroom [63].

Therefore, the intentional selection of authentic stories is crucial for portraying the scientific community's true diversity and complexity, enabling students to envision themselves as active participants. Well-designed interventions illustrate the potential of this approach. One such example is a narrative-based museum field trip centered on Leonardo da Vinci, in which fourth-grade students showed improved long-term retention of scientific information and developed a more personal, multidimensional view of scientists as complex individuals [64].

3.2. Realistic Fiction

Realistic fiction offers a highly adaptable narrative format for making scientific concepts meaningful and accessible. By situating scientific ideas within plausible, everyday scenarios, this approach bridges the gap between abstract content and students' lived experiences and can serve as powerful tools for presenting everyday phenomena as mysteries, stimulating curiosity and critical thinking while fostering active, problem-centered learning [65,66]. Narrative connections to everyday life can also enhance interdisciplinary learning by revealing conceptual continuities across biology, chemistry, and physics [67].

Empirical evidence robustly supports the educational benefits of this format. Studies demonstrate that narrative environments enhance comprehension of scientific ideas while simultaneously helping students transfer their learning to practical, everyday contexts [68,69]. One study, for example, integrated narrative science stories featuring relatable characters who solve problems using scientific principles into physics lessons for seventh-grade students [35]. The results showed improvements in academic achievement, motivation, and overall classroom climate. Moreover, the use of mystery-based narratives has proven particularly effective: in physics, they have been shown to increase student participation, collaboration, and conceptual understanding, while excerpts from classic detective fiction like Sherlock Holmes have been used to model how evidence-based reasoning evolves from concrete observation to abstract inference [70,71].

In younger learners, realistic fiction has been shown to support conceptual understanding and responsible behavior, particularly through picture-based stories and animated narratives that present scientific ideas in engaging, relatable formats [72,73]. The development of dedicated resources for primary education exemplifies how narrative can be effectively embedded into early science curricula [39].

3.3. Science Fiction and Fantasy

Science fiction and fantasy are highly imaginative narrative formats that introduce unique opportunities in science education. By moving beyond the boundaries of everyday experience, these genres invite students to explore scientific concepts in creative, speculative, and entirely fictional worlds. Their value lies not only in sparking attention and curiosity, but in providing a "safe space" to confront uncertainty, ethical dilemmas, and the far-reaching implications of science and technology [2,74]. From a postmodern perspective, science and environmental education have been conceptualized as forms of storytelling, with the narrative techniques found in literary fiction—particularly postmodern science fiction—offering powerful tools to critically examine the complex relationship between humans and the environment [75].

These genres prove particularly effective in stimulating discussion about emerging or controversial scientific topics. One learning intervention, inspired by Mary Shelley's Frankenstein, invited students to assume the roles of scientists facing ethical dilemmas, fostering critical reflection on the societal implications of science [76]. Similarly, fantasy stories—though less directly tied to actual scientific developments—can serve as powerful entry points for reasoning and investigation, especially with younger students. They enable educators to anthropomorphize natural processes, build magical worlds governed by scientific "rules," and design challenges that nurture creativity and conceptual growth. Adapted versions of classic fairy tales that embed scientific principles, and fantasy-based play, have also been linked to increased engagement and deeper learning in elementary science education [77,78].

However, these genres present distinct challenges. While narrative structures organize information temporally and causally, fictional elements like supernatural powers risk fostering misconceptions or blurring the lines between science and make-believe [79,80]. Some studies have documented ecological inaccuracies in traditional tales that may inadvertently reinforce naïve or scientifically inaccurate beliefs [81]. Thus, teachers become essential mediators—critically selecting narratives, framing their use, and guiding students to distinguish imaginative devices from scientific principles, transforming stories into inquiry springboards rather than definitive explanations.

4. Narratives in Chemistry Education

Chemistry education confronts unique challenges stemming from its multilayered representational demands. The influential Johnstone triangle framework—distinguishing macroscopic (observable phenomena), submicroscopic (molecular/atomic interactions), and symbolic (equations, formulas) levels (Figure 1)—reveals students' persistent difficulties in integrating these perspectives, often resulting in fragmented understanding and entrenched misconceptions [82,83]. These challenges intensify with chemistry's specialized vocabulary and concepts that feel disconnected from students' lived experiences.

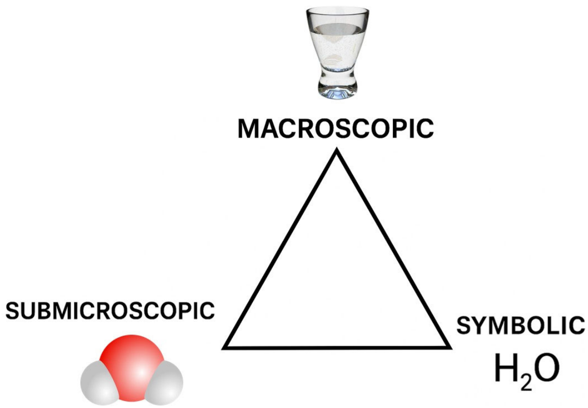

Figure 1. Johnstone's triangle as applied to water, illustrating the three levels of chemical representation: macroscopic (observable phenomena, here depicted by a glass of water), submicroscopic (the molecular model of a water molecule), and symbolic (the chemical formula H_2O).

Narrative strategies have emerged as powerful pedagogical responses to these representational complexities. By weaving scientific content into story structures, educators create conceptual bridges that connect laboratory observations with molecular explanations and symbolic representations. Some theorists argue that narratives function as meaning-making frameworks, explicitly linking the macroscopic, submicroscopic, and symbolic levels to provide a more holistic understanding [84,85].

Empirical studies support this view—for instance, chemistry lessons that incorporate everyday-life narratives or stories drawn from students' and teachers' real experiences have been shown to significantly enhance students' understanding of physical and chemical changes while also reducing persistent misconceptions and making abstract chemical ideas more accessible and personally relevant [86,87].

Recent pedagogical innovations showcase narrative's versatility. Inquiry-driven approaches, such as the 'magic sand' activity, exemplify this integration. Here, a brief narrative—the story of a sandcastle builder faced with mysterious, unwettable sand—is used during the 'Engage' phase to spark curiosity and establish a personal context for the investigation [88]. This story then frames the entire inquiry journey, which is structured around the 5E learning cycle [89]. One notable application involved a narrative adaptation of Romeo and Juliet, embedded within another 5E sequence to address common misconceptions about atomic models [90]. Reimagining electrons as the central characters, the activity promoted active engagement and helped upper secondary students construct more accurate representations of orbitals and energy levels. Teachers consistently observe how such narratives heighten engagement among initially reluctant learners, though their effectiveness depends critically on educators' storytelling confidence [42]. In another example, role-playing activities based on climate change scenarios were used to connect stoichiometric reasoning with real-world societal decisions, fostering greater motivation and self-efficacy through enhanced personal relevance [91].

Detective narratives hold particular resonance in chemical education. The Chemical Adventures of Sherlock Holmes series [92]—a collection of 17 stories published in the Journal of Chemical Education— exemplifies this approach, challenging students to solve mysteries through qualitative analysis, stoichiometric calculations, or organic chemistry reasoning. These stories deliberately position learners as investigators who interpret clues, analyze data, and reason scientifically—transforming classrooms into problem-solving environments. Building on this tradition, a modified version of one such story was implemented in which preservice chemistry teachers used QR-coded clues to collaboratively identify an unknown substance, engaging in scientific reasoning while also confronting common high school chemistry misconceptions [93]. Equally noteworthy are literary adaptations like Agatha Christie's The Mysterious Affair at Styles [94], which provides narrative frameworks for exploring solubility, equilibria, and organic structures, reinforcing chemistry's inherent nature as investigative science.

For younger audiences, resources like Quimicuentos [95] blend imaginative storytelling with foundational scientific ideas. Other outreach initiatives have successfully combined chemistry-themed tales with hands-on experimentation, allowing students to experience scientific concepts both narratively and practically [96]. In fact, fiction offers multiple opportunities to connect with the chemistry curriculum and foster scientific literacy. Works such as Harry Potter or Cinderella have been used in primary chemistry education, integrating reading with the learning of basic concepts such as properties or states of matter, with positive results [97,98]. These approaches not only enhance conceptual understanding but also actively counteract chemophobia [96] by fostering more positive relationships with the discipline.

Beyond full-length stories, the very structure of common inquiry-based activities provides a fertile ground for teachers to construct compelling micro-narratives. Techniques like the Predict–Observe–Explain (POE) sequence [99] inherently follow a classic narrative arc: a setup (the prediction), a conflict (the unexpected observation), and a resolution (the search for a new explanation).

One illustrative example is the combustion of steel wool, which a teacher can frame not as a simple demonstration, but as a miniature mystery within the POE approach. By doing so, the teacher deliberately constructs a story designed to create a "violation of expectation," a powerful mechanism for sparking what Klassen [100], drawing on narrative theory, terms "explanation-seeking curiosity." Students are challenged to predict the outcome, often anticipating a decrease in mass. The observation that the steel wool gains mass creates a moment of cognitive dissonance and suspense—a narrative hook that compels them to investigate the unseen role of oxygen in the reaction. This practice of transforming a demonstration into a dramatic event echoes Michael Faraday's historic public lectures, where suspense and masterful storytelling transformed abstract scientific principles into unforgettable narratives of discovery [85].

Finally, recent theoretical work advocates for enriching chemistry education by integrating what Mahaffy [101] has called the "human element." His proposed tetrahedral model, which expands Johnstone's triangle by adding this dimension, emphasizes the relevance of personal, social, and cultural contexts in learning chemistry. Sharing stories about chemists' lives and discoveries—such as Kekulé's dream of the benzene ring—underscores the role of intuition and serendipity in scientific progress [102]. Empirical studies support this perspective, showing that the deliberate inclusion of diverse personal narratives enhances students' sense of belonging, motivation, and critical thinking [103,104], encouraging them to see chemistry not merely as abstract knowledge but as a human-centered discipline.

5. Narratives and Gamification: Toward Immersive Science Learning Environments

Gamification—the integration of game-based elements into non-game contexts—has become a prominent force in educational innovation, with extensive research confirming its capacity to enhance student motivation and engagement [105–108]. Among all elements, narrative stands out as a potential catalyst for transforming disconnected activities into meaningful and immersive learning journeys [109]. Rather than serving as a decorative add-on, narrative functions as a foundational architecture that organizes game mechanics and pedagogical challenges into unfolding stories infused with purpose, drama, and suspense [110,111]. The literature confirms this potential, finding consistently positive or mixed-positive effects of narrative in gamified contexts [112].

Design frameworks such as the Mechanics–Dynamics–Aesthetics (MDA) model [113] provide a robust theoretical scaffold for implementing narrative in gamified learning. In this model, narrative not only shapes the "aesthetics" (emotional responses), but actively configures game mechanics (rules, challenges) and player dynamics (interactions, decision-making). Crucially, the educational value of the storyline is greatly enhanced when the narrative is closely aligned with the specific knowledge and skills being developed, ensuring the framework is purposeful [114]. This does not mean the narrative must be complex; simple, "thin" storylines can be highly engaging if they are relevant to the learning experience [115]. Recent implementations [116,117] have demonstrated the impact of integrating cohesive narratives—such as medieval quests or fantasy island adventures—with notable improvements in preservice teachers' attitudes toward science.

From a motivational perspective, narrative acts as a powerful engine by addressing basic psychological needs. Embedding instructional activities within narrative contexts has been shown to heighten both enjoyment and motivation, leading to better knowledge retention [118]. According to Self-Determination Theory (SDT), this occurs because narrative-driven gamification is exceptionally well-suited to satisfy three basic needs: it enhances autonomy by offering activities perceived as personally meaningful; strengthens competence through attainable challenges with immediate feedback; and fosters relatedness by creating shared experiences that build social bonds [119–122]. This motivational synergy often culminates in a state of presence or immersion—the subjective experience of being psychologically inside the narrative world—which, while not a basic need itself, further amplifies engagement and commitment [120,123]. Evidence from gamified courses that unfold through semester-long, themed narrative journeys shows that these immersive structures can effectively satisfy all three SDT needs and significantly boost intrinsic motivation among preservice teachers in a science course [124].

Beyond motivation, narrative also provides crucial cognitive scaffolding, an especially critical function in disciplines like chemistry. According to Cognitive Load Theory (CLT), learning is most effective when the extraneous cognitive load is reduced as much as possible and the intrinsic cognitive load is calibrated or optimized to match the learner's expertise and the inherent complexity of the material [125]. Chemistry is a prime example of a high-load domain, as its abstract concepts, specialized vocabulary, and multi-level representations impose significant strain on working memory [126–128]. Narrative structures can address this challenge by sequencing content logically and helping students connect new ideas to prior knowledge, thereby facilitating more efficient schema construction and, thus, maximizing germane cognitive load [129].

Recent empirical studies further illustrate these theoretical claims. Darejeh et al. [130] found that embedding content within contextually rich narratives can significantly reduce cognitive overload in digital learning environments. However, their study only examined immediate effects in novice adult users, limiting its generalizability to other populations or to long-term learning. The benefits of narrative depend heavily on thoughtful design; misaligned narratives or poor integration of materials can induce a split-attention effect and increase extraneous load, negatively affecting learning [131–133]. In particular, Adams et al. [132] highlighted that positive effects only emerge when narrative elements are closely aligned with learning goals, and their results may also be constrained by the short experimental duration.

One of the most comprehensive applications of all these principles is found in structural gamification, where narrative becomes the organizing framework for an entire course rather than a supplementary element [106]. One illustrative example involved a structurally gamified university science course for preservice teachers, set within the Star Wars universe, which led to notable improvements in student engagement, course organization, and overall perception of the learning experience [134]. The absence of a cohesive narrative thread in such long-term interventions can lead to fragmentation and diminished motivation [135]. This approach culminates in the development of game-based NCLEs, which blend immersive stories, interactive problem-solving, and adaptive scaffolding [136]. In these environments, students are positioned as protagonists who use scientific knowledge to solve meaningful dilemmas, transforming not only the narrative context but also their own relationship with science [137,138].

6. Conclusions and Prospects

This review has synthesized a substantial body of evidence demonstrating the multifaceted value of narrative approaches in science education, with a specific focus on the unique challenges and opportunities within chemistry teaching, and in gamification. The analysis confirms that narrative is not merely a pedagogical tool, but a fundamental mode of human cognition that can bridge the gap between abstract scientific knowledge and students' lived realities.

By providing temporal structure, causal coherence, and emotional resonance, narratives scaffold the understanding of complex concepts, effectively bridging the representational gaps inherent in disciplines like chemistry. Furthermore, narrative integration within gamified environments emerges not as a superficial enhancement, but as a foundational design principle that transforms learning into an immersive, intrinsically motivating quest by satisfying basic psychological needs.

Several key insights warrant emphasis. The effectiveness of any narrative format is highly contingent on intentional design and critical implementation. Authentic scenarios humanize science and foster nuanced NoS understanding, yet they risk perpetuating stereotypes if not carefully framed. Realistic fiction excels at grounding abstract concepts in relatable contexts, while science fiction/fantasy provides a unique arena for exploring scientific concepts in speculative worlds, stimulating ethical reasoning and fostering imaginative inquiry.

Crucially, across all these formats, a unifying thread emerges: the indispensable role of the educator as a critical mediator. This review highlights that the success of narrative-based learning is not inherent to the story itself but relies on the teacher's ability to frame the narrative, guide discussions, challenge misconceptions, and explicitly connect the story's elements to scientific principles. Whether it is transforming a POE demonstration into a "miniature mystery", using a fantasy story as a springboard for inquiry, or facilitating ethical debates inspired by science fiction, the teacher acts as the essential bridge between the narrative world and the world of scientific reasoning.

Furthermore, the evidence suggests that the 'humanizing' potential of narrative operates on two crucial levels: the epistemological and the sociocultural. Epistemologically, stories of scientific discovery (e.g., Kekulé's dream) reveal the messy, creative, and serendipitous nature of the scientific enterprise, challenging the myth of a single, rigid scientific method. Socio-culturally, the intentional inclusion of narratives from diverse scientists is a powerful act of educational equity. It broadens students' perceptions of who can be a scientist, fosters a sense of belonging, and empowers a more diverse generation to see themselves as agents of inquiry and change.

Despite these compelling advantages, significant challenges persist. Practical barriers, including educators' limited time, training, and confidence, remain substantial hurdles. Notably, recent empirical work with preservice teachers highlights difficulties in adapting scientific language and a fear of introducing misconceptions when creating science narratives [139]. The fundamental tension between engagement and rigor, highlighted in the introduction, necessitates ongoing vigilance. While narratives make science accessible, ensuring they accurately represent scientific concepts requires careful curation, explicit framing, and complementary activities that distinguish narrative devices from scientific explanations.

To address these barriers, sustained professional development models—such as collaborative lesson study, peer mentoring, and hands-on workshops focused on narrative design—can be effective in building teachers' confidence and expertise. Providing access to curated narrative resources, exemplars, and opportunities for reflective practice also supports the integration of narrative approaches in science classrooms. Moreover, some universities now offer specialized courses for faculty focused on impactful storytelling in teaching, and these models could be adapted to primary and secondary science education. Ultimately, professional development programs should address both the pedagogical techniques of storytelling and the deep content knowledge required to maintain scientific accuracy.

Looking ahead, these findings yield a clear agenda for the field's future. For research, the priority must be to move beyond descriptive studies toward controlled, comparative research that clarifies what works, for whom, and under what conditions. Future work should employ robust experimental designs—such as randomized con-trolled trials or quasi-experiments—to directly compare the effectiveness of different narrative formats across student populations, educational stages, and disciplines. Studies should assess outcomes like motivation, conceptual understanding, ethical reasoning, and long-term retention; mixed-methods approaches, combining quantitative (e.g., achievement tests, motivation scales) and qualitative data (e.g., interviews, student narratives), are encouraged to capture both impact and mechanisms.

Further directions include systematically testing the impact of specific narrative elements—such as character development or plot structure—and directly comparing outcomes between structurally narrative gamified environments and those with merely superficial themes. A particularly valuable direction is the design of narratives aimed at helping students navigate chemistry's challenging representational levels. Furthermore, the rise of artificial intelligence-powered tools demands investigation into how interactive and co-created narratives mediate learning [140,141].

Regarding classroom practice and instructional design, the potential of structuring entire curricula as coherent, purpose-driven stories warrants greater exploration. This requires interdisciplinary collaboration and a critical engagement with new digital tools. For assessment, as narrative approaches become more central, frameworks must evolve beyond traditional tests. Promising alternatives include portfolio-based evaluation, narrative journaling, and performance tasks embedded within the story world.

In conclusion, narrative offers a generative path forward for science education—one that balances rigor with imagination, cognitive depth with emotional resonance, and disciplinary knowledge with human experience. The thoughtful integration of narrative, informed by this forward-looking agenda, can empower students not only to learn science, but to see themselves as creative scientific thinkers and contributors to inquiry within the scientific enterprise.

Funding: The research has been funded by the Institute of Professional Development (IDP) of Universitat de Barcelona, grant number REDICE24-3707.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CLT	Cognitive Load Theory
MDA	Mechanics-Dynamics-Aesthetics
NCLE	Narrative-Centered Learning Environment
NoS	Nature of Science
POE	Predict–Observe–Explain
SDT	Self-Determination Theory

References

1. Soares, S.; Gonçalves, M.; Jerónimo, R.; Kolinsky, R. Narrating Science: Can It Benefit Science Learning, and How? *J. Res. Sci. Teach.* **2023**, *60*, 2042–2075. [CrossRef]
2. Jarvis, C. The Educational Power of Fiction—An Interdisciplinary Exploration. In *Professional Education with Fiction Media*; Springer: Cham, Switzerland, 2019; pp. 1–26. [CrossRef]
3. Rimmon-Kenan, S. *Narrative Fiction: Contemporary Poetics*, 2nd ed.; Routledge: London, UK, 2002.

4. Mawasi, A.; Nagy, P.; Wylie, R. Systematic Literature Review on Narrative-Based Learning in Educational Technology Learning Environments (2007–2017). In Proceedings of the 14th International Conference of the Learning Sciences (ICLS 2020), Nashville, TN, USA, 19–23 June 2020; International Society of the Learning Sciences: Bloomington, IN, USA, 2020; pp. 1213–1220.
5. Nasir, W.M.F.W.M.; Halim, L.; Arsad, N.M. A Systematic Review of the Digital Storytelling Activities That Promote Thinking Skills in a Science Classroom. In Proceedings of the 2nd International Conference on Social Sciences (ICONESS 2023), Purwokerto, Indonesia, 22–23 July 2023; EAI: Gent, Belgium, 2023. [CrossRef]
6. Bolkan, S. Storytelling in the Classroom: Facilitating Cognitive Interest by Promoting Attention, Structure, and Meaningfulness. *Commun. Rep.* **2021**, *34*, 1–13. [CrossRef]
7. Ghanizadeh, A.; Tabeie, M.; Pourtousi, Z. The Role of University Instructor's Narrative in Students' Sustained Attention, Emotional Involvement, and Cognitive Learning. *J. Appl. Res. High. Educ.* **2024**, *16*, 195–207. [CrossRef]
8. Kromka, S.M.; Goodboy, A.K. Classroom Storytelling: Using Instructor Narratives to Increase Student Recall, Affect, and Attention. *Commun. Educ.* **2018**, *68*, 20–43. [CrossRef]
9. Avraamidou, L.; Osborne, J. The Role of Narrative in Communicating Science. *Int. J. Sci. Educ.* **2009**, *31*, 1683–1707. [CrossRef]
10. Johnstone, A.H. Teaching of Chemistry—Logical or Psychological? *Chem. Educ. Res. Pract. Eur.* **2000**, *1*, 9–15. [CrossRef]
11. Osborne, J.; Simon, S.; Collins, S. Attitudes towards science: A review of the literature and its implications. *Int. J. Sci. Educ.* **2003**, *25*, 1049–1079. [CrossRef]
12. Potvin, P.; Hasni, A. Interest, Motivation and attitude towards science and Technology at K-12 Levels: A Systematic Review of 12 Years of Educational Research. *Stud. Sci. Educ.* **2014**, *50*, 85–129. [CrossRef]
13. Willingham, D.T. *Why Don't Students Like School?* 2nd ed.; Jossey-Bass: San Francisco, CA, USA, 2021.
14. Dahlstrom, M.F. Using Narratives and Storytelling to Communicate Science with Nonexpert Audiences. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 13614–13620. [CrossRef]
15. Bruner, J. *Actual Minds, Possible Worlds*; Harvard University Press: Cambridge, MA, USA, 1986.
16. Bruner, J. The Narrative Construction of Reality. *Crit. Inq.* **1991**, *18*, 1–21. [CrossRef]
17. Jonassen, D.H.; Hernandez-Serrano, J. Case-Based Reasoning and Instructional Design: Using Stories to Support Problem Solving. *Educ. Technol. Res. Dev.* **2002**, *50*, 65–77. [CrossRef]
18. Bruner, J.S. *Making Stories: Law, Literature, Life*; Harvard University Press: Cambridge, MA, USA, 2002.
19. Huber, J.; Caine, V.; Huber, M.; Steeves, P. Narrative Inquiry as Pedagogy in Education: The Extraordinary Potential of Living, Telling, Retelling, and Reliving Stories of Experience. *Rev. Res. Educ.* **2013**, *37*, 212–242. [CrossRef]
20. Schank, R.C.; Berman, T.R. The pervasive role of stories in knowledge and action. In *Narrative Impact: Social and Cognitive Foundations*; Green, M.C., Strange, J.J., Brock, T.C., Eds.; Lawrence Erlbaum Associates Publishers: Mahwah, NJ, USA, 2002; pp. 287–313.
21. Prins, R.; Avraamidou, L.; Goedhart, M. Tell Me a Story: The Use of Narrative as a Learning Tool for Natural Selection. *Educ. Media Int.* **2017**, *54*, 20–33. [CrossRef]
22. Wolfe, M.B.; Woodwyk, J.M. Processing and Memory of Information Presented in Narrative or Expository Texts. *Br. J. Educ. Psychol.* **2010**, *80*, 341–362. [CrossRef]
23. Sabatinelli, D.; Lang, P.J.; Bradley, M.M.; Flaisch, T. The Neural Basis of Narrative Imagery: Emotion and Action. *Prog. Brain Res.* **2006**, *156*, 93–103. [CrossRef]
24. Negrete, A. Remembering Rhythm and Rhyme: Memorability of Narratives for Science Communication. *Geosci. Commun.* **2021**, *4*, 1–9. [CrossRef]
25. Kidd, C.; Hayden, B.Y. The Psychology and Neuroscience of Curiosity. *Neuron* **2015**, *88*, 449–460. [CrossRef]
26. Loewenstein, G. The Psychology of Curiosity: A Review and Reinterpretation. *Psychol. Bull.* **1994**, *116*, 75–98. [CrossRef]
27. Johnstone, A.H. Why Is Science Difficult to Learn? Things Are Seldom What They Seem. *J. Comput. Assist. Learn.* **1991**, *7*, 75–83. [CrossRef]
28. Gilbert, J.; Hipkins, R.; Cooper, G. Faction or Fiction: Using Narrative Pedagogy in School Science Education. In Proceedings of the Redesigning Pedagogy Conference, Singapore, 30 May–1 June 2005.
29. Ogborn, J.; Kress, G.; Martins, I.; McGillicuddy, K. *Explaining Science in the Classroom*; Open University Press: Buckingham, UK, 1996.
30. Kokkotas, P.; Rizaki, A.; Malamitsa, K. Storytelling as a Strategy for Understanding Concepts of Electricity and Electromagnetism. *Interchange* **2010**, *41*, 379–405. [CrossRef]
31. Bayer, S.; Hettinger, A. Storytelling: A Natural Tool to Weave the Threads of Science and Community Together. *Bull. Ecol. Soc. Am.* **2019**, *100*, e01542. [CrossRef]
32. Adúriz-Bravo, A. Teaching the Nature of Science with Scientific Narratives. *Interchange* **2015**, *45*, 167–184. [CrossRef]
33. Dinsmore, D.L.; Zoellner, B.P.; Parkinson, M.M.; Rossi, A.M.; Monk, M.J.; Vinnachi, J. The Effects of Different Types of Text and Individual Differences on View Complexity about Genetically Modified Organisms. *Int. J. Sci. Educ.* **2017**, *39*, 791–813. [CrossRef]
34. Hadzigeorgiou, Y.; Klassen, S.; Klassen, C.F. Encouraging a "Romantic Understanding" of Science: The Effect of the Nikola Tesla Story. *Sci. Educ.* **2012**, *21*, 1111–1138. [CrossRef]

35. Akarsu, B.; Kariper, İ.A.; Coşkun, H. Scientific stories in teaching. *Mersin Univ. J. Educ.* **2015**, *11*, 349–365.
36. Shaby, N.; Dillon, J.; Peleg, R.; Ben-Zvi Assaraf, O.; Pattison, S.; Pierroux, P.; Barzilay, M.; Grenon, M.; Steier, R.; Svarovsky, G.N.; et al. Telling tales: The use of narratives in informal STEM settings. *Res. Sci. Technol. Educ.* **2025**, *43*, 1–22. [CrossRef]
37. Engel, A.; Lucido, K.; Cook, K. Rethinking narrative in science learning. *Child. Educ.* **2018**, *94*, 4–12. [CrossRef]
38. Koch, J. *Science Stories: Science Methods for Elementary and Middle School Teachers*, 6th ed.; Cengage Learning: Boston, MA, USA, 2018.
39. Smith, C.; Pottle, J. *Science Through Stories*; Hawthorn: Stroud, UK, 2015.
40. Mott, B.W.; Callaway, C.B.; Zettlemoyer, L.S.; Lee, S.Y.; Lester, J.C. Towards narrative-centered learning environments. In *AAAI Fall Symposium 1999*; The AAAI Press: Menlo Park, CA, USA, 1999; pp. 78–82.
41. Rowe, J.; Mott, B.; Lester, J. Narrative-centered learning environments. In *Encyclopedia of the Sciences of Learning*; Seel, N.M., Ed.; Springer: Boston, MA, USA, 2012; pp. 2423–2426. [CrossRef]
42. Peleg, R.; Yayon, M.; Katchevich, D.; Mamlok-Naaman, R.; Fortus, D.; Eilks, I.; Hofstein, A. Teachers' views on implementing storytelling as a way to motivate inquiry learning in high-school chemistry teaching. *Chem. Educ. Res. Pract.* **2017**, *18*, 304–309. [CrossRef]
43. Hidi, S.; Renninger, K.A. Four-phase model of interest development. *Educ. Psychol.* **2006**, *41*, 111–127. [CrossRef]
44. Dorion, K.R. Science through Drama: A multiple case exploration of the characteristics of drama activities used in secondary science lessons. *Int. J. Sci. Educ.* **2009**, *31*, 2247–2270. [CrossRef]
45. Matamit, H.N.H.; Roslan, R.; Shahrill, M.; Said, H.M. Storytelling challenges in primary science. *Int. J. Eval. Res. Educ.* **2020**, *9*, 716–722. [CrossRef]
46. Wang, T.; Uttamchandani, S.; Zou, X.; Hmelo-Silver, C.E.; Rowe, J.; Lester, J.C. Learning with Stories: Characteristics and Learning Outcomes in Narrative-Centered Science Learning Environments. In Proceedings of the 17th International Conference of the Learning Sciences—ICLS 2023, Montreal, QC, Canada, 10–15 June 2023; International Society of the Learning Sciences: Bloomington, IN, USA, 2023; pp. 1202–1205. [CrossRef]
47. Kapsala, N.; Mavrikaki, E. Storytelling as a pedagogical tool in NOS instruction. In *Nature of Science in Science Instruction*; Springer: Cham, Switzerland, 2020; pp. 485–512. [CrossRef]
48. Acevedo-Díaz, J.A.; García-Carmona, A. Rosalind Franklin y el ADN. *Rev. Cient.* **2016**, *25*, 162–175. [CrossRef]
49. Aragón-Méndez, M.M.; García-Carmona, A.; Acevedo-Díaz, J.A. Aprendizaje de estudiantes de secundaria sobre la naturaleza de la ciencia mediante el caso histórico de Semmelweis y la fiebre puerperal. *Rev. Cient.* **2016**, *27*, 302–317. [CrossRef]
50. Hadzigeorgiou, Y. Humanizing the teaching of physics through storytelling: The case of current electricity. *Phys. Educ.* **2006**, *41*, 42–46. [CrossRef]
51. Isabelle, A.D. Teaching Science Using Stories: The Storyline Approach. *Sci. Scope* **2007**, *31*, 16–25.
52. The Story Behind the Science: Bring Science and Scientists to Life. Available online: https://www.storybehindthescience.org (accessed on 22 June 2025).
53. Clough, M.P. Using Stories Behind the Science to Improve Understanding of Nature of Science, Science Content, and Attitudes Toward Science. In *Nature of Science in Science Instruction. Science: Philosophy, History and Education*; McComas, W.F., Ed.; Springer: Cham, Switzerland, 2020. [CrossRef]
54. Project Storytelling: Supporting Educational Processes in Science Teaching. Available online: https://www.science-story-telling.eu (accessed on 22 June 2025).
55. Klassen, S.; Klassen, C.F. Science Teaching with Historically Based Stories: Theoretical and Practical Perspectives. In *International Handbook of Research in History, Philosophy and Science Teaching*; Matthews, M.R., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 1503–1529. [CrossRef]
56. Arya, D.J.; Maul, A. Scientific discovery narrative in middle school. *J. Educ. Psychol.* **2012**, *104*, 1022–1032. [CrossRef]
57. Lin-Siegler, X.; Ahn, J.N.; Chen, J.; Fang, F.F.A.; Luna-Lucero, M. Even Einstein struggled: Effects of learning about great scientists' struggles. *J. Educ. Psychol.* **2016**, *108*, 314–328. [CrossRef]
58. Kumala, M. The Neverending Story—Using the Narrative as a Fundamental Approach to Teaching Biology and Beyond. *Evo. Educ. Outreach* **2010**, *3*, 526–531. [CrossRef]
59. Heering, P. False friends: What makes a story inadequate for science teaching? *Interchange* **2010**, *41*, 323–333. [CrossRef]
60. Milne, C. Philosophically correct science stories? *J. Res. Sci. Teach.* **1998**, *35*, 175–187. [CrossRef]
61. Cansiz, M.; Sunngur, S.; Öztekın, C. Improving NOS understanding through history of science instruction: Contextualized explicit and reflective approach. *Turk. Online J. Educ. Technol.* **2016**, 307–313.
62. Hansson, L.; Arvidsson, Å.; Heering, P.; Pendrill, A.-M. Rutherford visits middle school. *Phys. Educ.* **2019**, *54*, 045002. [CrossRef]
63. Collins, S.N. The importance of storytelling in chemical education. *Nat. Chem.* **2021**, *13*, 1–2. [CrossRef] [PubMed]
64. Shaby, N.; Ben-Zvi Assaraf, O. "Leonardo da Vinci was a Renaissance Man"—Using narrative-based pedagogy on a museum field trip. *J. Museum Educ.* **2024**, *49*, 142–151. [CrossRef]

65. Kim, M.Y.; Park, J. Linking scientific concepts with students' personal daily lives: Using the metaphysical meaning of scientific concepts. *J. Balt. Sci. Educ.* **2024**, *23*, 882–898. [CrossRef]
66. Konicek-Moran, R. *Everyday Science Mysteries*; NSTA Press: Arlington, VA, USA, 2008.
67. Strandt, S. Science Narratives for Teaching and Learning. In *Pedagogy in a New Tonality*; Gouzouasis, P., Ed.; SensePublishers: Rotterdam, The Netherlands, 2011; pp. 227–234. [CrossRef]
68. McQuiggan, S.W.; Rowe, J.P.; Lee, S.; Lester, J.C. Story-based learning: The impact of narrative on learning experiences and outcomes. In *Intelligent Tutoring Systems, Lecture Notes in Computer Science*; Woolf, B.P., Aïmeur, E., Nkambou, R., Lajoie, S., Eds.; Springer: Berlin/Heidelberg, Germany, 2008; pp. 530–539. [CrossRef]
69. Wrzesien, M.; Alcañiz Raya, M. Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the E-Junior project. *Comput. Educ.* **2010**, *55*, 178–187. [CrossRef]
70. Maharaj-Sharma, R. Using storytelling to teach a topic in physics. *Educ. Inq.* **2024**, *15*, 227–246. [CrossRef]
71. Schrader, C.L. Everyone wants to be a model teacher. Part I: Observations versus inferences. *J. Chem. Educ.* **1984**, *61*, 1001–1002. [CrossRef]
72. Kalogiannakis, M.; Nirgianaki, G.-M.; Papadakis, S. Teaching magnetism to preschool children: The Effectiveness of Picture Story Reading. *Early Child. Educ. J.* **2018**, *46*, 535–546. [CrossRef]
73. Yang, B.; Wu, N.; Tong, Z.; Sun, Y. Narrative-Based Environmental Education Improves Environmental Awareness and Environmental Attitudes in Children Aged 6–8. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6483. [CrossRef]
74. Ağlarcı Özdemir, O.; Önen Öztürk, F. Science fiction as an instructional strategy. *Int. J. Sci. Math. Educ.* **2023**, *21*, 187–209. [CrossRef] [PubMed]
75. Gough, N. Environmental education, narrative complexity and post-modern science/fiction. *Int. J. Sci. Educ.* **1993**, *15*, 607–625. [CrossRef]
76. Mawasi, A.; Nagy, P.; Finn, E.; Wylie, R. Using Frankenstein-themed science activities for science ethics education. *J. Moral Educ.* **2022**, *51*, 353–370. [CrossRef]
77. Kotsis, K.T.; Tsiouri, E. Once upon a time—Integrating fairy tales into physics education: The case of Mechanics. *Eur. J. Educ. Pedagogy* **2023**, *4*, 31–39. [CrossRef]
78. Banister, F.; Ryan, C. Developing science concepts through storytelling. *Sch. Sci. Rev.* **2001**, *83*, 75–84.
79. Cervetti, G.N.; Bravo, M.A.; Hiebert, E.H.; Pearson, P.D.; Jaynes, C.A. Text genre and science content: Ease of Reading, Comprehension, and Reader Preference. *Read. Psychol.* **2009**, *30*, 487–511. [CrossRef]
80. Klein, P.D. The challenges of scientific literacy: From the viewpoint of second-generation cognitive science. *Int. J. Sci. Educ.* **2006**, *28*, 143–178. [CrossRef]
81. Kazantzidou, D.; Kotsis, K. Errors and inaccuracies about the environment in fairy tales. *Sci. Educ. Res. Praxis* **2017**, *61*, 9–23.
82. Taber, K.S. Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chem. Educ. Res. Pract.* **2013**, *14*, 156–168. [CrossRef]
83. Reid, N. *The Johnstone Triangle: The Key to Understanding Chemistry*; Royal Society of Chemistry: Cambridge, UK, 2021. [CrossRef]
84. Winston, J. Teaching chemistry as a story: Using narrative structure as a framework for science education. *Electron. J. Sci. Educ.* **2019**, *23*, 59–72.
85. Rees, S.; Newton, D. Storytelling. In *Creative Chemists: Strategies for Teaching and Learning*; Royal Society of Chemistry: Cambridge, UK, 2020; pp. 78–91.
86. Demircioğlu, H.; Dinç, M.; Çalık, M. The effect of storylines embedded within context-based learning approach on grade-6 students' understanding of physical and chemical change concepts. *J. Baltic Sci. Educ.* **2013**, *12*, 682–691. [CrossRef]
87. Boström, A. Narratives as tools in designing the school chemistry curriculum. *Interchange* **2008**, *39*, 391–413. [CrossRef]
88. Peleg, R.; Katchevich, D.; Yayon, M.; Mamlok-Naaman, R.; Dittmar, J.; Eilks, I. The magic sand mystery. *Science in School* **2015**, *32*, 37–40.
89. Bybee, R.W. *The BSCS 5E Instructional Model: Creating Teachable Moments*; NSTA Press: Arlington, VA, USA, 2015.
90. Aquilina, G.; Dello Iacono, U.; Gabelli, L.; Picariello, L.; Scettri, G.; Termini, G. "Romeo and Juliet: A Love out of the Shell": Using storytelling to address students' misconceptions and promote modelling competencies in science. *Educ. Sci.* **2024**, *14*, 239. [CrossRef]
91. Flener Lovitt, C.E.; Bertram, M.; Campbell, D.; Shinneman, A.C.; Groom, M.; Hathaway, D.; Lambert, A.; Lasker, G.A. Embodying change: Courses that integrate narrative, storytelling, and embodied learning in climate change education. *J. Chem. Educ.* **2025**, *102*, 516–526. [CrossRef]
92. Jacobsen, E.K. Sherlock Holmes Goes Viral. *J. Chem. Educ.* **2011**, *88*, 368–369. [CrossRef]
93. Jiménez-Valverde, G.; Calafell-Subirà, G.; Espaza-Pagès, M. Un misterio gamificado para trabajar concepciones erróneas sobre la Química. In Proceedings of the 30 Encuentros Internacionales de Didáctica de las Ciencias Experimentales, Melilla, Spain, 7–9 September 2022; pp. 1311–1316.

94. Southward, R.E.; Hollis, W.G., Jr.; Thompson, D.W. Precipitation of a murder: A creative use of strychnine chemistry in Agatha Christie's The Mysterious Affair at Styles. *J. Chem. Educ.* **1992**, *69*, 536–537. [CrossRef]
95. Oryace, S. *Quimicuentos*; Universidad de Concepción: Concepción, Chile, 1992.
96. Morais, C. Storytelling with chemistry and related hands-on activities: Informal learning experiences to prevent "chemophobia" and promote young children's scientific literacy. *J. Chem. Educ.* **2015**, *92*, 58–65. [CrossRef]
97. Wally, L.M.; Levinger, N.E.; Grainger, D.W. Employing popular children's literature to teach elementary school chemistry: An engaging outreach program. *J. Chem. Educ.* **2005**, *82*, 1489–1495. [CrossRef]
98. Talaue, F.T.; Kim, M.; Aik-Ling, T. Finding common ground during collaborative problem solving: Pupils' engagement in scenario-based inquiry. In *Authentic Problem Solving and Learning in the 21st Century*; Cho, Y.H., Caleon, I., Kapur, M., Eds.; Springer: Singapore, 2015; pp. 133–151. [CrossRef]
99. White, R.T.; Gunstone, R.F. *Probing Understanding*; Falmer Press: London, UK, 1992.
100. Klassen, S. The construction and analysis of a science story: A proposed methodology. *Sci. Educ.* **2009**, *18*, 401–423. [CrossRef]
101. Mahaffy, P.G. The future shape of chemistry education. *Chem. Educ. Res. Pract.* **2004**, *5*, 229–245. [CrossRef]
102. Kortam, N.; Hugerat, M.; Mamlok-Naaman, R. The story behind the discovery: Integrating short historical stories in science teaching. *Chem. Teach. Int.* **2021**, *3*, 1–8. [CrossRef]
103. Collins, S.; Steele, T.; Nelson, M. Storytelling as pedagogy: The power of chemistry stories for classroom engagement. *J. Chem. Educ.* **2023**, *100*, 2664–2672. [CrossRef]
104. Mackey, K.; McHugh, M.; McGlacken, G.P. Some people and personalities of organic chemistry: A teaching hook for mid-level university students. *Chem. Teach. Int.* **2022**, *4*, 327–338. [CrossRef]
105. Deterding, S.; Dixon, D.; Khaled, R.; Nacke, L. From game design elements to gamefulness: Defining "gamification". In Proceedings of the MindTrek '11: Proceedings of the 15th International Academic MindTrek Conference, Tampere, Finland, 28–30 September 2011; ACM: New York, NY, USA, 2011; pp. 9–15. [CrossRef]
106. Kapp, K.M. *The Gamification of Learning and Instruction*; Pfeiffer: San Francisco, CA, USA, 2012.
107. Hassan, L.; Hamari, J. Gameful civic engagement: A review of the literature on gamification of e-participation. *Gov. Inf. Q.* **2020**, *37*, 101461. [CrossRef]
108. Zourmpakis, A.-I.; Kalogiannakis, M.; Papadakis, S. Adaptive gamification in science education: An analysis of implementation and adapted game elements on students' motivation. *Computers* **2023**, *12*, 143. [CrossRef]
109. Werbach, K.; Hunter, D. *For the Win: How Game Thinking Can Revolutionize Your Business*; Wharton Digital Press: Philadelphia, PA, USA, 2012.
110. Chang, C.; Wei, H. Exploring engaging gamification mechanics in massive online open courses. *Educ. Technol. Soc.* **2016**, *19*, 177–203.
111. McNamara, D.S.; Jackson, G.T.; Graesser, A.C. Intelligent tutoring and games (ITaG). In *Gaming for Classroom-Based Learning: Digital Role-Playing as a Motivator of Study*; Baek, Y.K., Ed.; IGI Global: Hershey, PA, USA, 2010; pp. 44–65. [CrossRef]
112. Sailer, M.; Homner, L. The gamification of learning: A meta-analysis. *Educ. Psychol. Rev.* **2020**, *32*, 77–112. [CrossRef]
113. Hunicke, R.; LeBlanc, M.; Zubek, R. MDA: A formal approach to game design and game research. In Proceedings of the AAAI Workshop on Challenges in Game AI, San Jose, CA, USA, 25–29 July 2004.
114. Ke, F.; Grabowski, B. Gameplaying for maths learning: Cooperative or not? *Br. J. Educ. Technol.* **2007**, *38*, 249–259. [CrossRef]
115. Clark, D.B.; Tanner-Smith, E.E.; Killingsworth, S.S. Digital games, design, and learning: A systematic review and meta-analysis. *Rev. Educ. Res.* **2016**, *86*, 79–122. [CrossRef]
116. Jiménez-Valverde, G.; Heras-Paniagua, C.; Fabre-Mitjans, N.; Calafell-Subirà, G. Gamifying Teacher Education with FantasyClass: Effects on Attitudes towards Physics and Chemistry among Preservice Primary Teachers. *Educ. Sci.* **2024**, *14*, 822. [CrossRef]
117. Fabre-Mitjans, N.; Jiménez-Valverde, G.; Guimerà-Ballesta, G.; Calafell-Subirà, G. Digital Gamification to Foster Attitudes Toward Science in Early Childhood Teacher Education. *Appl. Sci.* **2025**, *15*, 5961. [CrossRef]
118. Cordova, D.I.; Lepper, M.R. Intrinsic motivation and the process of learning: Beneficial effects of contextualisation, personalisation and choice. *J. Educ. Psychol.* **1996**, *88*, 715–730. [CrossRef]
119. Ryan, R.M.; Deci, E.L. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* **2000**, *55*, 68–78. [CrossRef]
120. Rigby, C.S.; Ryan, R.M. *Glued to Games: How Video Games Draw Us in and Hold Us Spellbound*; Praeger: Santa Barbara, CA, USA, 2011. [CrossRef]
121. Sailer, M.; Hense, J.U.; Mayr, S.K.; Mandl, H. How gamification motivates: An experimental study of specific game-design elements on psychological need satisfaction. *Comput. Hum. Behav.* **2017**, *69*, 371–380. [CrossRef]
122. Bormann, D.; Greitemeyer, T. Immersed in virtual worlds and minds: Effects of in-game storytelling on immersion, need satisfaction, and affective theory of mind. *Soc. Psychol. Personal. Sci.* **2015**, *6*, 646–652. [CrossRef]
123. McGonigal, J. *Reality is Broken: Why Games Make Us Better and How They Can Change the World*; Penguin Publishing Group: New York, NY, USA, 2011.

124. Jiménez-Valverde, G.; Fabre-Mitjans, N.; Heras-Paniagua, C.; Guimerà-Ballesta, G. Tailoring Gamification in a Science Course to Enhance Intrinsic Motivation in Preservice Primary Teachers. *Educ. Sci.* **2025**, *15*, 300. [CrossRef]
125. Sweller, J. Cognitive load theory, learning difficulty, and instructional design. *Learn. Instr.* **1994**, *4*, 295–312. [CrossRef]
126. Hartman, J.R.; Nelson, E.A.; Kirschner, P.A. Improving student success in chemistry through cognitive science. *Found. Chem.* **2022**, *24*, 239–261. [CrossRef]
127. Hartman, J.R.; Nelson, E.A. "Do we need to memorize that?" or cognitive science for chemists. *Found. Chem.* **2015**, *17*, 263–274. [CrossRef]
128. Reid, N. The learning of chemistry: The key role of working memory. In *Learning with Understanding in the Chemistry Classroom*; Devetak, I., Glažar, S.A., Eds.; Springer: Dordrecht, The Netherlands, 2014; pp. 87–113. [CrossRef]
129. Paas, F.; Renkl, A.; Sweller, J. Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instr. Sci.* **2004**, *32*, 1–8. [CrossRef]
130. Darejeh, A.; Marcus, N.; Sweller, J. The effect of narrative-based e-learning systems on novice users' cognitive load while learning software applications. *Educ. Technol. Res. Dev.* **2021**, *69*, 2451–2473. [CrossRef]
131. Dicheva, D.; Dichev, C.; Agre, G.; Angelova, G. Gamification in education: A systematic mapping study. *Educ. Technol. Soc.* **2015**, *18*, 75–88.
132. Adams, D.M.; Mayer, R.E.; MacNamara, A.; Koenig, A.; Wainess, R. Narrative games for learning: Testing the discovery and narrative hypotheses. *J. Educ. Psychol.* **2012**, *104*, 235–249. [CrossRef]
133. Chandler, P.; Sweller, J. The split-attention effect as a factor in the design of instruction. *Br. J. Educ. Psychol.* **1992**, *62*, 233–246. [CrossRef]
134. Sánchez-Martín, J.; Cañada-Cañada, F.; Dávila-Acedo, M.A. Just a game? Gamifying a general science class at university: Collaborative and competitive work implications. *Think. Skills Creat.* **2017**, *26*, 51–59. [CrossRef]
135. Heras-Paniagua, C.; Jiménez-Valverde, G.; Calafell-Subirà, G. La necesidad de una narrativa en la gamificación estructural de una asignatura. In *Narrativas y Usuarios de la Sociedad Transmedia*; Paredes-Otero, G., Ed.; Dykinson: Madrid, Spain, 2022; pp. 57–79. Available online: https://hdl.handle.net/2445/215656 (accessed on 22 June 2025).
136. Rowe, J.; Shores, L.; Robison, J.; Hoffman, K.; Lester, J. Narrative-centered learning: A self-regulated perspective. In *AAAI Fall Symposium 2009*; The AAAI Press: Menlo Park, CA, USA, 2009; pp. 87–92.
137. Barab, S.A.; Dodge, T.; Ingram-Goble, A.; Pettyjohn, P.; Peppler, K.; Volk, C.; Solomou, M. Pedagogical dramas and transformational play: Narratively rich games for learning. *Mind Cult. Act.* **2010**, *17*, 235–264. [CrossRef]
138. Barab, S.A.; Gresalfi, M.; Ingram-Goble, A. Transformational play: Using games to position person, content and context. *Educ. Res.* **2010**, *39*, 525–536. [CrossRef]
139. Cruz-Lorite, I.M.; Zagalaz, J.; Franco-Mariscal, A.J. Digital storytelling as a strategy to develop critical thinking in preservice preschool teachers. In *Critical Thinking in Science Education and Teacher Training*; Franco-Mariscal, A.J., Ed.; Contemporary Trends and Issues in Science Education 64; Springer Nature: Cham, Switzerland, 2024; pp. 263–283. [CrossRef]
140. Chu, H.; Liu, S. Can AI tell good stories? Narrative transportation and persuasion with ChatGPT. *J. Commun.* **2024**, *74*, 347–358. [CrossRef]
141. Dayo, F.; Memon, A.A.; Dharejo, N. Scriptwriting in the age of AI: Revolutionising storytelling with artificial intelligence. *J. Media Commun.* **2023**, *4*, 24–38.