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Narrative as inquiry: narrative co-design and immersive environments for science learning in Inner Areas

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Abstract: The relationship between narrative and scientific inquiry offers a pedagogical perspective on how students organize their experiences, construct causal explanations, and negotiate the meaning of scientific phenomena through collaborative activities. Based on this premise, the article develops a theoretical and methodological framework that integrates narrative co-design, serious games, and immersive environments to support science learning in lower secondary schools within the inland areas of the Gargano region (Apulia, Italy). Drawing on recent scientific literature, the work examines how the shared construction of narratives can engage students and teachers in formulating questions, interpreting evidence, and revising explanations, while simultaneously fostering reflection on the processes through which scientific knowledge is developed. Narrative is understood as a tool for mediating inquiry when the development of a story requires students to examine the relationships between events and justify their own interpretations. These relationships guide the design of game dynamics, where investigative decisions lead to concrete consequences, and the use of augmented reality to explore phenomena that are difficult to observe directly. The proposed methodology adopts a design-based research approach, linking contextual exploration, collaborative storytelling, prototype development, and classroom experimentation through iterative cycles of implementation and revision. A multimodal assessment strategy combines narrative artifacts, classroom interactions, and individual explanation tasks to investigate conceptual understanding, metacognitive reflection, and participation. Throughout this process, the teacher's mediation and the resources of local school communities are considered integral components of the pedagogical design. This contribution provides a foundation for studying how narrative co-design can foster scientifically meaningful and sustainable learning experiences, with educational resilience understood as the capacity to adapt such experiences to changing contextual conditions.

Keywords: Narrative co-design; Inquiry-based science education; Serious games; Immersive learning environments; Inner areas.

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1. Rational and purpose

Understanding a scientific phenomenon means relating observations to their corresponding explanations and recognizing the foundations upon which an explanation can be accepted, challenged, or revised. In an educational setting, this relationship requires mediation: students need not only access to phenomena and

representations but also the opportunity to formulate questions and discuss the meaning of their own observations. Narration serves as a potential form of mediation, as it situates events within a story that establishes an intelligible connection between actions and consequences. Recent studies on the use of narratives in science education have therefore refocused attention on the role that stories can play in fostering understanding, while simultaneously highlighting the need to define the necessary pedagogical conditions and cognitive processes involved (Soares et al., 2023; Jiménez-Valverde, 2025).

This article examines a specific configuration within this dynamic: students and teachers collaboratively construct a narrative around a scientific problem, using it as a basis for designing an interactive learning environment. The educational issue concerns what students must understand and negotiate when deciding how to represent a phenomenon, which actions to make possible, and what to consider a satisfactory explanation. Consequently, narrative construction becomes an integral part of the scientific learning process. A change in the story can make a shift in the explanation visible, while a disagreement regarding the plausibility of an event can spark a discussion about the concepts and evidence required to explain it.

Recent research on learning through game creation makes this question particularly relevant. For instance, Puttic et al. (2024) examine collaborative game construction in a middle school science classroom, documenting how scientific, computational, and design practices intersect as students work. Similarly, Judson et al. (2026) study the development of an understanding of climate change within an extended collaborative narrative game-design program for high school students.

These studies justify an examination of the educational work involved in the act of creation. Their diverse settings and metrics also highlight why the benefits of co-design must be studied in relation to the specific activities, participants, and forms of guidance through which it is implemented.

This article develops a theoretical framework and methodological architecture for investigating how students and teachers collaboratively construct, examine, and revise narrative accounts of scientific phenomena. The focus is, in particular, on the relationship between narrative production and scientific inquiry—specifically, the conditions under which the construction of a shared narrative requires learners to interpret evidence, negotiate causal explanations, and reconsider their initial hypotheses. The proposed research focuses on lower secondary schools in the inland areas of the Gargano, in northern Puglia, where the interplay between local resources and school organization influences both educational opportunities and the feasibility of interventions. These contexts are analyzed in terms of their local specificities: environmental phenomena, community knowledge, and inter-school networks can provide meaningful starting points for inquiry, while factors such as geographical distance, access to equipment, and the availability of professional support can shape how activities are organized and sustained. Consequently, contextual analysis is an integral component of the research design, guiding decisions regarding content, modes of participation, and technological resources. Sustainability is understood here as the capacity to maintain a meaningful scientific inquiry through adaptations tailored to the specific conditions of each school.

Against this backdrop, the article examines how the collaborative construction of narratives can foster scientific understanding, metacognitive reflection, and engagement. It further explores how these processes can be supported by

transforming narrative materials into a web-accessible serious game that incorporates augmented reality modules. The investigation is guided by three interconnected questions: (i) how narrative construction enables students to formulate scientific problems and develop evidence-based explanations; (ii) how such explanatory relationships can be translated into game mechanics and augmented representations that support inquiry; (iii) how narrative artifacts, classroom interactions, and individual tasks can provide complementary evidence of learning. These questions define a design-based research architecture, structured into four interconnected phases: context exploration, collaborative narrative design, prototype development, and classroom experimentation. The research is situated within a program institutionally funded by the University of Foggia[1].

2. Theoretical framework

The theoretical foundation of the proposed framework lies in an understanding of narrative as a mode of organizing experience through relationships among events, intentions and consequences. Bruner's (1991) account of narrative meaning-making provides a starting point for examining how these relationships shape the interpretation of experience. In science education, this perspective draws attention to how learners transform an encountered phenomenon into a problem requiring explanation: they construct an account of what happened, identify what remains uncertain and consider the causal relationships that might explain it. Narrative can thus mediate between everyday experience and disciplinary understanding, provided that the account remains open to questioning and revision. This mediating function depends on distinguishing narrative coherence from scientific validity. An intelligible sequence of events may make a persuasive account without establishing the adequacy of its explanation. Scientific reasoning requires that explanatory claims be supported by relevant evidence and interpreted through appropriate disciplinary concepts. Narrative as inquiry therefore involves a continuing relationship between the construction of an account and the examination of its explanatory grounds. Learners must consider both how events connect within the story and whether the proposed connections withstand scrutiny in light of available evidence. Research on narrative in science education supports a differentiated examination of these processes. Soares et al. (2023) review evidence concerning learning through scientific narrative texts and examine conditions that may explain variation in outcomes. Their analysis directs attention to the relationships among learners, textual characteristics and instructional activities, providing grounds for caution against attributing educational benefits to narrative in general. Collaborative storymaking introduces further demands that require specific investigation. Whereas readers interpret an existing account, students engaged in narrative co-design must articulate explanations, negotiate competing interpretations and make decisions about how scientific relationships will be represented. Whether these activities support learning depends on how they are organized and on the reasoning they

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require. Inquiry-based science education provides a disciplinary structure for specifying those requirements. Pedaste et al. (2015) identify orientation, conceptualisation, investigation, conclusion and discussion as the principal phases of inquiry, encompassing the formulation of questions and hypotheses, the examination of evidence and the communication of findings. These functions offer a basis for connecting narrative development with scientific investigation. An unexplained event may establish a problem; competing accounts may generate alternative hypotheses; and differences between their predictions may motivate the collection or analysis of evidence. The critical relationship is reciprocal: the developing narrative gives purpose to investigation, while the findings constrain how the narrative can proceed. Narrative becomes a mediation of inquiry when learners can justify the need for an investigation, explain what its evidence supports and revise their shared account accordingly.

The relationship between narrative construction and scientific inquiry unfolds through successive cycles of interpretation and revision. Initial narrative drafts may reveal an unfounded causal assumption, an overlooked variable, or a conclusion that extends beyond the available evidence. Such issues provide opportunities for teacher intervention and further exploration, allowing students to reconsider both the narrative they are constructing and the underlying scientific model. Comparing successive versions can foster metacognitive reflection, making shifts in reasoning visible and open to analysis. In this way, students can identify their initial hypotheses, reflect on which observations necessitated a revision, and explain how the new version overcomes previously encountered difficulties. Reflection is, therefore, grounded in documented changes to explanations and the reasons that prompted them. These processes also depend on the social organization of interpretive work. González-Howard et al. (2024) emphasize the importance of students understanding the roles and expectations associated with argumentation within STEM-based design challenges. This is crucial in collaborative narrative design, as contributing to the creation of a shared product does not necessarily entail participating in its scientific interpretation. For instance, a student might be responsible for illustrations while exerting only limited influence over the scientific explanations depicted within them. It is the teacher's role to create spaces where students can propose interpretations, request justifications, examine alternatives, and participate in collective decision-making. In this context, the concept of "epistemic agency" refers to students' capacity to influence the construction and evaluation of knowledge. It defines the quality of participation envisioned in narrative co-design, as well as the conditions required for collaborative co-authorship to become intellectually meaningful. The synthesis proposed by Walker and Nouri (2025), bridging phenomenon-based learning and scientific storylines, offers further insights into the coherence of investigative sequences, the role of teacher professional development, and the necessity of adapting to specific contexts. While a scientific storyline connects questions and explanations within a coherent path of inquiry, a fictional narrative represents events through settings, characters, and their actions. Narrative co-design can integrate these two dimensions when the events within the narrative raise questions that demand investigation, and the resulting evidence guides the development of the shared story. Teachers support this process by aligning narrative choices with curricular goals and fostering critical analysis of the explanations that emerge along the way. Transforming a narrative into a serious

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game extends this dynamic to the relationship between scientific reasoning and player actions. Explanatory connections, articulated within a written narrative, must be operationalized through game rules, available actions, and feedback mechanisms. Scientific understanding becomes relevant to the gameplay when it informs decisions and helps players interpret their consequences. In a game centered on ecosystem changes, for instance, progress might depend on selecting significant observations, analyzing relationships between variables, and evaluating alternative explanations. Such actions would link advancement within the narrative to the investigation of a scientific problem. Conversely, progress based on collecting items unrelated to that problem would offer little insight into the player's level of understanding. The design challenge, therefore, lies in making the interpretation of scientific evidence a decisive factor in the development of the game.

The distinction between learning through play and learning through game design is central to this discussion. Puttick et al. (2024) examine student game creation as an opportunity to investigate how disciplinary knowledge coordinates with the requirements of an interactive system. Based on this premise, the proposed theoretical framework makes the transition from narrative materials to game mechanics an explicit object of design and analysis. For each inquiry-based activity, the design documentation would link the scientific problem, the explanation represented within the narrative, the choices available to the player, and the feedback through which the consequences of those choices become understandable. Documenting these connections would allow teachers and researchers to assess whether the gaming experience preserves the explanatory relationships developed during the collaborative construction of a narrative. The role of motivational components requires a complementary yet distinct analysis. Zourmpakis et al. (2023) examine adaptive gamification in primary school science education, focusing on student motivation and reactions to game elements. Their findings offer insights into how challenge, progression, and feedback can support engagement, while leaving open the question of how such elements foster the formulation of scientific explanations and the transfer of knowledge. In the proposed environment, decisions that entail consequences would therefore be accompanied by opportunities for students to articulate the evidence and reasoning underlying their choices. Feedback provided following an error would help students identify and analyze the underlying difficulty, allowing them to reconsider their explanation before a solution is presented. Augmented reality (AR) expands this design scope, thanks to its representational potential. By linking physical objects or contexts to digital models, AR makes spatial relationships, dynamic processes, and phenomena, otherwise not directly observable, accessible for analysis. Vidak et al. (2024) discuss these opportunities, along with the technical and cognitive challenges they present in physics education, while Faria and Miranda (2024) synthesize research on the use of AR in the natural sciences and biology, across both primary and secondary schooling. Such reviews provide a foundation for identifying the specific interpretive needs that AR can help address, as well as for examining how its use is supported by specific tasks, teacher guidance, and classroom interaction. Ultimately, the pedagogical contribution of an augmented reality representation depends on what students are asked to observe, manipulate, and explain through it. This approach also requires attention to the epistemic status of the model. Students need opportunities to distinguish measured data from simulated values, recognize

simplifications, and examine the relationship between the represented processes and the phenomena they are intended to explain. Ainsworth's (2006) model of learning through multiple representations provides a framework for analyzing this work. Within the proposed narrative environment, students are tasked with coordinating the sequence of events, the observations made available by the game, and the models used to interpret them. The activities make these connections explicit, requiring students to justify their claims by referring to specific features of a representation and to evaluate the limitations of the conclusions that can be drawn from it. Consequently, immersion is examined in relation to the forms of interaction and interpretation enabled by a given environment. Lin et al. (2024) analyze the design of educational and scientific games in virtual reality (VR) by adopting a perspective based on embodied cognition, emphasizing the link between interaction and disciplinary activity. Within the framework adopted here, this relationship guides the selection of technological features based on the scientific work they enable users to perform. The proposed environment consists of a web-accessible serious game that integrates specific AR modules and does not require the use of virtual reality headsets. Decisions regarding technological complexity are driven by the potential contribution of the chosen solutions to the inquiry process, as well as by their accessibility and the practical conditions necessary to ensure consistent participation within a school setting.

3. Methodology

The proposed study adopts a design-based research approach to investigate the relationship between the collaborative construction of scientific narratives, their development into an interactive learning environment and the educational processes that emerge during classroom use. As articulated by the Design-Based Research Collective (2003), this approach connects theoretical propositions with the design and systematic examination of educational interventions in authentic settings. In the present study, the central proposition concerns the conditions under which narrative construction can mediate scientific inquiry. A serious game developed from collaboratively authored narrative materials provides the environment through which this proposition would be investigated. Evidence generated across subsequent design and implementation cycles would inform revisions to both the prototype and the theoretical account of how narrative supports inquiry. The research is organized into four interconnected phases: contextual exploration; co-design and narrative development; prototype design and technological integration; and classroom piloting and data collection. Each phase has defined purposes, procedures and expected outputs, while its findings may prompt reconsideration of earlier decisions. Classroom piloting might, for example, reveal that a narrative sequence resolves a scientific problem before learners have examined competing explanations, requiring revision of the story and its associated tasks. Similarly, prototype testing might identify difficulties in interpreting an augmented representation, prompting changes to the model, the available interactions or the accompanying guidance. The four phases thus provide a structure for documenting how design decisions are developed, examined and revised through collaboration among schools, teachers, students, researchers and developers.

3.1. Exploratory phase

The exploratory phase defines the educational problem and examines the contextual conditions for developing and investigating the intervention. Schools and classes would be selected according to their relevance to the lower secondary science curriculum and the feasibility of sustained participation in the design process. The research protocol would specify recruitment procedures and document the characteristics of each participating setting, providing a basis for interpreting subsequent design decisions and classroom evidence. Data collection would combine teacher interviews and focus groups, classroom observation and the elicitation of students' initial explanations of the selected scientific phenomenon. Interviews and focus groups would explore curricular priorities, teachers' experience of inquiry-based teaching and educational technologies, perceived challenges in science education and the organisational support available for collaborative design. Classroom observation would examine how learning activities are ordinarily organised, how resources are accessed and how opportunities to formulate and discuss explanations are distributed among students. Students' initial accounts would make their existing interpretations available for analysis, helping identify conceptual difficulties, questions for investigation and potential starting points for narrative development. These sources would be examined together to establish how teachers' reported priorities relate to classroom practices and learners' expressed understandings. Contextual exploration would also address the territorial and material conditions of participation. Analysis would identify locally meaningful scientific questions and resources, including environmental phenomena, community expertise and established relationships among schools. It would document access to equipment, connectivity, accessibility requirements and the time available for collaborative work. These conditions would inform the scope and organisation of the intervention from its initial design. The phase would culminate in a contextual profile and a design brief agreed with participating teachers. The brief would specify the scientific focus, students' initial interpretations, intended learning objectives and the organisational and technological conditions for participation. These outputs would guide the subsequent co-design phase and provide an explicit basis for reviewing how the developing intervention responds to the needs and resources of each school.

3.2. Co-design and narrative phase

The second phase centres on collaborative workshops in which students and teachers develop a shared narrative around the scientific phenomenon identified during contextual exploration. Participants would propose a setting, actors and events through which the phenomenon becomes a problem requiring explanation. Collective writing, drawing and discussion would make learners' interpretations explicit, allowing the group to examine the causal relationships embedded in their emerging account. Teachers would support the formulation of investigable questions and maintain connections with curricular objectives and students' prior understanding. Narrative development would proceed through the examination of alternative explanations and the evidence needed to evaluate them. Participants would consider what each explanation predicts, which observations could distinguish competing interpretations and how available evidence constrains the developing story. Successive drafts would be retained alongside annotations

documenting substantive changes and their justification. For example, recognising that an observation is compatible with more than one explanation might lead the group to reconsider a character's initial conclusion and introduce a further investigative task. Such revisions would make the relationship between evidence, interpretation and narrative development available for analysis. The narrative drafts, visual representations and emerging scientific questions would subsequently be organised into a storyboard connecting events with investigative activities. An accompanying design record would specify the opportunities for learners to formulate hypotheses, interpret observations, compare explanations and communicate provisional conclusions. It would also document the evidence required for these activities and the reasoning expected to connect them.

Metacognitive prompts would support comparison across versions, asking participants to identify what changed, why a revision was necessary and how it affected the scientific adequacy of the account. The collaborative process would be documented with attention to how students contribute to the construction and evaluation of explanations. Workshop records would identify proposals, requests for clarification, challenges to claims and instances in which a participant's reasoning influences a collective decision. Examining these interactions alongside contributions to the narrative artefact would help establish how interpretive responsibility is distributed and whether different perspectives receive substantive consideration. The phase would produce a narrative and storyboard reviewed for scientific accuracy and curricular coherence, together with a documented account of how participants' explanations developed through collaborative authorship.

3.3. Prototype design and technological integration

The third phase involves the development of a web-based serious game, grounded in the collaboratively created storyboard. Researchers, teachers, and developers work together to translate narrative events and investigative tasks into game mechanics, interactive representations, and feedback systems. This process is guided by an explicit mapping of learning objectives, narrative content, and player actions, allowing the team to verify that the implemented activities preserve the scientific reasoning envisioned during the co-design phase. A task focused on data interpretation, for instance, would require students to examine observations, assess their relevance, and justify a decision. Early prototypes make these interactions available for review before significant resources are invested in visual production. AR modules are introduced when they address a specific representational need: the decision to depict a molecular process, a spatial relationship, or a system change via AR stems from an assessment of what students need to observe, manipulate, or explain. Researchers and teachers evaluate the scientific accuracy of each model, as well as the opportunities it provides for distinguishing between observations, simulated processes, and explanatory inferences. Technical specifications define how information is labeled, which properties can be manipulated, and how feedback encourages further inquiry when an interpretation is incomplete. The complexity of the tasks and the pedagogical support are structured progressively, accounting for potential conceptual difficulties, and are refined through formative reviews. This support may vary based on the sequence of observations, the specificity of the stimuli, and the guidance provided for comparing different explanations. Decisions regarding these elements remain explicit within the project, allowing for an analysis

of their pedagogical objectives. Accessibility and the continuity of participation also guide the development process, incorporating solutions for the shared use of devices, the management of variable connectivity, and alternative modes of interaction. In cases where an augmented reality representation cannot be used, an alternative is designed that preserves opportunities for scientific reasoning.

Differences in spatial manipulation, interaction, and access to information are documented so that their implications can be considered during classroom implementation and subsequent analysis. This phase leads to the creation of an initial prototype, a teacher's guide, and a design document that links scientific goals to narrative events, game mechanics, and representational choices. A formative review, conducted with teachers and students, allows for the assessment of usability, the clarity of instructions and feedback, and the interpretability of the scientific representations. The findings inform revisions prior to classroom testing and determine whether the prototype is ready for investigation; however, any claims regarding its contribution to learning would require evidence derived from the subsequent research phase.

3.3. Pilot phase and data collection instruments

The fourth phase involves testing the serious game in the classroom. This pilot project will analyze the tool's usability, the clarity of its narrative tasks and scientific representations, and its integration into regular teaching activities. Particular attention will be paid to how students interact with the game, interpret instructions and feedback, and engage with the augmented reality modules. Classroom observations, student reactions to the proposed activities, and feedback from both teachers and students will help identify any technical difficulties, unclear content, or areas requiring additional support. Furthermore, teachers will assess the suitability of the activities in relation to curricular objectives, available lesson time, and classroom resources. The results obtained will guide the revision of the prototype and the accompanying teacher's guide, providing an initial assessment of the game's feasibility and laying the groundwork for further investigation into its educational contribution.

Table 1. Research phases and expected products

Research phase	Principal procedures	Expected product and evidence
1 Contextual exploration	Teacher interviews, focus groups, classroom observation and students' initial explanations.	Contextual profile and agreed design brief specifying the phenomenon, educational aims and conditions of participation.
2 Narrative co-design	Collaborative writing, drawing, discussion of causal accounts and comparison	Scientifically reviewed narrative, storyboard and documented questions, inter-

	of narrative versions.	pretations and revisions.
3 Prototype development	Translation into rules and feedback; selection of AR representations; formative review.	Web-accessible prototype, teacher guide and mapping between objectives, narrative events and game functions.
4 Classroom pilot	Observed enactment, multimodal data collection, individual explanation and transfer tasks.	Evidence about feasibility and learning processes, revision record and revised prototype.

4. Expected results

The research aims to contribute to the understanding of how collaborative narrative construction can support scientific inquiry in lower secondary school. Its theoretical contribution concerns the conditions under which the creation of stories encourages students to formulate questions, examine causal relationships, and revise explanations in light of evidence. In this perspective, narrative coherence acquires educational value when it supports the scientific justification of the unfolding narrative. The primary methodological outcome will be a documented co-design process that links context exploration, collaborative storytelling, technological development, and classroom experimentation. Expected outputs include a narrative revised for scientific accuracy, a web-accessible serious game integrating specific augmented reality modules, and a guide for teachers. Documenting design choices and subsequent revisions will allow for an examination of the relationships between learning objectives, narrative events, game mechanics, and representations. In line with the conjecture mapping approach proposed by Sandoval (2014), this documentation will make explicit how specific design features are intended to foster scientific reasoning. From an educational standpoint, collaborative storytelling offers students the opportunity to articulate their own interpretations, discuss alternative explanations, and reflect on the evolution of their understanding. The involvement of teachers aims to facilitate the integration of scientific objectives, narrative activities, and technological resources into coherent instructional sequences. As suggested by Strat et al. (2024), preparing for inquiry-based teaching requires explicit attention to the professional knowledge and the decisions that such an approach entails. The project partnership will provide teachers with a setting to examine these connections through the development and review of concrete materials. Classroom testing will offer an initial assessment of the game's usability, clarity, and suitability for standard educational conditions. Observations and feedback from teachers and students will guide the refinement of the prototype, its augmented reality modules, and the accompanying teacher's guide. This phase will define the practical conditions for implementation and identify questions for further inquiry into learning. Another expected contribution concerns the adaptation of the project for schools located in the inland areas of the Gargano region. Local environmental issues, community knowledge, and school networks will inform the design, while

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also accounting for constraints related to equipment, connectivity, and organizational resources. In line with Walker and Nouri's (2025) focus on contextual adaptation, the materials and guidelines produced will help schools support meaningful activities, even under varying conditions of use. Here, educational resilience is understood as the capacity to adapt the educational offering while preserving its scientific and pedagogical objectives.

5. Conclusions

This article has developed a conceptual and methodological framework connecting narrative co-design, scientific inquiry, serious games and augmented reality in lower secondary schools in Italian inner areas. Its central proposition is that collaborative narrative construction can mediate inquiry when the development of a shared account depends on interpreting evidence and reconsidering explanations. The educational significance of narrative therefore rests on the scientific work required to construct and revise it. The four-phase research architecture translates this proposition into a proposed process of contextual exploration, collaborative narrative development, prototype design and classroom testing. Continuity across these phases is essential: the scientific questions emerging during storymaking must remain consequential within gameplay, and technological representations must support learners' interpretation of the phenomena under investigation. Teacher mediation and attention to local conditions provide the basis for maintaining these connections. The framework remains open to empirical examination. Classroom piloting will assess the feasibility and clarity of the proposed environment and guide its refinement; establishing its contribution to conceptual understanding, reflection and participation will require further investigation. The article's contribution lies in specifying the theoretical relationships and design decisions through which narrative as inquiry can be developed and studied in context.

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