

Learning with Stories: Characteristics and Learning Outcomes in Narrative-Centered Science Learning Environments

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Abstract: In K-12 science education research and design, narratives are commonly employed to contextualize content and foster engagement. This literature review analyzes 104 empirical studies, identifying three primary narrative types: authentic, realistic fiction, and science fiction/fantasy. Students are often positioned as problem investigators or professionals in story plots. The narrative types are correlated with nine science learning outcomes, revealing their use and student positioning in K-12 science learning environments. Future research will focus on evaluating the effectiveness of narratives in enhancing science learning and exploring supporting technologies and mediation.

Introduction and background

Sociocultural theories emphasize the importance of embedding learning in meaningful tasks (CTGV, 1997). By creating narrative flow and mimicking complex scenarios, using stories in learning environments can contextualize learning objectives and promote learners' immersion and involvement (Barab, 2007; Hmelo-Silver, 2004). Given the role of storytelling in art, communication, social life, and sensemaking across cultures, it is an appealing tool for educators and designers to use in creating engaging and effective science learning environments (Mawasi, 2020). However, many types of narratives exist, ranging from simple one-time animating scenarios to expansive immersive learning environments. Further, narratives can be embedded in different instructional models such as problem-based, project-based, or game-based learning environments (Hmelo-Silver, 2004). To explore what kinds of stories researchers have designed and their effectiveness, we initiated a systematic scoping literature review on the role of narrative in science education. Based on this review, the present paper focuses on the kinds of stories researchers design and how different story types affect science learning. The present paper aims to answer the following research questions:

- What types of stories has the field used in K-12 science learning environments?
- How are learners positioned within these stories?
- How are different types of learning outcomes related to types of narratives?

In this paper, we use “narrative” and “story” interchangeably. Both fiction and non-fiction narratives are pervasive in human life and integral to cognition (Dickey, 2011). They represent information in terms of sequences of related events, often with cause-and-effect relationships (Prince, 2003). Humans have used stories to construct, communicate, and learn (Mott et al., 1999). Therefore, when narratives are embedded in learning, they leverage learners' inherent cognitive competencies to situate them into the context formed by the narrative (Wells, 1986). However, given the wide use of stories and narratives in science education, it is not clear if there are important differences in what kinds of stories are told, how students are positioned in those stories in K-12 science education, and whether different kinds of stories promote different learning outcomes. In this paper, we build on Mawasi et al.'s (2020) literature review to examine narrative in both digital and non-digital environments from a learning sciences perspective.

Method

To conduct this literature review, our team followed practices outlined by Alexander (2020). We iterated on search terms and selected databases. We ultimately used the search terms:

- (“narrative-centered” OR “story-centered” OR “scenario-centered” OR “problem-centered” OR “narrative-based” OR “story-based” OR “scenario-based” OR “problem-based”) AND (STEM OR science OR engineering) AND (learn OR learning OR education) AND (classroom OR school OR class) AND (method OR study OR studies OR methods OR methodology)

We searched four databases using specified terms: Web of Science, ERIC, selected ACM conferences, and the ISLS proceedings repository. Ultimately, we prioritized studies that met each of four inclusion criteria,

namely that the articles had to include: (1) narrative-related instruction, including scenarios, stories, and problems, with the specific narrative explained in the article; (2) empirical data about student performance in the environments; (3) studies based in a science discipline; and (4) K-12 school contexts. An initial search yielded 4,273 hits, and after two review rounds, 109 articles remained as valid studies. Excluding five articles with narratives only for assessment, 104 articles were analyzed.

Employing an inductive approach akin to thematic analysis (Braun & Clarke, 2006), we examined scenarios in each article, assigning initial codes to narrative features and developing groupings. Themes were identified and described preliminarily. Our systematic review aimed to characterize existing narrative types in studies, focusing on how stories support learners considering their age, curricular standards, and learning outcomes. To assess the effects of narrative learning environments, we examined each dependent variable for positive, negative, or neutral (i.e., no effect). Utilizing a vote count approach, we included qualitative and quantitative studies, deeming an effect positive if statistically significant or qualitatively improved.

Findings

Types of Narrative

Inductive coding identified three narrative types concerning reality: (1) authentic scenarios, (2) realistic fiction scenarios, and (3) science fiction and fantasy scenarios. *Authentic narratives*, found in 31 of 104 studies, involve real-world events, people, or phenomena, making science learning personally relevant and plausible. In some studies, natural phenomena were described, such as the mechanisms for how vaccinations work (Yang et al., 2021). Other studies focused on narratives that requested students to investigate social issues (Sterling, 2007) or environmental issues (Evrin & Dadli, 2020). In another example, Drymiotou et al. (2021) used STEM-related career-based scenarios to situate students within personally relevant contexts.

Realistic fiction, following realistic logic, the objects in the stories exist in the real world, and the characters behave as real people would (Chavez, 2022). As the most frequent narrative type in 55 of 104 articles, realistic fictions mimic real-world situations, allowing researchers to incorporate scientific concepts into the narrative more easily. Fifteen of the 55 studies positioned the realistic fiction narratives as requests from stakeholders (Cerezo, 2004). Still others positioned their realistic stories as mysteries to be solved. For example, Sabourin et al. (2013) put students in a game-based learning environment called Crystal Island to investigate a mysterious disease. Often used in problem-based learning environments, these narratives can be presented as requests from stakeholders or mysteries requiring investigation.

The remaining 18 studies employed non-realistic stories, including *science fiction* and *fantasy*. Science fictions are tales of potential future science and fantasy with supernatural elements (California Department of Education, 2021). Examples include Alien Rescue, a technology-enhanced STEM astronomy curriculum that employs PBL (Liu et al., 2002). Some other studies utilize widely known fantasy stories, including *Harry Potter* (Beaton, 2004), *Cinderella* (Talaue et al., 2015), and *Frankenstein* (Mawasi et al., 2022). These narratives offer complex systems for exploring science concepts without real-world constraints.

Student Roles

We examined whether the 104 reviewed studies positioned learners as characters in the narratives. In 39 studies, students had *no role*, learning from a third-person perspective, while 65 studies involved students as active participants, adopting *professional roles* or acting as *problem investigators*.

In 39 studies, narratives served as instructional materials providing context and problem triggers without assigning student roles. This could be because the stories are based on or imitate real-world events that have already occurred; students could not change what happened (Batlolona et al., 2019). Some studies provided multiple scenarios around disciplinary ideas. For example, Evrin and Dadli (2020) arranged five independent scenarios about the ecosystem and related concepts. These stories were authentic or realistic fiction, allowing students to investigate and analyze situations from a third-person perspective.

In 29 studies, students assumed *professional roles*, designing projects for stakeholders. Such curricula often involved writing, drawing, or hands-on exercises. For example, in a study conducted by Lee and Bae (2008), students were requested by the city board to propose and present solutions to two problems involving the construction of a high school and vocational issues in Hawaii. Adopting professional roles provides simulated experience, allowing students to apply knowledge and develop skills like communication and collaboration.

Lastly, 36 studies positioned students as *problem investigators* of a mystery (e.g., Sabourin et al., 2013), phenomenon (e.g., Cheng et al., 2017), or object (e.g., Sterling, 2007). For example, students investigated car accidents using Newtonian Kinematics and Friction (Kapur & Kinzer, 2007). The position of problem investigator

may enable students to experience narrative transportation by drawing them into the story as agentic participants in the narrative flow.

Types of Learning Outcomes

Our final research question addressed science learning outcomes associated with narrative use. We identified nine themes characterizing the outcomes: (1) content learning; (2) inquiry skills; (3) other cognitive, higher-order thinking, and ethics skills; (4) collaboration and interaction; (5) argumentation; (6) motivation, engagement, and participation; (7) self-efficacy and confidence; (8) interests and attitude; and (9) self-regulation. Using a "vote count" approach, we examined learning outcomes in both quantitative and qualitative studies. For each type of narrative, we identified the types of outcomes measured and then the number of positive effects. We analyzed the relationship between learning outcomes and narrative types, noting that multiple outcomes were examined in many studies, totaling more than the 104 studies reviewed.

Various assessment tools were employed to measure learning outcomes including qualitative, quantitative, and mixed-method approaches. *Content learning*, *inquiry skills*, *cognitive*, *higher-order thinking*, and *ethics* were primarily assessed through formative and summative assessments, while *collaboration*, *interaction*, and *argumentation skills* were often measured using surveys and questionnaires. *Motivation*, *engagement*, *participation*, *self-efficacy*, *confidence*, *interests*, *attitude*, and *self-regulation* were typically reported through questionnaires and interviews. Realistic fiction was the most studied narrative type for promoting disciplinary learning, such as content knowledge. For instance, Georgiou and Kyza (2021) used a mystery to foster collaborative problem-solving and achieve high conceptual learning gains. Realistic fiction was also used to facilitate learning and to support practice of inquiry collaboration, and self-regulation and thinking skills. Content knowledge was the most frequently measured outcome across all narrative categories, with inquiry skills also frequently assessed in realistic fiction studies.

Vote count results show predominantly positive outcomes, particularly for content learning (93%). Inquiry skills and argumentation also demonstrated uniformly positive results. Measures of inquiry skills include problem solving, scientific inquiry, investigation, and data collection. Other cognitive and higher-order thinking skills, which include reflective thinking, critical thinking, and creative thinking, had lower proportions of positive effects, but there were also a relatively small number of studies in which those were measured. These were lowest in authentic scenarios and highest in realistic fiction. A small number of studies measured collaboration, and these were generally positive across narrative types. Argumentation was only measured in realistic fiction with all positive results. Affective and strategic measures were generally positive, with the exception of interest in science fiction and fantasy narratives, where only 3 out of 6 studies showed positive effects.

Discussion and Implications

This study examined narrative types, student roles, and the relationship between narratives and learning outcomes in K-12 science learning contexts. Using a systematic approach, we analyzed 104 articles from four databases and categorized narratives as authentic, realistic fiction, or science fiction/fantasy. We also discussed student roles (problem investigator and professional) and potential learning outcomes. This review aids in understanding narratives used in K-12 science classrooms and their associated learning outcomes.

The systematic literature review highlights the importance of effectively utilizing narratives in K-12 science classrooms to facilitate learning and skill development. Educators should consider context, resources, information, and student roles in narrative-centered learning environments, while also focusing on potential learning outcomes. Learning designers should engage in in-depth research or co-design with target students, teachers, and communities to develop relevant content and storylines. Further research is needed to understand the effectiveness of different narrative types, problem types, tasks, and pedagogical approaches in narrative-centered learning environments.

References

- Alexander, P. A. (2020). Methodological guidance paper: The art and science of quality systematic reviews. *Review of Educational Research*, 90, 6-23.
- Barab, S. A., Sadler, T. D., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: Supporting consequential play. *Journal of Science Education and Technology*, 16, 59–82.
- Beaton, M. J. (2004). Harry Potter as a Context for Problem Based-Learning. *Science scope*, 27(4), 15-17.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.

- California Department of Education. (2021, May 4). Literary genres. *Literary Genres Recommended Literature List*. (CA Dept of Education). Retrieved July 23, 2022, from <https://www.cde.ca.gov/ci/cr/rl/litrlgenres.asp>.
- Cerezo, N. (2004). Problem-based learning in the middle school: A research case study of the perceptions of at-risk females. *RMLE Online*, 27(1), 1-13.
- Chavez, L. (2022, January 3). Realistic fiction. *LibGuides*. Retrieved July 23, 2022, from <https://libguides.merrimack.edu/RealisticFiction>
- Cheng, M. T., Lin, Y. W., She, H. C., & Kuo, P. C. (2017). Is immersion of any value? Whether, and to what extent, game immersion experience during serious gaming affects science learning. *British Journal of Educational Technology*, 48(2), 246-263.
- Cognition and Technology Group at Vanderbilt. (1997). *The Jasper project: Lessons in curriculum, instruction, assessment, and professional development*. Erlbaum.
- Dickey, M. D. (2011). Murder on Grimm Isle: The impact of game narrative design in an educational game based learning environment. *British journal of educational technology*, 42(3), 456-469.
- Drymiotou, I., Constantinou, C. P., & Avraamidou, L. (2021). Enhancing students' interest in science and understandings of STEM careers: the role of career-based scenarios. *International Journal of Science Education*, 43(5), 717-736.
- Evrin, U. R. A. L., & DADLI, G. (2020). The effect of problem-based learning on 7th-grade students' environmental knowledge, attitudes, and reflective thinking skills in environmental education. *Journal of Education in Science Environment and Health*, 6(3), 177-192.
- Georgiou, Y., & Kyza, E. A. (2021). Bridging narrative and locality in mobile-based augmented reality educational activities: Effects of semantic coupling on students' immersion and learning gains. *International Journal of Human-Computer Studies*, 145, 102546.
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational psychology review*, 16(3), 235-266.
- Lee, H., & Bae, S. (2008). Issues in implementing a structured problem-based learning strategy in a volcano unit: A case study. *International Journal of Science and Mathematics Education*, 6(4), 655-676.
- Liu, M., Williams, D., & Pedersen, S. (2002). Alien Rescue: A problem-based hypermedia learning environment for middle school science. *Journal of educational technology systems*, 30(3), 255-270.
- Mawasi, A., Nagy, P., Finn, E., & Wylie, R. (2022). Using Frankenstein-themed science activities for science ethics education: An exploratory study. *Journal of Moral Education*, 51(3), 353-369.
- Mawasi, A., Nagy, P., & Wylie, R. (2020). Systematic Literature Review on Narrative-Based Learning in Educational Technology Learning Environments (2007-2017). In Gresalfi, M. and Horn, I. S. (Eds.), *The Interdisciplinarity of the Learning Sciences*, 14th International Conference of the Learning Sciences (ICLS) 2020, Volume 3 (pp. 1213-1220). Nashville, Tennessee: *International Society of the Learning Sciences*.
- Mott, B. W., Callaway, C. B., Zettlemoyer, L. S., Lee, S. Y., & Lester, J. C. (1999, November). Towards narrative-centered learning environments. In *Proceedings of the 1999 AAAI fall symposium on narrative intelligence* (pp. 78-82).
- Sterling, D. R. (2007) Methods and Strategies: Modeling Problem-Based Instruction. *Science and Children*, 45(4), 50-53
- Talaue, F. T., Kim, M., & Aik-Ling, T. (2015). Finding Common Ground During Collaborative Problem Solving: Pupils' Engagement in Scenario-Based Inquiry. In *Authentic Problem Solving and Learning in the 21st Century* (pp. 133-151). Springer, Singapore.
- Wells, C. (1986) *The meaning makers: Children learning language and using language to learn*. Heinemann, Portsmouth, NH.
- Yang, X., Zhang, M., Kong, L., Wang, Q., & Hong, J. C. (2021). The effects of scientific self-efficacy and cognitive anxiety on science engagement with the "question-observation-doing-explanation" model during school disruption in COVID-19 pandemic. *Journal of Science Education and Technology*, 30(3), 380-393.

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