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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 et al., 2007). 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, with 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 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. We build on Mawasi et al's (2020) 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 (Evrim & 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. 65 studies involved students as active participants, adopting *professional roles* or acting as *problem investigators*, while in 39 studies, students had *no role*, learning 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 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. In 36 studies, students were positioned 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 experience narrative transportation by drawing students into the story as agentic participants in the narrative flow.

Finally, in 39 studies, narratives served as instructional materials providing context and problem triggers *without* assigning student roles. This could be because the stories were based on or imitate real-world events that had already occurred; students could not change what happened (Batlolona et al., 2019). Some studies provided multiple scenarios around disciplinary ideas. For example, Evrim 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.

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*; and *other cognitive*, *higher-order thinking*, *and ethics skills* were primarily assessed through formative and summative assessments, while *collaboration and interaction*, and *argumentation* skills were often measured using surveys and questionnaires. *Motivation*, *engagement*, *and participation*; *self-efficacy and confidence; interests and 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 review aids in building our understanding of how narratives have been used in K-12 science classroom research and their associated learning outcomes. Our findings suggest that many types of narratives have been effective, but that it is productive to consider the desired learning goals as well as how disciplinary knowledge can be embedded in narrative-centered inquiry before making decisions about narrative type and student positioning. For educators, this often may require making choices about what narratives and positions will be most engaging to students in ways that increase participation as compared to a non-narrative-centered discussion of the topic. Learning designers should engage in in-depth research or co-design with target students, teachers, and communities to develop relevant content and storylines with a deep attention to the relevant science ideas and how they can best be situated in a learning progression as well as a narrative. Further research is needed to understand the what alignments between different narrative types, problem types, tasks, and pedagogical approaches result in which kinds of learning gains in narrative-centered learning environments.

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