

Systematic Literature Review on Narrative-Based Learning in Educational Technology Learning Environments (2007-2017)

Areej Mawasi, Arizona State University, amwass@asu.edu

Peter Nagy, Arizona State University, pnagy1@asu.edu

Ruth Wylie, Arizona State University, ruth.wylie@asu.edu

Abstract: Research on learning with digital media and educational technology has been central in the Learning Sciences over the past decade. To support learning with these tools, multiple instructional approaches and pedagogies have been implemented, including storytelling and adding narrative elements. The purpose of this paper is to present results of a systematic literature review on the integration of narrative elements in educational technology systems over the past decade, between 2007-2017. We seek to identify and synthesize prior work at the intersection of narrative-based learning and educational technologies. Our findings focus on four categories: theoretical approaches, context, learning goals, and intervention type. We conclude by discussing the potential benefits of narrative-based learning in designing learning environments mediated by educational technology and digital media.

Introduction

Adding storytelling elements to learning environments is not new in educational research. Many education scholars have examined the use of story elements and narrative as instructional and pedagogical approaches (e.g., Barab et al., 2007; Easterday, Aleven, Scheines, & Carver, 2017; Pinkard, Erete, Martin, & McKinney de Royston, 2017; Lester, et al., 2014). Research suggests that adding story elements has the potential to increase knowledge transfer, knowledge recall, and understanding of abstract concepts, as well as provide situated learning experiences (e.g., Bruner, 2003; Graesser et al., 1994; Koedinger & Nathan, 2009; Jonassen, 2003; Mayer, 1982).

In the past decade, researchers have incorporated storytelling elements in the design of learning environments mediated by educational technology and digital media as a way to improve learning outcomes and support metacognitive processes (e.g., Barab et al., 2007; Easterday et al., 2017; Lester et al., 2014). For example, narrative-based instruction has been embedded in learning environments that combine game-based learning, problem solving in science and interactive engagement with systems and peers (e.g., Rowe & Lester, 2015). In these works, the integration of narrative-based instruction takes different forms: game-based intelligent tutoring systems (e.g., Easterday et al., 2017), narrative-centered learning systems (e.g., Rowe & Lester, 2015), transformative play experiences (e.g., Barab et al., 2007), multi-user virtual environments (e.g., Neville, 2015), and transmedia storytelling experiences (e.g., Gilliam et al., 2017). We consider these educational technology environments as *narrative-based learning environments* and define a *narrative-based learning environment* as an environment that integrates storytelling elements into an educational technology or digital media learning environment. Narrative (fictional or non-fictional, linear or nonlinear) plays a major role in creating engaging experiences because it involves learners with solving story-based problems (Salen & Zimmerman, 2004). Such experiences empower learners to act, play, take roles, make decisions, solve problems, challenge themselves, and complete activities within the narrative (Barab et al., 2010 a; Barab et al., 2010 b; Gee, 2017; Mott et al., 1999). Furthermore, when learners engage with such activities, they are able to imagine multiple scenarios, and therefore, to think about possible futures and prepare for future actions (Gee, 2017).

In this paper, we present findings from a systematic literature review of work that uses narrative-based learning in the design of digital learning environments. In other words, we focus on narrative as an instructional strategy in the design of educational technologies. With the increasing ubiquity of educational technology and digital media for learning, it is important to identify which elements in the design of such environments can support learning processes. Therefore, this systematic literature review is valuable because researchers and educators need to identify how elements such as *narrative* in educational technologies can contribute to learning. The systematic literature review methodology is based on literature review strategies described by Booth et al. (2016).

This review aims to address the following questions: What does scholarship in the Learning Sciences and related scholarship say about incorporating narrative-based instructional strategies in educational technologies (e.g., educational games, tutoring systems, multimedia)? Which theoretical frameworks drive the scholarly research around narrative-based learning? How does the literature address the learning objectives and outcomes of narrative-based educational technologies? By addressing these questions, the goal is to identify the potential benefits of narrative-based learning in creating engaging learning environments.

First we describe the search methods and selection of articles. Second, we describe the data analysis process, including the synthesis for the articles and emergent themes. Third, we report results and discuss our analysis, where we identified similarities and differences between articles, as well as strengths and weaknesses to identify gaps and opportunities in the field of narrative-based learning. Fourth, we provide insights for future steps for using narrative elements in the design of learning environments.

Methods

Search and selection

In the first phase of the systematic literature review, we focused on identifying terms related to narrative-centered learning in educational technology and digital media. We followed suggestions from Booth et al. (2016) and identified terms by exploring relevant articles. We reviewed conference papers to identify commonly used keywords in conferences related to educational technology. We did an initial search in the following databases: ACM Digital Library, the Artificial Intelligence in Education Conference website, ICLS, and the International Conference on Intelligent Tutoring Systems website. To identify keywords connected to narrative-based learning, we started with terms such as: educational games, digital games, narrative-based learning, game-based learning, and serious games. This step yielded a selection of 280 articles. To narrow the corpus, we followed Booth's (2012) strategy: guided by our research questions, we chose to focus on the following terms: narrative, narrative-centered learning, narrative-based learning, game-based learning, and educational games. Next, using these keywords, we identified peer-reviewed articles in the following databases: ERIC, Web of Knowledge, and ProQuest. We chose three databases instead of one, because when we started the research process using "narrative-based learning" and "narrative-centered learning" on ERIC, a commonly used database for education research, the results were either too narrow or irrelevant. Therefore, we expanded the search to include peer-reviewed articles from Web of Knowledge and ProQuest. These two databases (i.e., Web of Knowledge and ProQuest) include references from a wide range of fields in social sciences, including education. Since we had overlapping literature across the databases, we tried additional search strategies on the two databases.

These are the thesaurus searching and search filtering (Booth et al., 2016) results from each database we searched:

- **ERIC** – Searching on ERIC included two steps. First, we did two basic searches using the terms *narrative-centered learning* and *narrative-based learning* for peer-reviewed articles published between 2007 and 2017. This resulted in 28 articles for narrative-centered learning and 116 articles for narrative-based learning. We then searched each article of the 28 and 116 for an exact match for each of the two phrases, which resulted in 6 articles for narrative-centered learning and 6 articles for narrative-based learning. We read the title and abstract for each paper and included articles that discussed learning environments that incorporated a narrative element. In addition, we removed any duplicate articles. After this process, we were left with 34 articles for further review. In addition, this process enabled us to identify major scholars in the field who are conducting work on narrative-based learning (e.g., Barab, Lester, Mayer).
- **Web of Knowledge** – On this database, we combined the following terms and searched: narrative AND game-based learning AND learning. This resulted in 43 peer-reviewed articles. After reading the titles and abstracts, we selected 18 articles to include in the corpus, following the criteria mentioned above.
- **ProQuest** – On ProQuest, we conducted two searches. We searched similar terms, but also filtered the journals to education-related journals. For example, when we searched the terms: -narrative AND game OR educational game AND narrative OR narrative-centered learning AND educational games OR narrative-based learning AND game-, the initial results yielded 983 articles. To reduce the number of articles, we filtered the journals, then selected education-related journals from different disciplines. The filtering process yielded 43 articles, and we selected 6. In the second round, we tried a broader scope of terms, and the result was 1700 articles, after we chose different conditions AND/OR to filter and narrow down the keywords. Additionally, we filtered the scope of journals, and the results were 52 articles; from that set, we selected only 5 that were relevant to the review goals.

In the second phase, to further narrow the number of articles we applied inclusion and exclusion criteria to the corpus. Initially, the number of articles from all the databases was 57, with 9 articles overlapping. To finalize the corpus, we reviewed the title, abstract, and conclusion of each paper to see if the authors mentioned narrative as an element that supported the learning process. Because the goal of this review is focused on learning environments mediated by educational technology and digital media, we omitted papers that did not have implications for educational technology systems design. We also omitted papers that focused only on the technical

aspects of educational technology, such as system programming and development. And finally, we omitted papers that used the same narrative-based experience (e.g., 7 articles discussed *Crystal Island*, a game-based learning environment designed to teach STEM) and instead chose one book chapter that discussed the narrative-based learning aspects of *Crystal Island* (Lester et al., 2013), and one article that discussed the design of *Crystal Island* (Lester et al., 2014). This left us with 23 total papers.

The third phase of the systematic literature review focused on finalizing the selection of the studies. We conducted a hand-search for articles in major journals and did a bibliography search by reviewing the references of the selected papers using the keywords we used earlier (Booth et al., 2016). We also hand-searched the following journals: *The International Journal of Artificial Intelligence in Education* (IJAIED), *The International Journal of the Learning Sciences* (IJLS), and *Educational Psychologist*. We did not select any additional articles from IJAIED or *Educational Psychologist*. We selected one additional article from IJLS: Easterday et al., 2017. Finally, we included one article from *Educational Researcher*: an article on narrative and transformative play in the *Quest Atlantis* game (Barab et al. 2010b), as it represents an interactive media strategy that involves narrative in learning experiences and is related to prior work that Barab and colleagues have conducted on the game. At the end of these three phases, our corpus consisted of 16 articles and one book chapter.

Methods of synthesis and analysis

According to Booth et al. (2012), the synthesis process helps in identifying patterns of homogeneity and heterogeneity among the findings to identify variations and shared characteristics in the selected scholarly literature. To synthesize the selected literature, we first read the introduction and conclusion of each article. This helped us identify initial elements to focus on when reading the whole piece (e.g., context, intervention type, participants, outcomes). We created a spreadsheet with the following categories: title, year, abstract, keywords, research questions, theoretical framework, learning environment, quotes, conclusions, implications, and notes. Guided by our research questions, we read each article and added it to the spreadsheet. We then used this data to identify additional patterns of similarities and differences between the articles.

We conducted a thematic analysis to identify characteristics for heterogeneity and homogeneity and to evaluate the quality of the study (Booth et al., 2012). We identified major themes based on theoretical framework, context (settings, educational level, participants, discipline), learning environment, goals, and intervention type. We identified similarities and differences related to the theoretical framework and context.

Results

In this section, we present the results of the systematic literature review based on the following themes: theoretical approaches, learning goals, context, and intervention. The articles selected in this literature review have all been published in the past decade (2007-2017). The selected articles were drawn from peer-reviewed journals that connect with the Learning Sciences, such as: *The International Journal of the Learning Sciences*, *Science Education*, *Educational Researcher*, and *Journal of Educational Psychology*.

Theoretical approaches

The selected articles referenced multiple theories, including motivational theories (e.g., self-regulation, efficacy, interest), situated cognition theories, activity theory, interactional theories, and transformative play.

Articles focused on motivational-related theories assert that the integration of narrative in educational technologies and digital media has the potential to increase learners' motivation and interest in the subject matter (e.g., Lester et al., 2013). Contrary to this view, Adams et al., (2012), claim that we should differentiate between motivation that results from incorporating narrative and motivation that results from gamification elements in game-based learning environments. Through an analysis of online games, Dickey (2007) asserts that narrative environments increase learners' intrinsic motivation. For example, Easterday et al. (2017) employed narrative in the design of a tutoring system for policy argumentation, as an instructional tool to increase students' interest and intrinsic motivation. Purdue et al. (2017) used narrative-based learning to increase self-efficacy towards writing among adolescent male students. Furthermore, Lester et al.'s (2013) narrative-based learning intervention in science education supported students' self-regulation.

Despite the promising potential of narrative-based learning, Adams et al. (2012) argue that the integration of narrative as an instructional strategy increases learners' cognitive load and distracts them. To illustrate this point, the scholars compared two groups of learners, one that had narrative integrated in their instructional materials and one that did not. While work that supports narrative integration hypothesizes that the narrative group would have better learning outcomes, work based on cognitive load theory hypothesizes that narrative distracts and increases extraneous cognitive load. Thus, the non-narrative group would have better learning outcomes. The results of the Adams et al. study indicate that students in the narrative group performed worse than those in the

non-narrative group, suggesting that students do not necessarily learn better when engaged in narrative-based scenarios. While the authors provide empirical evidence for their hypothesis, other narrative-based learning work conducted using other types of interventions indicated that narrative-based learning can have benefits for learning processes and outcomes with respect to self-efficacy and identity (e.g., Pinkard et al., 2017).

In addition to motivation theories, literature in this area builds upon situated cognition theories to assert that narrative-based learning enables students to experience meaningful learning and increases interest in the subject matter (e.g., Pinkard et al., 2017). Thus, narrative helps learners to create schemas and apply what they learned to their daily life (Barab et al., 2007, 2010; Easterday et al., 2017; Gilliam et al., 2016, 2017; Lester et al., 2013, 2014; Pinkard et al., 2017; Pruden, Kerkhoff, Spires, & Lester, 2017; Neville, 2013, 2015). Situated cognition theories assert that contextual affordances help learners to connect declarative and procedural knowledge by engaging in social and situated activities (Driscoll, 2005; Brown et al., 1989; Greeno, 1989). The papers that were guided by situated cognition theory emphasize learning as a practice that extends beyond school, is involved in learners' daily life activities, and is mediated through different cultural mechanisms, symbols, and strategies. This work is important because rather than accounting for individual characteristics of learners, it considers the sociocultural dimensions of learning processes and contexts in which learning occurs. Additionally, provide examples of benefits of narrative in engaging learners with meaningful participation. For example, Pinkard et al. (2017) designed an out-of-school learning environment for non-dominant girls who are not regular participants in STEM activities to increase their interest and participation in STEM. In this environment, girls receive support from experienced mentors. They engage in computational practices and position themselves as creators, learn new concepts, and co-design products. Moreover, girls became involved in project-based learning activities where they interact with their mentors and other peers. Another example of a learning environment that was based on this approach is a game for teaching the German language, where the theme of the game is around recycling in Germany, as a way to connect learners with activities situated in everyday German culture (Neville, 2015). Finally, based on situated cognition theories and activity theory, Barab et al. (2007; 2010b) suggested a Transformative Play framework that combines person, content, and context, where learners (players) are positioned as protagonists who solve real-world problems and engage in meaningful decision-making processes.

Learning environment goals

The interventions had a variety of learning goals; some focused on learning processes and others on learning outcomes. These goals center around the following pedagogical approaches: engaging learners with cognitive processes (e.g., cognitive engagement, conceptual change, reasoning), engaging learners in fictional experiences, inquiry-based learning in science domains, increasing students' motivation (e.g., self-regulation and self-efficacy), developing problem solving skills around socio-scientific issues, and engaging learners in situated learning activities.

Cognitive processes

The articles that focused on cognitive processes as a learning goal were mostly based on instructional principles that foster reasoning and construction of schemas, and mainly took the form of intelligent tutoring systems (Adams et al., 2012; Arroyo et al., 2013; Lane et al., 2013; Lester et al., 2013; Lester et al., 2014; Easterday et al., 2017). For example, Lester et al. (2013, 2014) used narrative-based learning as a way to foster metacognitive processes such as motivation towards STEM. They embedded the narrative in a game-based tutoring system to engage learners with situated activities where they take on the role of scientist. Learners go through processes where they reflect on their activity while also thinking about it within the context of the narrative.

Fiction and fantasy

Armstrong & Landers (2017), Barab et al. (2010a), and Easterday et al. (2017) argue that fantasy and fiction elements increase learners' interest in the subject matter and therefore enhance learning processes and outcomes. Armstrong & Landers (2017) incorporated fantasy elements into the narrative of a game-based training intervention; however, while the integration of narrative made students more satisfied and improved learners' perceptions of the training, there was no significant difference on declarative knowledge and a slight disadvantage among participants in the game condition for procedural knowledge. On the other hand, Easterday et al. (2017), Lester et al. (2013), and Pinkard et al. (2017) assert that the fantasy elements affect students' motivation and interest. Easterday et al. (2017) describe the potential of fantasy from a cognitive perspective, while Pinkard et al. (2017) describe it from a sociocultural perspective. Gilliam et al.'s (2017) findings on engaging learners with *the Source* -- an Alternate Reality Game, suggest that engaging underrepresented youth in immersive narrative-based environments may help them develop STEM interest, engagement, and identities, because these environments help learners practice STEM skills across social contexts.

Inquiry-based learning and problem solving

We use inquiry-based learning to refer to activities that engage learners in problem-solving tasks. *Quest Atlantis*, an inquiry-based learning game, enables students to engage in experiences where they take on the role of a protagonist and attempt to solve a STEM-related social problem (Barab et al., 2007, 2010). In *Digital Youth Divas*, young women were involved in computational problem-solving activities (Pinkard et al., 2017). Other scholarly literature integrated inquiry-based learning and problem solving in design interventions (e.g., Arroyo et al., 2013; Lester et al., 2013, 2014; Lane et al., 2013; Gilliam et al., 2016, 2017; Sadler et al., 2015). For example, in *Quest Atlantis*, students are exposed to socio-scientific issues through quests and are tasked with finding solutions for the issues. These works show that narrative can be used to support learners' problem-solving and inquiry skills.

Motivation and self-regulation

Crystal Island (Lester et al., 2013) engages learners in inquiry-based learning and problem solving by having them adopt the role of a microbiologist and complete interactive missions. Findings from studies on the game assert that that narrative-based learning environments increase learner's self-regulation as the game incorporates self-regulation mechanisms. The potential of narrative-based learning environments to increase learners' motivation is also discussed in other work, which asserts that these types of activities impact students' interest, and thus affect their learning (e.g., Easterday et al., 2017; Pinkard, 2017; Purden et al., 2017).

Engaging learners in situated activities

A variety of articles used situated learning as an instructional strategy to engage learners in real-world settings and activities, to increase their knowledge transfer and help them apply what they learn in different settings (e.g., Barab et al., 2007, 2010; Lane et al., 2013; Neville et al., 2015).

Intervention type

Some articles that we reviewed overlap in the type of educational technology design intervention. While some articles fit more than one category, we identified five major categories: (1) intelligent tutoring systems (e.g., Arroyo et al., 2013; Easterday et al., 2017), (2) digital media tools that involve narrative elements (Pinkard et al., 2017), (3) transmedia storytelling and alternate reality games (e.g., Gilliam et al., 2017), (4) transformative play experiences (Barab et al., 2007; Sadler et al., 2015), and (5) multi-user virtual environments (e.g., Neville, 2015). In these learning environments, learners mostly had direct interaction with the system, with less focus on interactive engagement with peers (e.g., collaborative activities). For example, the tutoring system for policy argumentation (Easterday et al., 2017) engaged one student in playing a game individually, while the *Digital Youth Divas* learning environment (Pinkard et al., 2017) was unique because it had multiple participants and multiple interventions that fostered collaboration between students, considering the context in which these activities are happening.

Context

Our review represents a variety of settings (see Table 1 and 2), education level of participants (Table 1 and 2), subject area (see Table 3), and diversity of participants (only four studies focused on a specific population such as gifted learners, or learners of a specific gender identity).

Five studies were conducted in formal learning settings with a goal of increasing learners' interest in STEM (Arroyo, 2013; Barab et al., 2013; Lester et al., 2013; Sadler et al., 2015). In these studies, participants were in middle school or high school. On the other hand, studies that targeted students in higher education settings were often controlled lab experiments (Adams et al., 2012; Easterday et al., 2017; Neville, 2015; Wouters et al., 2017). The subject areas of these studies include STEM, language, intercultural communication, and social sciences. Studies conducted in informal learning settings such as public libraries, makerspaces, and workshops had a variety of participants from elementary, middle, and high schools (Barab, 2007; Gilliam et al., 2016, 2017; Pinkard et al., 2017; Purden, 2017). One study was conducted in a workplace where researchers evaluated a gamified training system (Armstrong, 2017). Additionally, participants from prevocational education (middle school) participated in a study on how serious games influence mathematical learning (Wouters et al., 2017).

Four studies identified a specific target population for the intervention. Participants in Barab et al. (2007) study were 4th-grade gifted learners, which according to the authors might bring "constraints to the generalizability" (p. 64), given that the curriculum was developed to be aligned with a fifth-grade non-gifted population. To distinguish their work from similar out-of-school programs, Pinkard et al. (2017) focused their research questions on underrepresented, or non-dominant, young women in middle school. Gilliam et al. (2017) recruited 144 underrepresented youth from Chicago to participate in a five-week summer program, where participants were exposed to STEM topics through an alternate reality game. Finally, Purdue et al. (2017) designed

an intervention to enhance writing through narrative-based learning. Their approach considered gender differences among learners, and narrowed their research questions to tackle the challenges of adolescent men struggling with writing.

Tables 1, 2, and 3: Settings of the studies, Level of participants of the studies, Subject areas of the studies

Setting	# of Studies (%)	Participants	# of Studies (%)	Subject Area	# of Studies (%)
Formal learning	5 (29.4%)	Elementary School	1 (5.9%)	STEM	11 (64.7%)
Lab	4 (23.5%)	Middle School	4 (23.5%)	Social Sciences	1 (5.9%)
Informal Learning	4 (23.5%)	High School	4 (23.5%)	Writing	1 (5.9%)
Controlled experiment in formal learning environment	1 (5.9%)	Higher education	4 (23.5%)	Language	1 (5.9%)
Workplace	1 (5.9%)	Workplace	1 (5.9%)	Soft Skills	1 (5.9%)
Other	2 (11.8%)	Other	3 (17.6%)	Intercultural Communication	1 (5.9%)
				Sex Education	1 (5.9%)

Discussion, implications, and limitations

In this systematic literature review, we analyzed recent literature that used narrative elements in the design of educational technology and digital media learning environments across various learning settings. The review presented prior work related to narrative, which centered on two major theoretical frameworks: cognitive and sociocultural perspectives. Within each framework, different theories were employed to answer the research questions (e.g., information processing, motivation, situated cognition). Our analysis helped us to understand the different intervention types used to answer the research questions about narrative as an instructional strategy.

Integrating narrative elements into educational technologies helps learners engage in immersive experiences that encourage them to take up different roles, play, challenge themselves, and experience failure (Gee, 2017). While the studies we reviewed discussed the potential of narrative elements to support learning processes like metacognition, identity, interest (e.g., Pinkard et al., 2017), some studies suggest that such elements can increase learners' cognitive load and thus distract them from learning (e.g., Adams et al., 2012). These different results could potentially be a result of different procedures and methods used by researchers, or of differences in the intervention involved. The review reveals that narrative-based learning environments engage learners in fictional experiences that foster their imagination and interests in learning domains (e.g., Easterday et al., 2017; Pinkard et al., 2017). Thus, these environments have the benefits to help learners engage in multiple identities and ways they position themselves and support their engagement in learning domain practices.

One major limitation of this review is that the literature reviewed is from a narrowed discipline on narrative-based learning. To better understand the impact of narrative as an instructional tool, the Learning Sciences may adopt a broader and a more interdisciplinary approach to study the implications of narrative-based learning (e.g., Wong et al., 2020; Luong et al., 2020), including paying attention to literature on storytelling, popular modalities, and transmedia. For instance, combining cultural psychology, critical theory, and narrative-based learning may bring new perspectives to support the design of equity-oriented learning environments by bridging between "relevance" and "cognitive knowledge" (Lee, 2009, p.84) and enabling diverse learners to engage with multiple modalities and cultural resources (e.g., Penuel, Clark, & Bevan, 2016; Pinkard et al., 2017). Finally, since narrative is a complex and multifaceted concept (Dahlstrom, 2014), Learning Science researchers might benefit from adopting a more holistic understanding that could help to (a) define and operationalize narrative more rigorously, (b) create new or refine existing frameworks that support the integration of narrative-based learning (e.g., Barab et al., 2010; Penuel et al., 2016), and (c) generate more interdisciplinary scholarship around narratives that can inform pedagogy (e.g., Hobbs & Davis, 2013).

This systematic literature review is an attempt to identify what the existing literature says about the integration of narrative in educational technology environments, which theoretical frameworks have been employed to design and study such environments, and the learning environment goals of narrative-based learning environments. Further research in the field may use this work as a way to explore the benefits of narrative-based learning activities in the design of interactive learning environments. For instance, what impact does narrative have on learners' engagement, motivation, and learning processes, rather than focusing only on learning gains as

a result of narrative-based learning interventions? How can narrative-based learning environments and digital storytelling cultivate learners' identities and possible futures? What are possible ways to design narrative-based learning environments that take into considerations diverse learners' identities?

Additionally, when using narrative-based learning, researchers should investigate specific elements in the narrative that mediate learning processes. For example, the role of fiction and imagination in engaging learners with solving real-world problems, understanding how fantasy can contribute to instructional pedagogies employed to enhance learning outcomes, and examining how such interventions can increase learners' self-efficacy. Finally, in our digital age, educational technology and digital media tools have multiple affordances to support the diverse repertoires of learners (Lave & Wenger, 1991). Instructional tools like narrative can be one way to support learners as they explore the diverse roles they can play, therefore, encouraging them to imagine a range of possible futures for themselves and society (cf. Gee, 2017; Jenkins et al., 2020). Finally, although we conducted this work systematically (Booth et al., 2012; 2016), our biases as well as existing biases in the field may have influenced the results. For example, the studies selected by this process were predominately conducted in the United States (n=16); this suggests a need to adjust procedures to represent more voices from other parts of the world when conducting systematic reviews. Similarly, in an attempt to reduce personal bias, we reviewed the results of the process as a team through discussion and consulted researchers who did research in areas of game-based learning and digital storytelling.

References

- Adams, D. M., Mayer, R. E., MacNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. *Journal of educational psychology*, 104(1), 235.
- Armstrong, M. B., & Landers, R. N. (2017). An evaluation of gamified training: Using narrative to improve reactions and learning. *Simulation & Gaming*, 48(4), 513-538.
- Arroyo, I., Bursleson, W., Tai, M., Muldner, K., & Woolf, B. P. (2013). Gender differences in the use and benefit of advanced learning technologies for mathematics. *Journal of Educational Psychology*, 105(4), 957.
- Barab, S. A., Dodge, T., Ingram-Goble, A., Pettyjohn, P., Peppler, K., Volk, C., & Solomou, M. (2010). Pedagogical dramas and transformational play: Narratively rich games for learning. *Mind, Culture, and Activity*, 17(3), 235-264.
- Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, content, and context. *Educational Researcher*, 39(7), 525-536.
- 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(1), 59-82.
- Booth, A., Sutton, A., & Papaioannou, D. (2012). Systematic approaches to a successful literature review. Sage
- Booth, A., Sutton, A., & Papaioannou, D. (2016). Systematic approaches to a successful literature review. Sage.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, 18(1), 32-42.
- Bruner, J. S. (2003). *Making stories: Law, literature, life*. Harvard University Press
- Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *PNAS*, 111(4), 13614-13620.
- Dickey, M. D. (2007). Game design and learning: A conjectural analysis of how massively multiple online role-playing games (MMORPGs) foster intrinsic motivation. *Educational Technology Research and Development*, 55(3), 253-273.
- Driscoll, M. P. (2005). *Psychology of learning for instruction*. Harlow: Pearson.
- Easterday, M. W., Aleven, V., Scheines, R., & Carver, S. M. (2017). Using tutors to improve educational games: a cognitive game for policy argument. *Journal of the Learning Sciences*, 26(2), 226-276.
- Gee, J. P. (2017). *Teaching, learning, literacy in our high-risk high-tech world: A framework for becoming human*. Teachers College Press.
- Gilliam, M., Jagoda, P., Fabiyi, C., Lyman, P., Wilson, C., Hill, B., & Bouris, A. (2017). Alternate reality games as an informal learning tool for generating STEM engagement among underrepresented youth: A qualitative evaluation of the source. *Journal of Science Education and Technology*, 26(3), 295-308
- Gilliam, M., Jagoda, P., Jaworski, E., Hebert, L. E., Lyman, P., & Wilson, M. C. (2016). "Because if we don't talk about it, how are we going to prevent it?": Lucidity, a narrative-based digital game about sexual violence. *Sex Education*, 16(4), 391-404.
- Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological review*, 101(3), 371
- Greeno, J. G. (1989). Situations, mental models, and generative knowledge. *Complex information processing: The impact of Herbert A. Simon*, 285-318.

- Hobbs, L., & Davis, R. (2013). Narrative pedagogies in science, mathematics and technology. *Research in Science Education*, 43(3), 1289-1305.
- Jenkins, H., Peters-Lazaro, G., & Shresthova, S. (Eds.). (2020). *Popular Culture and the Civic Imagination: Case Studies of Creative Social Change*. NYU Press.
- Jonassen, D. H. (2003). Designing research-based instruction for story problems. *Educational Psychology Review*, 15(3), 267-296.
- Koedinger, K. R., & Nathan, M. J. (2004). The real story behind story problems: Effects of representations on quantitative reasoning. *The journal of the learning sciences*, 13(2), 129-164.
- Lane, H. C., Hays, M. J., Core, M. G., & Auerbach, D. (2013). Learning intercultural communication skills with virtual humans: Feedback and fidelity. *Journal of Educational Psychology*, 105(4), 1026
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press
- Lee, C. D. (2009). Historical evolution of risk and equity: Interdisciplinary issues and critiques. *Review of research in education*, 33(1), 63-100.
- Lester, J. C., Mott, B. W., Robison, J. L., Rowe, J. P., & Shores, L. R. (2013). Supporting self-regulated science learning in narrative-centered learning environments. In *International handbook of metacognition and learning technologies* (pp. 471-483). Springer, New York, NY.
- Lester, J. C., Spires, H. A., Nietfeld, J. L., Minogue, J., Mott, B. W., & Lobene, E. V. (2014). Designing game-based learning environments for elementary science education: A narrative-centered learning perspective. *Information Sciences*, 264, 4-18.
- Luong, K. T., Moyer-Gusé, E., & McKnight, J. (2020). Let's Go to the Movies...for Science!: The Impact of Entertainment Narratives on Science Knowledge, Interest, and Information-Seeking Intention. *Journal of Media Psychology: Theories, Methods, and Applications*. <http://dx.doi.org/10.1027/1864-1105/a000272>
- Mayer, R. E. (1982). Memory for algebra story problems. *Journal of educational psychology*, 74(2), 199.
- Mayer, R. E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of educational psychology*, 93(1), 187.
- Mott, B. W., Callaway, C. B., Zetlemoyer, 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).
- Neville, D. O. (2010). Structuring Narrative in 3D Digital Game-Based Learning Environments to Support Second Language Acquisition. *Foreign Language Annals*, 43(3), 446-469.
- Neville, D. O. (2015). The story in the mind: the effect of 3D gameplay on the structuring of written L2 narratives. *ReCALL*, 27(1), 21-37.
- Penuel, W. R., Clark, T. L., & Bevan, B. (2016). Infrastructures to Support Equitable STEM Learning across Settings. *Afterschool Matters*, 24, 12-20.
- Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital Youth Divas: Exploring narrative-driven curriculum to spark middle school girls' interest in computational activities. *Journal of the Learning Sciences*, 26(3), 477-516.
- Pruden, M., Kerkhoff, S. N., Spires, H. A., & Lester, J. (2017). Enhancing writing achievement through a digital learning environment: Case studies of three struggling adolescent male writers. *Reading & Writing Quarterly*, 33(1), 1-19.
- Rowe, J. P., & Lester, J. C. (2015, June). Improving student problem solving in narrative-centered learning environments: A modular reinforcement learning framework. In *International Conference on Artificial Intelligence in Education* (pp. 419-428). Springer, Cham.
- Sadler, T. D., Romine, W. L., Menon, D., Ferdig, R. E., & Annetta, L. (2015). Learning Biology Through Innovative Curricula: A Comparison of Game-and Nongame-Based Approaches. *Science Education*, 99(4), 696-720.
- Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT press.
- Wong, A. E., Dirghangi, S. R., & Butner, J. (2020). Storied across time: Construction, validation, and relationships of the cinematic self scale, Self and Identity, DOI: 10.1080/15298868.2020.1717593
- Wouters, P., Oostendorp, H., Vrugte, J., Vandercruysse, S., Jong, T., & Elen, J. (2017). The effect of surprising events in a serious game on learning mathematics. *British journal of educational technology*, 48(3), 860-877.

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