15. Narrative-Based Hands-On Activities for Science and Science Ethics Education: The Frankenstein200 Experience

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Abstract: This paper introduces the Frankenstein200 experience, which combines simple hands-on activities and narrative-based learning to enable learners to position themselves as scientists and learn about science and science ethics. Presenting findings from 2 studies in science museums, the current work describes how Frankenstein200 was implemented and tested in informal education settings and the impact it had on learners. Results from this research suggest that narrative-based learning experiences such as Frankenstein200 can serve as an effective tool for tackling complex and abstract issues in an approachable way, motivating people to engage in scientific conversations, and encouraging people to see themselves as scientists and creators.

Introduction

In science education, narrative-based learning conceptualizes narratives as effective educational tools that allow people to make sense of, understand, and remember abstract theories and notions more easily (Arya & Maul, 2012). Narratives are important because they can pull learners in by showing a "why" or rationale behind abstract science concepts and theories (Adams, Mayer, McNamara, Koenig, & Wainess, 2012). Science narratives may also allow learners to become familiar with science concepts and apply them to solve problems, both in and out of the school context (Engel, Lucido, & Cook, 2018). This might take the form of role-playing experiences (e.g., players taking on the role of scientists or inventors), various challenges and puzzles (e.g., finding a cure to save other characters' lives), and dilemmas (e.g., should scientists test on animals?) (Dickey, 2006). Through these activities, learners are invited to position themselves as scientists and solve problems, meet and work with other scientists, and make discoveries about the world.

Educators can run narrative-based learning projects by designing experiences online (e.g., video games) and offline (e.g., hands-on activities) through which learners can develop new skills and competencies. These activities are compelling for learners because they are salient for the narrative context, helping characters reach their goals or resolving a conflict. Prior research shows great promise for narrative-based learning across a wide range of domains, such as English literature (e.g., Fleming, 2013), mathematics (e.g., McCarthy, Tiu, & Li, 2018), and engineering (e.g., Stansell, Tyler-Wood, & Austin, 2016). These studies demonstrate that narratives can have positive effects on learners' academic motivation, persistence, and achievement (Lee, Park, & Jin, 2006; Marsh, 2010; Pivec, 2007). However, there is still a great need for further research on how narrative-learning design can support learning activities in informal education settings (Andre, Durksen, & Volman, 2017). For example, it is not clear exactly how fictional science narratives support learners' engagement and contribute to pedagogies intended to bolster learners' performance in science (e.g., Mawasi, Nagy, & Wylie, 2020). One particularly important issue concerns the social aspects of narratives in informal settings. That is, informal learning activities often invite learners to collaborate with each other, educators, facilitators, and/or other people (e.g., siblings, parents) when partaking in science narratives.

This paper seeks to address this need through the example of Frankenstein200 (https://frankenstein200.org), a narrative-based learning experience inspired by Mary Shelley's legendary 19th-century novel *Frankenstein; or, The Modern Prometheus*. We were interested to explore how the culturally ubiquitous Frankenstein narrative can help learners engage in conversations about science, refine their images of scientists, and become more curious and confident in their own scientific capacities. We formulated the following research question: How can our narrative-based learning activities help learners build a more nuanced understanding of scientific concepts and prompt conversation about science?

The paper proceeds as follows. First, we describe Frankenstein200, which uses various hands-on activities ("Frankenstein's Footlocker") intended to help learners expand their knowledge about contemporary issues related to emerging technologies such as synthetic biology, biomechanical engineering, and robotics. This work incorporates themes from *Frankenstein* (e.g., science ethics, the limits of scientific exploration) to engage learners in conversations about scientific responsibility and creativity. Second, we show how Frankenstein200 was implemented in an informal education setting and present qualitative findings from data collected from museums across the United States. And finally, we propose guidelines and recommendations on how narrative-based learning experiences can be used for science and science ethics education in informal settings.

Methods

Context and Research Site

In conjunction with the global celebration of the bicentennial of the publication of Mary Shelley's *Frankenstein* in 2018, Frankenstein Footlocker kits were awarded to 51 science and children's museums throughout the United States. As a condition of being awarded a kit, museums were encouraged to organize two Frankenstein-themed events: one event in early 2018 to align with the bicentennial celebration (the novel was originally published in January 1818), and another event in October 2018 to align with that year's Halloween programming. Interview and observational data were collected from nine museum partners in January and February 2018 and from four sites in October 2018. In January and February, we collected observational data to learn about participants' engagement and about how museum educators facilitated the activities. We also interviewed museum visitors to investigate their perceptions of the activities. In terms of observational data, the research protocol focused on two areas regarding participant engagement: the interaction between museum facilitators and visitors, and the interaction between parents and children during activities. During January/February and October 2018, a total of 143 observations and 45 individual interviews with children between 5 and 12 years of age were conducted. Data sources encompassed field and observational notes and audio-recorded interviews.

Activities

The Frankenstein200 experience consists of seven hands-on activities that prompt deeper conversations about scientific and technological creativity, the limits of scientific exploration, and social responsibility. Frankenstein200 took widely used science-education activities and connected them with a compelling narrative to engage participants in deeper thinking and conversation about the social and ethical issues surrounding scientific work. Each of the hands-on activities uses easily available and inexpensive materials, making them broadly accessible (see Table 1). The activities and facilitation guides are available at https://www.nisenet.org/frankensteinkit.

Hands-on activity	Description
Scribbler	A mini-robot that participants create using an electric toothbrush motor, a foam pool-noodle piece, and markers that draw designs on paper.
Dough Creature	Participants create simple circuits using two types of homemade modeling clay, a battery pack, and an LED light.
FrankenToy	A stuffed animal created by recombining elements of existing stuffed animals.
Automata	Automata are mechanical sculptures that combine elements such as cams, levers, and linkages. After creating their devices, participants are asked to reflect on questions related to creativity, engineering, and responsibility.
Battery Stacks	Participants make a model of a voltaic pile, the first kind of battery that converts chemical energy to electrical energy. Participants also learn the history behind the invention and how it works.
Spark of Life	By placing their hands on zinc and copper sheets, participants experience how electricity can flow through their body. This activity is intended to illustrate how batteries and some medical technologies work.
Monster Mask	Participants make a mask with a special feature: an LED bulb that lights up.

Table 1. Description of hands-on activities used in Frankenstein200.

For example, a Scribbler is made of simple materials: pool noodles, markers, and rubber bands. Learners animate their Scribblers with an electric toothbrush wedged inside the pool noodle so it can move and draw on a sheet of paper (see Figure 1). Creating the artifact is only the first step of the experience; after the child builds a Scribbler, a facilitator can ask questions such as: (a) Is your drawing art? If so, who is the artist? (b) If someone wanted to buy your drawing, should you get the money or should your Scribbler get the money? (c) What if your Scribbler was turned on and drew on something important? Who should be responsible? Depending on the age of the learner, the facilitator can then proceed to discuss ethical issues surrounding emerging technology such as autonomous vehicles and begin to introduce the concept of unintended consequences. The activity FrankenToy, on the other hand, is a “creature” assembled from different parts of toys. By mixing and matching parts of plush animals and dolls, learners create their own creatures, act out the story of their creation, and take photos of them (see Figure 1). This activity is guided by the following facilitating questions: (a) Could your creature be real? Why or why not? (b) Could it be dangerous? (c) What would happen if your creature did something bad? Who would be responsible?

Figure 1. Example of the Scribbler (on the left) and FrankenToy (on the right) activities.

Dough Creature uses play dough to provide opportunities for learning about electronics and circuits. Using two types of homemade play dough, a battery pack, and an LED light, participants create simple circuits. After completing the activity, participants are given a discussion card and encouraged to ask each other reflection questions (e.g., "Why did some of the circuits work and some not? What did you learn from this activity? What would your creature do if it was alive?").

As illustrated by these three examples, each of the activities builds upon themes from the Frankenstein story. Frankenstein is an incredibly popular narrative, familiar even to those who have not read the novel. Despite being more than 200 years old, the story still serves as a cautionary tale about scientific discovery and responsibility. By creating a set of activities and facilitation questions wrapped within the Frankenstein narrative, we aspired to create an engaging and educational experience.

Results

Observational findings show two main trends in engagement. First, facilitators boosted participants' engagement and interest by invoking images from the Frankenstein narrative. While the activities were designed for children to be able to complete on their own, we saw a number of parents take part in the activities on their own or help their children create the products. Take the following example from a Scribbler activity: The museum facilitator invites a 7-year-old boy to the activity, telling him about how Dr. Frankenstein's monster was assembled from different body parts. The boy gets excited and agrees to build "a monster." After explaining how to create a Scribbler, the facilitator draws a parallel between this activity and scientists' and engineers' work in general. She also adds, "They [scientists and engineers] constantly try to figure things out." The boy realizes that he has to change the battery in the toothbrush because it is not working. When the Scribbler starts vibrating and drawing on a sheet of paper, the facilitator asks the participant why he thinks "the monster" is working now. The boy says that the battery and the heights of the markers had to be changed. The facilitator mentions that this is how scientists and engineers work: They see a problem and try to find a solution. The boy agrees and says, "I am like a scientist. Cool!" The parent, who was watching her child working on the Scribbler activity, is very happy about how the boy managed to make the activity work. In other cases, learners made connections between the hands-on activity they completed and their everyday science knowledge about science and innovation. For example, a young boy aged 8 years was initially struggling to make his Automata work. He had created a green head, which he called "Frankenstein's head," and mounted it on top of a box. The wheels he had selected did not rotate properly, so he could not make the head turn around by itself. Later, he realized that he needed to make some adjustments and experiment with new designs. Seeing that the participant tried to come up with new ideas, the facilitator encouraged him by saying, "You're doing a great job! Engineers and scientists go through this every day with the things they build." After about five more minutes, the boy could make his Frankenstein's head move and he got very excited. The facilitator said, "You figured it out!" The boy said, "It was an accident … like the potato chips!" When the facilitator asked him what he meant, the boy said that the Automata reminded him about how potato chips were invented by accident. He added, "Sometimes you need to try really hard to make things work!"

In addition to encouraging participants to become creators, facilitators helped visitors gain a more complex understanding of science concepts and responsibility by asking facilitation questions. Grappling with these questions required participants to reflect on thematic issues that were salient to the activities, providing opportunities to reflect upon emerging science and engineering practices, such as robotics or synthetic biology, and connect them to questions around ethics and responsibility. Take the following example from another Scribbler activity. After an 8-year-old girl completed the activity and the Scribbler started drawing on a sheet of paper, the facilitator asked the participant who the artist was. The girl pointed at the Scribbler and said, "The machine." The participant also argued that if the Scribbler created something valuable, worth a million dollars, "the robot" should get the money rather than the inventor. However, if something went wrong and the Scribbler did something bad, the inventor should get the blame because it was she who created the machine and therefore she is responsible for its actions. In another case, an 8-year-old boy completed the Dough Creature activity. While the boy was working on the activity, the facilitator also asked questions about Victor Frankenstein. The boy said, "Frankenstein was made by a mad doctor." When asked whether he saw a connection between the activity and the Frankenstein story, the boy said, "Yes, they were both building a monster." The facilitator and the participant went on to talk about the responsibilities of scientists. The boy noted that responsibility is important because something bad can happen and things can go wrong in the course of scientific work. In his view, it is his responsibility as a creator to make sure his Dough Creature works safely and does not cause harm to others.

These examples illustrate that the Frankenstein story can serve as an effective tool to spark interest in science, allow participants to make connections between the Frankenstein's Footlocker activities and their everyday experiences, engage in ethical deliberations, and position participants as scientists and creators.

Results from the interview data suggest two additional trends. First, Frankenstein's Footlocker could help participants better understand how scientists think and work. When it comes to the figure of Victor Frankenstein, many young learners could see similarities between the work Victor did and the activities they as participants completed. Take the following example:

> Interviewer: What do you know about Frankenstein?
> Boy (10 years old): That he's a little—like he's a person and he got made up of scientist out of like human body parts, and that he doesn't like fire and that whole—like he would yell, "Fire," when there is a fire is close by. And he just runs all over the place and he's really silly, and it's just really fun.
> Interviewer: Cool. Do you think any of the activities today remind you of Frankenstein?
> Boy: Yeah. Especially the baby doll, like—because you get to make your own baby doll out of other parts, like a puppy dog or like a dinosaur or something like that. Like they have on the table.

Here, although the learner gets a little off track with describing the creature, he has knowledge of the story, including, with the fire detail, how it is expressed in movies and TV, and he manages to make a clear connection about how he is creating an engineered being in this activity, like Victor in the Frankenstein story.

In addition, by engaging in hands-on activities, learners could see how scientists create, learn from their mistakes, and overcome difficulties. Take the following example:

> Interviewer (after the participant completed the Automata activity): What was the most interesting thing that you learned from this activity?
> Boy (11 years old): Probably like how scientists think of one idea. And how they fail. They try again and sometimes things can be invented by accident.
> Interviewer: Do you see yourself as a scientist or an inventor?
> Boy: Yes, I can see myself as an inventor. I would like to invent things like this machine.

In this sense, the Frankenstein narrative helped some participants reflect on the responsibilities of scientists when they design and conduct experiments. The example below highlights one of the recurring themes from our interviews:

> Interviewer: So, one of the ideas around the story Frankenstein is that it's important that we take responsibility for things that we create, and so, how do you think that people can be more responsible for things that they create?
> Girl (10 years old): By knowing what they can do. Like if you make off a robot or something, you have to know what they can do before like putting it out into the world, because if you don't know, it can do something and it might hurt somebody or something.

For many of our participants, being a responsible scientist means that people need to take care of their creations. Otherwise, scientific experiments might lead to accidents and disasters. For our participants, no matter if the creation is organic or synthetic, scientists should be careful when they run experiments. Take the following example:

> Interviewer: So, we talked a lot about these activities, about being creative and being responsible for the things that you create. Do you think people should be responsible when they create something?
> Girl (8 years old): Well, if you're not responsible, the thing might get out of hand and destroys stuff.
> Interviewer: So, can you tell me a real-life example of somebody creating something and not being responsible for it?
> Girl: Well, it's like when you have a kitten. Your cat has kittens and you don't want to take care of the kittens. So, the kittens really need to be taken care of. And you don't take care of them.

Second, participants could learn about a variety of scientific and engineering concepts and practices through the Frankenstein's Footlocker. In connection with the Frankenstein story, even simple activities could help learners get a better grasp on the potential uses of technologies. Take the following example:

> Interviewer: Do you see any connection between Frankenstein and the activities that you did here?
> Girl (9 years old): Making the [Dough Creature]. Because you had to make circuits to bring it alive.
> Interviewer: And what did you learn from the Squishy Circuits?
> Girl: I learned that not everything can like electricity can go through.
> Interviewer: Why?
> Girl: Because it can't go through a table because we tried that.

Other participants learned about design and the capabilities of technologies. By experimenting and observing how different components, such as conductive dough or metal sheets, enabled or hindered certain actions (e.g., making sound, changing color), learners could develop a better understanding of the qualities of materials. Take the following example:

> Interviewer: What did you learn from that activity [referring to the Battery Stack]?
> Boy (11 years old): Let's see … I've learned from the activity, the battery stacking, the zinc sheets, the things. Well, that was pretty interesting how it could make any noise from that.

However, some participants could not fully articulate what new things they learned by completing the activities. Instead, they realized that creating scientific artifacts can be challenging and difficult. Take the following short passage:

> Interviewer: What did you learn from FrankenToy? Did you learn something new?
> Boy (8 years old): How weird it is to create things. And how hard it is.

These examples demonstrate that by completing the hands-on activities, young learners gained a better understanding of how technologies work and what purposes they can be used for.

Discussion and Implications

Findings from our museum studies suggest three major conclusions for informal science education. First, narrative-based learning experiences can show participants that science learning can happen anywhere, in and beyond science labs. Frankenstein200 activities opened up new ways for participants to learn about science and engineering (e.g., how electricity works, how to build simple robots).

Second, narrative-based learning can serve as an effective tool for tackling complex and abstract issues in an engaging and nonthreatening way, by allowing even young learners to acknowledge that science has social and ethical implications. This project used Frankenstein as an imaginative tool to facilitate conversation and help learners conceptualize scientific responsibility and the limits of scientific exploration by providing hands-on experiences.

Third, and finally, narrative-based learning can motivate and inspire learners to recognize that anyone can be a scientist. Frankenstein's Footlocker provides physical activities for learners to create *and* position themselves as scientists. These experiences can help them recognize their potential as science learners and develop a stronger interest in science and science ethics.

While implementing facilitation practices in museum settings may pose various challenges to educators (e.g., activities with discussion require more time to complete), they can help younger visitors approach complex issues such as science ethics. We hope that our qualitative findings can help museum professionals and researchers develop, implement, and evaluate public programs that use narrative-based learning principles for informal science educational purposes.

References

Adams, D. M., Mayer, R. E., McNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. *Journal of Educational Psychology*, *104*(1), 235–249.

Andre, L., Durksen, T., & Volman, M. L. (2016). Museums as avenues of learning for children: A decade of research. *Learning Environments Research*, *20*(1), 47–76.

Arya, D. J., & Maul, A. (2012). The role of the scientific discovery narrative in middle school science education: An experimental study. *Journal of Educational Psychology*, *104*(4), 1022–1032.

Dickey, M. D. (2006). Game design narrative for learning: Appropriating adventure game design narrative devices and techniques for the design of interactive learning environments. *Educational Technology Research and Development*, *54*(3), 245–263.

Engel, A., Lucido, K., & Cook, K. (2018). Rethinking narrative: Leveraging storytelling for science learning. *Childhood Education*, *94*(6), 4–12.

Fleming, L. (2013). Expanding learning opportunities with transmedia practices: Inanimate Alice as an exemplar. *Journal of Media Literacy Education*, *5*(2). Retrieved from https://digitalcommons.uri.edu/jmle/vol5/iss2/3

Lee, K. M., Park, N., & Jin, S. (2006). Narrative and interactivity in computer games. In P. Vorderer & J. Bryant (Eds.), *Playing video games* (pp. 259–274). Mahwah, NJ: Erlbaum.
Marsh, T. (2010). Activity-based scenario design, development, and assessment in serious games. In R. van Eck (Ed.), *Gaming and cognition: Theories and practice from the learning sciences* (pp. 213–225). New York, NY: Information Science Reference.
Mawasi, A., Nagy, P., & Wylie, R. (2020). Systematic literature review on narrative-based learning in educational technology learning environments (2007–2017). In M. Gresalfi & I. S. Horn (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020* (Vol. 3; pp. 1213–1220). Nashville, TN: International Society of the Learning Sciences.
McCarthy, E., Tiu, M., & Li, L. (2018). Learning math with Curious George and Odd Squad: Transmedia in the classroom. *Technology, Knowledge and Learning*, 23(2), 223–246.
Pivec, M. (2007). Play and learn: Potentials of game-based learning [Editorial]. *British Journal of Educational Technology*, 38(3), 387–393.
Stansel, A., Tyler-Wood, T., & Austin, S. (2016). The development of a transmedia STEM curriculum: Implications for mathematics education. *Journal of Mathematics Education*, 9(2), 72–80.

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