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Glenn W. Ellis
Smith College, gellis@smith.edu

Isabel Huff
Springfield Technical Community College

Al Rudnitsky
Smith College, arudnits@smith.edu

Beth McGinnis-Cavanaugh
Springfield Technical Community College

Sonia K. Ellis
Smith College

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Engaging Children in Design Thinking Through Transmedia Narrative (RTP)

Dr. Glenn W. Ellis, Smith College

Glenn Ellis is a Professor of Engineering at Smith College who teaches courses in engineering science and methods for teaching science and engineering. He received a B.S. in Civil Engineering from Lehigh University and an M.A. and Ph.D. in Civil Engineering and Operations Research from Princeton University. The winner of numerous teaching and research awards, Dr. Ellis received the 2007 U.S. Professor of the Year Award for Baccalaureate Colleges from the Carnegie Foundation for the Advancement of Teaching and the Council for Advancement and Support of Education. His research focuses on creating K-16 learning environments that support the growth of learners' imaginations and their capacity for engaging in collaborative knowledge work.

Ms. Isabel Huff, Springfield Technical Community College

After participating in the instructional design of Through My Window during her four years as an undergraduate, Huff is now its outreach coordinator. She graduated summa cum laude from Smith College with a double major in Economics and Spanish in Spring 2014 and now works on the Springfield Technical Community College side of the Through My Window National Science Foundation grant.

Mr. Al Rudnitsky, Smith College

Al Rudnitsky teaches Introduction to the Learning Sciences; Thinking, Knowing and the Design of Learning Environments, How Do We Know What Students are Learning?, and instructional methods in elementary and middle school mathematics and science. He has authored books on curriculum design and teaching children about scientific inquiry. Current research interests focus on creating environments for "good talk" in elementary and middle school classrooms, and also on advancing the use of knowledge building pedagogy in higher education. His most recent article (2013) is entitled "Tasks and Talk: The Relationship Between Teachers' Goals and Student Discourse," in *Social Studies Research and Practice*.

Prof. Beth McGinnis-Cavanaugh, Springfield Technical Community College

Beth McGinnis-Cavanaugh, M.S. C. E. University of Massachusetts Amherst, is professor of physics and engineering at Springfield Technical Community College. She focuses on developing meaningful educational strategies to recruit and retain a diverse student body in engineering and designs innovative learning environments at all levels of the engineering pipeline. With expertise in the design of PD and learning communities, Beth leads a collaboration with educators as co-PI on an NSF K12 engineering education project. She is the 2014 Carnegie Foundation for the Advancement of Teaching and the Council for Advancement and Support of Education Massachusetts Professor of the Year.

Sonia K. Ellis, Smith College

Sonia K. Ellis holds a B.S. in chemical engineering from the University of Pennsylvania and an M.S. in chemical engineering from Princeton University. She is a writer and instructional designer. On the Through My Window project, she is the author of Talk to Me and TimeTilter, and a designer and editor of the online learning adventures.

Engaging Children in Design Thinking through Transmedia Narrative (RTP)

I. Abstract

This paper presents the implementation of Imaginative Education (IE) pedagogy for creating a transmedia learning environment that engages children in learning about engineering design. IE uses narrative to engage learners' imaginations; helps them master the cognitive tools necessary for progressing to higher levels of understanding; and helps them structure what they learn in meaningful ways. Included in the paper is an introduction to IE pedagogy and the use of transmedia in education; an overview of the online learning environment called Through My Window (TMW) that we have developed for middle school children; and a detailed look at a learning adventure on engineering design called Trapped in Time. Assessment data collected by external evaluators shows that TMW positively impacted student interest in engineering and increased STEM identity. Preliminary results for the Trapped in Time learning adventure indicate improved understanding of engineering design.

II. Introduction

The National Research Council reports that the U.S. “will need a steady supply of well-trained engineers, scientists, and other technical workers...to succeed and prosper in the twenty-first century.”¹ Because our society is becoming increasingly dependent on engineering and technological advances, it is also recognized that all citizens need to have a basic understanding of engineering processes and uses to make informed choices and understand our world. To address these needs, there has been a growing nationwide interest to include engineering in both formal and informal pre-college education. In reviewing early attempts at K-12 engineering education, the NRC found that including engineering in K-12 education had numerous benefits including improved learning and achievement in science and mathematics; increased awareness of engineering and the work of engineers; understanding of and the ability to engage in engineering design; interest in pursuing engineering as a career; and increased technological literacy.²

Initially, individual states led the effort to include engineering in K-12 education. More recently, attention has shifted to the national level with the integration of engineering design into the Next Generation Science Standards (NGSS). The NRC notes that the insight and interest students gain from this integration should “help students see how science and engineering are instrumental in addressing major challenges that confront society today...”¹

While including engineering design in NGSS can potentially transform K-12 science education, the resources available to teachers for implementing this approach are still largely undeveloped. To address this need, we have developed an online learning environment called Through My Window (TMW) that introduces middle school children to engineering through transmedia storytelling. TMW includes two novels (*Talk to Me* and *TimeTilter*) that use engineering as plot elements; a website for each novel that allows children to join the characters from the novels in

immersive experiences; and an educator support website with a teachers guide and other tools for enhancing learning. This paper focuses on the Trapped in Time learning adventure that is associated with the *Talk to Me* novel. Included will be its theoretical underpinnings, a description of the adventure, and an assessment of its impact on learning.

III. Engaging Children's Imaginations

The engineering education literature has long recognized the need to rethink how students engage with content.³ Many have raised concerns that reductionist engineering courses that omit intellectual and sociopolitical histories help discourage women from scientific fields.⁴⁻⁶ To address these concerns, the overall design of the TMW learning environment is based on the theory of Imaginative Education (IE) developed by Kieran Egan.⁷⁻¹¹ Egan's approach builds on learners' characteristic ways of thinking to structure their engagement with ideas and knowledge. His intent is to capture learners' imaginations in their pursuit of understanding and in this way generate the kind of *caring* about learning that learners need to engage in deep learning.

In the IE approach, instruction supports a developmental sequence of five types of understanding—each with an array of cognitive tools—that enable learners to make sense of the world in different ways. The most important of these tools is narrative. Bereiter writes that “narratives...create in the reader the experience of significant conditions and events. When in the grip of a story, people don't think, ‘How is this relevant to me and my problems?’ Instead they experience events through the protagonists...”¹² Research has shown that story has long been used as a tool for communicating understanding to students.¹³ It is the primary means learners have for connecting their existing knowledge to new ideas¹⁴ and for expressing their understanding of the world.¹⁵ Stories ground complicated concepts in concrete terms and connect abstract ideas with emotions and events. Numerous researchers have published examples of how storytelling can be successfully applied in engineering education at a variety of grade levels.¹⁶⁻²³

According to IE theory, mythic understanding and romantic understanding are the narrative structures most appropriate for middle school children using Through My Window. Mythic understanding begins as learners develop enough linguistic ability to discuss and understand things they haven't physically experienced. At this age they become aware of a sense of mystery that surrounds our knowledge, and they are comfortable in a world containing myth and fantasy. Romantic understanding begins as learners see the world more realistically; as they search for the edges of the world they are beginning to comprehend, romantic learners become fascinated with the limits and extremes of reality. Romantic learners are also interested in heroes and how they face the challenges of reality.²⁴ Both mythic and romantic understanding are woven throughout TMW and the Trapped in Time online learning adventure.

IV. A Transmedia Approach to IE Narratives

Transmedia storytelling is “a process where integral elements of fiction get dispersed systematically across multiple delivery channels for the purpose of creating a unified and coordinated entertainment experience.”²⁵ Forms of media used by transmedia storytellers include video; websites; blogs; social media; photos, art, and diagrams; newspaper and magazine articles; journal entries; transcripts of phone calls or videos; documents and records; books or stories; and audio clips. When using transmedia to create learning environments, research has shown the importance of learners engaging in *transmedia play*.²⁶ In transmedia play, learners go beyond being merely consumers of information and instead become participants who create

“new information through connections, explorations, and other forms of imaginative—and productive—play.”²⁷

The impact of transmedia is similar to IE: “Transmedia consumers are more involved in the story...resulting in more engagement, intrinsic motivation, and media enjoyment.”²⁸ Additionally, “High engagement and media enjoyment result in children’s more elaborately processing information and thus encourage self-regulated learning.”²⁸ The benefits of using transmedia go beyond increased engagement. One is the variety of literacies that transmedia environments support, “including textual, visual, and media literacies, as well as multiple intelligences...[it] allows for important social sharing among collaborators.”²⁹ Another benefit is that “children must learn to read both written and multimedia texts broadly (across multiple media) and deeply (digging into details of the narrative).”²⁹

In the Trapped in Time learning adventure, users become participants in an interactive online graphic novel that is integrated with video and an online game. This transmedia approach makes interactive IE engineering narratives more immersive and emotionally engaging.

It is important to note that the *Talk to Me* novel and associated learning adventures are all available for free on the TMW website. Because it can be accessed by everyone, TMW addresses concerns about the shift toward transmedia resources widening the digital divide between rich and poor adolescents.^{29,30}

V. Overview of the Through My Window Learning Environment

Through My Window has a variety of elements that can be combined in different ways depending upon teacher needs. It includes the following components.

1. Print editions of two young adult novels: *Talk to Me*³¹ and *TimeTilter*.³²

In *Talk to Me*, fourteen-year-old Sadina Reyes is fighting the clock to keep her mother from being arrested for a crime she didn’t commit. Sadina thinks her little sister, Maddie, has information that could prove their mother is innocent. There’s one big problem: Maddie can’t talk. She has selective mutism, an anxiety disorder that makes it impossible for her to talk about what she’s seen.

Sadina searches desperately for a way to help her sister communicate. Sadina’s friends join together to help her transform Bella—Maddie’s robotic cat—into Chattercat, a talking robot that just might get some answers from Maddie. In using the engineering design process to build the robotic cat and solve the mystery, Sadina and her friends learn about artificial intelligence and experience ethical dilemmas paralleling the kinds of situations that professional engineers and technologically literate citizens might face.

In *TimeTilter*, fourteen-year-old Singer joins a band of displaced teens in a futuristic gaming site created by the mysterious company Collusia. Trapped in the TimeTilter, Singer and her team become the unwilling subjects of Collusia’s dangerous research on the limits of human perception. Under the influence of a new and proprietary chemical called the superzeitgeber, the team loses all sense of time—while other senses become mysteriously enhanced.

In order to escape, they'll have to find out why they're here, figure out how to tap into their new super powers of perception, and fight their way out of a world where you can't always be sure of what's real—and who you can trust. Key plot elements tie into bioengineering.

2. A free educational website³³ in which the *Talk to Me* novel can be accessed through an illustrated eReader and an audiobook. The website also has three extensive narrative-based, transmedia learning adventures (modules) in which users become part of the story.
 - Rio's Brain: After Sadina's friend Rio is separated from his brain, users explore a mysterious virtual mansion to learn about artificial intelligence and determine if an artificial brain can save Rio.
 - Trapped in Time: Sadina and her friends are trapped in a cave below a spooky house. Users help them apply the engineering design cycle to escape. (See the next section for a detailed description.)
 - Catalina's Revenge: Two characters are in a social media feud. Students help a third character figure out how to be a good friend and bystander, and explore the parallels with professional engineering ethics.
3. A free educational website³⁴ associated with the *TimeTilter* novel. The book provides a secret password that lets readers hack into a mysterious corporate website, where they can uncover the true intent behind the sinister game.
4. Significant support for teachers and parents through the Team Through My Window website.³⁵ This website includes information and a variety of tools for supporting educators, including video tutorials and a teacher's guide.



Figure 1: The Through My Window homepage (left) includes options for reading the *Talk to Me* novel and engaging in learning adventures. The Team Through My Window homepage (right) includes a variety of educator resources.

VI. Trapped in Time Online Learning Adventure

In this adventure, users travel back in time to learn about engineering design through an interactive transmedia learning module. Consistent with IE theory, all the tasks, questions, and writing prompts are integrated into the storyline. As a participant in this mysterious world, users are motivated to learn and engage with new ideas because they are needed to help *Talk to Me* characters Sadina, Catalina, and Carl escape from a cave. Requiring about two hours for children to complete, the adventure centers on engineering design as a flexible, creative process focused on helping people. Users learn about the design process organized into three elements—define, develop, and optimize—as presented in the Next Generation Science Standards (NGSS).³⁶

The learning adventure begins with a digital graphic novel in which Sadina, Catalina, and Carl are trick-or-treating at a spooky house. While exploring the house, Carl falls through a trap door. Sadina and Catalina try to help, but all three end up trapped in a cave where they discover a talking time machine. The time machine reveals (via a video) that it has tampered with the past by designing things for people instead of letting them design for themselves—and all knowledge of the design process has been lost. The time machine will help Sadina, Catalina, and Carl escape the cave, but only if they go back in time, help historical figures learn about the engineering design process, and “fix” history.

Early in the adventure, the talking time machine introduces users to the define, develop, and optimize phases of the design cycle by showing them videos with historical examples. The *define* video explains the importance of accurately and creatively defining the problem to be solved. It uses the example of David Bushnell, who defined the problem of defeating Britain’s powerful navy in the Revolutionary War in a way that led to his innovative design of the turtle submarine. The *develop* video portrays the importance of diverse teams working together to develop effective solutions through the story of IBM’s creation of Watson, the computer that played and won on Jeopardy. The *optimize* video explains that optimization is “making things better.” The video shows how engineers use prototypes in the evolution of artificial limbs.

After this introduction, users travel back to three time periods to apply what they have learned.

- Palo Alto in the 1990s: Users watch clips from Nightline's "The Deep Dive" video³⁷ showing how IDEO uses the design cycle to redesign the shopping cart. Learning is scaffolded through writing prompts in the user's electronic journal. Examples include “How does building on each other’s ideas help the design process?” and “How does ‘failing often to succeed sooner’ help the design process?”
- Chicago in 1893: Through video and a digital graphic novel, users encounter Nikola Tesla and Thomas Edison in the Chicago mayor’s office. The two historical figures are arguing about which is better for electrifying Chicago: alternating current or direct current. Sadina, Catalina, and Carl suggest to the mayor that they should first apply the design process to *define* the problem by assessing the needs of the people of Chicago. The Mayor loves the idea. Users then “interview” citizens by clicking on characters that they meet and taking notes in their online journal. Finally, they report what they have learned to the mayor and, via a video, see that their research has resulted in AC electricity lighting up the 1893 Chicago World's Fair.
- Houston in 1970 during the Apollo 13 mission: Through video and digital graphic novels, users learn about the oxygen tank explosion and the resulting challenge of fitting

command module air filters into the lunar module. They are tasked with helping the NASA engineers at the mission control center, where the engineers have many questions for the user about how to proceed. Should they work separately or together? Whose ideas should they use? Based on the user's answers, the story takes different paths (with options for users to change their advice). Finally, they get to see the conclusion of the episode through a video that shows the astronauts safely returning to earth.

The time machine has one final challenge: a game testing the user's knowledge of the design cycle. In this game, users have to place the "sub-steps" of the design cycle (like building a prototype and assessing user needs) within the appropriate element (define, develop, optimize) of the design cycle. Once they succeed, the time machine helps the characters escape from the cave, and the story concludes with a digital graphic novel.



Figure 2: Screenshots of the introductory digital graphic novel. Carl falls through the trap door (top). Characters meet the time machine (middle). Sadina shares her initial ideas about the engineering design process (bottom).



Figure 3: Screenshots from 1893 in Chicago. Tesla and Edison argue about the use of alternating and direct current (left). Users interview a Chicago citizen and write notes about the citizen's electricity needs (right).



Figure 4: Screenshots from Houston, 1970. The characters arrive at mission control (top left). The Apollo 13 engineers describe their problem (top right). An engineer asks a questions related to the develop and optimize parts of the design cycle (bottom left). In the final challenge, the time machine tests the user's knowledge of the design cycle (bottom right).

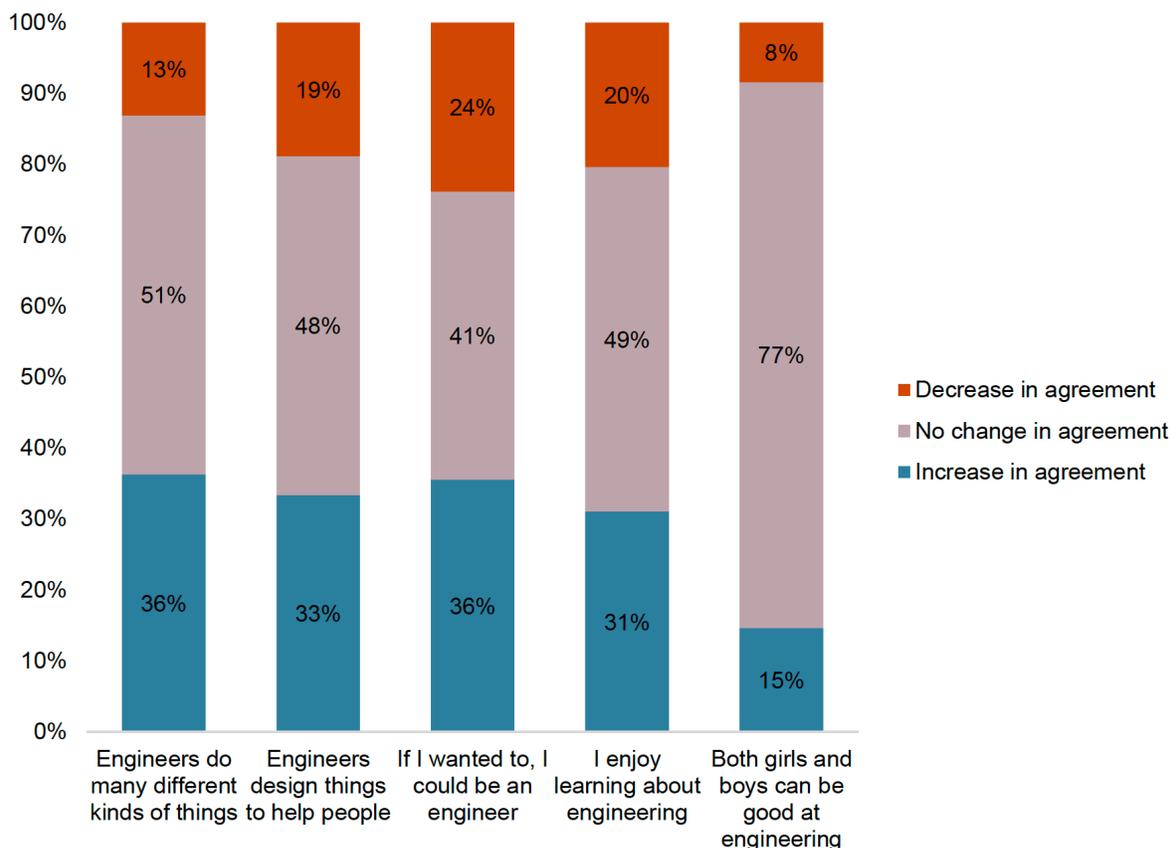
VI. Assessment

Fourteen middle and elementary schools and 30 afterschool programs implemented Through My Window (TMW) during the 2016-2017 school year. In each case, an external evaluator used a survey designed for this study to assess student attitudes about engineering before beginning the TMW program and then again (with additional questions) after completing TMW. During this time, 270 children completed both a pre-survey and a post-survey; 269 children completed only a pre-survey; and 36 children completed only a post-survey.

Impact of TMW on Interest in Engineering and STEM Identity

Five survey questions assessed student interest in engineering and attitudes related to STEM identity. The results are shown in Table 1. From 270 matching pre/post surveys, it was found that after using TMW between 31% and 36% of students increased their level of agreement with each of four statements. The prompt “Both girls and boys can be good at engineering” showed less of an increase in agreement than did the other prompts, but agreement levels with this prompt were already very high on the pre-survey (95%).

Table 1: Level Changes in Agreement from the Pre-Survey to the Post-Survey



Results were even stronger for students who started out with negative views. For example, of the 42 students who started off disagreeing with the statement “If I wanted to, I could be an engineer,” 75% responded with stronger levels of agreement on the post survey. TMW appeared to be equally effective for boys and girls; there were no statistically significant differences between their shifts in agreement.

Impact of Narrative and Multimedia Elements on Learning and Engagement

After completing the program, students were asked in a post-survey whether they liked the book and the online learning adventures, and how the book and the online learning adventures affected their interest in engineering. A total of 306 students completed these post-surveys. Of these students, 280 either read or listened to the novel and 258 completed at least one of the learning adventures. The results are shown in Table 2 and Table 3.

It was found that 92% liked the novel to some degree and 88% liked the learning adventures to some degree. Girls were significantly more likely to enthusiastically engage with the novel (53% of girls reported they like it a lot versus 27% for boys; p-value < 0.00001). About three-quarters of students indicated that both the novel and the learning adventures had a positive impact on their interest in engineering, with about one-third of students indicating that the book and the learning adventures made them interested or very interested in learning more about engineering.

Table 2: Student Responses to Whether They Liked the Book and Online Adventures

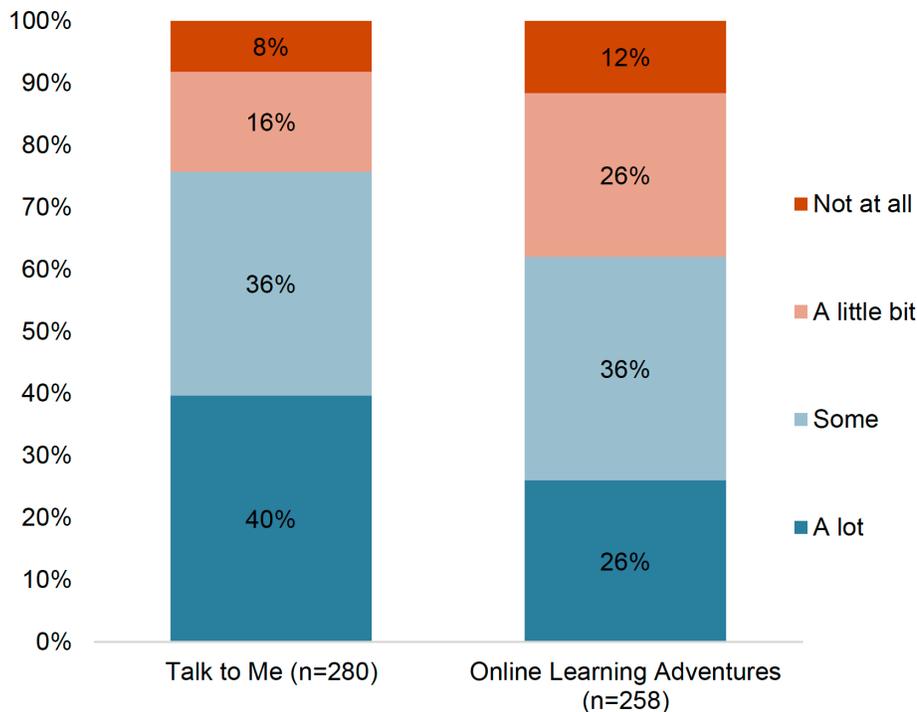
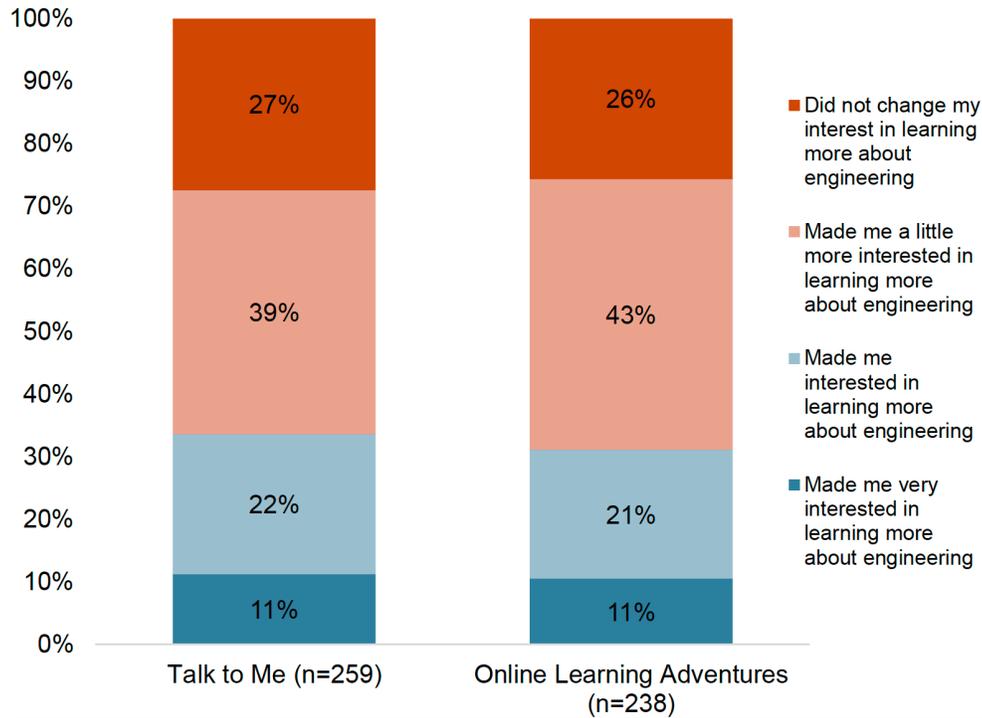


Table 3: Student Responses to How Much the Novel and Learning Adventures Affected Interest in Engineering



Impact of Trapped in Time on Learning Measures for Design

Users who completed the Trapped in Time learning adventure answered an additional three survey questions assessing their understanding of the Next Generation Science Standards for engineering design (see appendix for complete questions). Although the sample size was only 46 respondents (because the Trapped in Time adventure was released late in the school year), the results shown in Table 4 are encouraging and indicate the need for collecting additional data.

Table 4: Student Responses to Engineering Design Questions

Question	% Correct (Pre)	% Correct (Post)	p-value
Kids in a nearby town get to school every day by crossing a bridge. The town realized the bridge is old and not safe, so they asked engineers to help. The town wants to know all of its choices for solving this problem. First, the engineers should:	24	55	0.0025
Engineers are working on a design problem. They know what is needed and are ready to think about solutions. What should they do next?	85	95	0.112
Engineers are working on a project. They have tried several prototypes (models of their ideas) and all have failed. What advice would you give them?	72	82	0.257

Case Studies

External evaluators also completed detailed case studies of TMW used in formal and informal educational settings. They reported that TMW increased student interest in engineering; helped students recognize that engineering requires creativity and imagination; fostered student understanding of failure as part of the design process; and engaged students in engineering ethics. They also noted that formal school teachers praised the multimedia, narrative-based approach and commented on its strength in engaging students. The teachers also suggested improvements such as including more content that doesn't require 1:1 computer access and using shorter stories as opposed to full-length novels.

V. Discussion

The primary goal of TMW is to increase children's interest in engineering and support the development of STEM identity. To accomplish this goal, we combined theory (Imaginative Education) and technology (transmedia learning), which have both been shown to more effectively engage children. Assessment data collected from TMW users shows changing student attitudes about engineering and supports the potential of this combined approach. One user reported, "As kids we really like stories, and this one's a good way to learn and have fun doing it." Case studies provided further evidence and included more details about what was engaging. In one school, it was found that the *Talk to Me* novel and learning adventures "spurred passionate debate in class." It was found that the debates deeply engaged children and forced them to get better at articulating and defending their points of view. In another school, teachers noted the importance of TMW for increasing children's understanding of what sorts of problems are encountered in science, engineering, and design. It was reported that some students were particularly engaged by the idea that design adaptations in nature could be used as the basis for human technological and mechanical design applications, such as a frog's webbed feet and the way a fish tail moves.

Case studies also provided insights on the Trapped in Time learning adventure. Changing attitudes indicated improved student thinking related to the design process, and to the creativity and iteration involved. One student said, "I never really realized that there was so much thought process that goes into creating simple things." Another reported, "It's never just a one-shot thing where it always works out the first time. It takes multiple times." A third noted, "I feel like in this generation we're told to do things in a certain way, so there's like less and less creativity. If we were taught to do things in a different way, I feel like we would have better problem solving skills."

Lessons Learned

Formative assessment has been critical in providing direction for developing Through My Window in a way that best meets the wide range of formal and informal educator needs. This includes developing software that is robust on a wide variety of platforms (including those that may be outdated or that have only minimal support); that requires little or no technical expertise in supervising and supporting its use; and that is modular, flexible, and adaptable to a variety of learning environments and time schedules. We have responded to this need in several ways.

- We published print copies of both *Talk to Me* and *TimeTilter* so that they can be read in a variety of settings that don't require computer access. We also produced an e-reader and an audiobook of *Talk to Me* to provide even greater flexibility for educators.
- We made TMW more modular to allow various components to be combined in different ways and for different lengths of time. Like the printed novel, this provided additional gateways to the online learning adventures and more differentiated instruction.
- We used a different approach for designing and programming the TimeTilter educational website so that it doesn't need to retain and act upon a memory of user choices, inputs, and experiences (as occurs in the Trapped in Time learning adventure). This change resulted in greater robustness across a variety of platforms and simpler implementation for educators and children. The more dynamic approach to integrating the novel and website more than compensated for any loss in the dynamic nature of the user experience.

Future Directions

Future research will focus on conducting a more rigorous assessment of applying Imaginative Education (IE) and transmedia in a controlled setting. In this research we plan to adapt Through My Window to match the learning goals in a city school system in order to assess the potential of this approach for increasing (1) learners' capacities to engage in both far transfer (innovation) and direct application (efficiency) and (2) the formation of STEM identity. This new study will use a mixed methods approach, including a quasi-experimental research design incorporating both quantitative and qualitative data analytic methods. A combination of measures including standards-based science unit tests, existing district student and administrative data sources, student pre-post surveys, and a preparation for future learning (PFL) assessment tool.

VI. Conclusions

We have applied the theory of Imaginative Education to develop Through My Window, a transmedia learning environment for engineering education. Evidence indicates that this approach positively impacts interest in engineering and STEM identity and may have a greater impact on girls or children who initially hold negative views of engineering.

Included in Through My Window is an engineering design learning adventure called Trapped in Time that is consistent with the Next Generation Science Standards. Preliminary results show that students improved their understanding of core concepts related to engineering design. However, the small sample size indicates that additional data needs to be collected.

VII. Acknowledgements

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VIII. Appendix

Questions to assess learning in the Trapped in Time Adventure:

1. Kids in a nearby town get to school every day by crossing a bridge. The town realized the bridge is old and not safe, so they asked engineers to help. The town wants to know all of its choices for solving this problem. First, the engineers should:

- a. Fix the bridge.
- b. Build a new bridge.
- c. Figure out whether a bridge is the best way to get kids to school.
- d. Close the bridge to cars and only let people walk or bike across it

2. Engineers are working on a design problem. They know what is needed and are ready to think about solutions. What should they do next?

- a. Split into pairs to get ideas, then decide which pair has the best idea.
- b. Have each person come up with an idea, then vote on which idea is best.
- c. Work as a group, letting people talk about and add to each other's ideas.
- d. Decide who is in charge and have everyone follow that person's idea.

3. Engineers are working on a project. They have tried several prototypes (models of their ideas) and all have failed. What advice would you give them?

- a. Find out what didn't work and use that to fix your prototype.
- b. The failed prototypes mean you probably can't solve the problem.
- c. Keep trying the prototype; maybe it will work next time.
- d. Start over and do something else.

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