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Mysteries and Heroes: Using Imaginative Education to Engage Middle School Learners in Engineering

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Mysteries and Heroes: Using Imaginative Education to Engage Middle School Learners in Engineering

1. Abstract

This paper examines the use of cognitive tools described in Imaginative Education (IE) in a middle school level engineering education project, *Talk to Me*. Developed by Kieran Egan, IE proposes five different levels of understandings, or ways of seeing and structuring the world, that develop at different cognitive and linguistic stages. The use of cognitive tools that assist learners with different understandings, such as narrative, engages these learners in a way that allows them to learn concepts more deeply. *Talk to Me* is aimed at middle school learners, primarily female students, in order to increase engagement from an early level and encourage further pursuit of engineering education. It consists of a young-adult novel, a website, a number of interactive activities that tie into the novel, and a blog where women in undergraduate engineering programs share their experiences. All parts of *Talk to Me* have been designed utilizing cognitive tools suggested by IE. Beta testing occurred in 2010 with a group of elementary, middle, and high school teachers; the teachers responded with positive feedback, stating that they both could and would use *Talk to Me* in their classrooms. These preliminary results indicate that IE can serve as an effective strategy for engaging learners in engineering.

2. Introduction

The need to increase technical literacy throughout the population has become increasingly well documented over the past decade. At the same time, the need to sustain and diversify the engineering workforce is also recognized to be a critical need. Currently, the percentage of women in engineering fields is significantly lower than that of men, with women representing only about 10% of engineers worldwide according to a 2009 study by the UK Resource Center for Women in Science, Engineering, and Technology.[6] This low number can be attributed to a number of factors that impact women before, during and after an undergraduate engineering education. Goodman et al.[1] found that half of the women who left engineering left because of lack of interest in the field. Smith, Sheppard, Johnson and Johnson[2] highlight the need for increasing engagement in engineering education. They note that engagement affects a student's capacity to learn and to learn deeply, and may positively affect retention rates. Students who withdraw from engineering education often do so because they have become disengaged with the undergraduate engineering curriculum.[3]

Increasingly, engineering is being integrated into pre-college education. Learners in the early stages of their education are often fascinated with the hands-on, experimental aspect of engineering. However, there is increasing evidence that middle school is the level at which girls begin to disengage and lose interest in STEM fields. Day[4] writes: "As early as fourth grade, girls begin to turn off and tune out in science classes and drift away. By the time they enter high school, even if their interest revives, it's often too late. They don't have the foundation to pursue advanced courses." Countryman et al.[5] write about the enrollment disparity in computer science classes as learners enter high school; girls enroll in fewer computer science classes than do boys. The authors reference the influence of a culture in which boys are more often encouraged to explore hands-on activities than girls, and where gender stereotypes in computer games aimed at

younger learners appeal more to boys than to girls. Alice Parker, an engineering professor at the University of Southern California, also notes the importance of engaging female learners with engineering at a young age: "It's important to reach them in middle school because in high school, attitudes and preferences about career choices are already becoming entrenched, and it becomes more difficult to change their minds."[6]

To be most effective, engineering education at the middle school level (and all levels) must not only engage learners, but also support deep, intentional learning. Deep learning connotes an interpretive use of knowledge: the ability to extract knowledge learned in one situation and use it in new and different situations.[8] In *How People Learn*[7], the National Research Council (NRC) presents several findings that help reveal how effective learners gain and utilize knowledge. One of their findings indicates that in order to learn effectively, students must "understand facts and ideas in the context of a conceptual framework," such as narrative.

Successful engineering education thus increases learner engagement, helps retain learners in engineering, and promotes deep learning of the underlying concepts of engineering. To successfully target female engineers, this engineering education should be aimed at the middle school level. The question then becomes, *how should this engineering education be structured?* According to educational theorist Kieran Egan, the root cause of problems in education "stems from a fundamentally incoherent concept of education."[9] In *The Educated Mind*, Egan identifies three old educational ideas: education as socialization in the norms and values of society; Plato's use of reality (one must understand the world before one can change it); and Rousseau's focus on the use of curriculum, and how different developmental processes (such as those of male and female students) affect education. Egan then proposes a new educational idea, focusing on recapitulation and the theories of Vygotsky; these theories concentrate on the incorporation of sociocultural knowledge into education. Egan asks that we "consider degrees of culturally accumulated complexity in language," and the ways in which the development of language restructures how individuals organize their worldviews. Egan finally proposes that the "cause of our difficulties…is…the fact that the components of our conception of education are incompatible with one another."

Rather than trying to formulate a completely new type of educational system, Egan devised a method that utilizes basic understandings that all learners are capable of possessing. Egan's system, Imaginative Education (IE)[9, 10, 11], aims to reconceive education by focusing on different layers of understanding that develop alongside linguistic proficiency. IE centers on a succession of different "understandings" based roughly on different stages of linguistic competency. The use of cognitive tools that engage these various understandings promotes deeper and more meaningful learning. The various stages of understanding are neither mutually exclusive nor identical for every individual; nevertheless, certain shared characteristics among them fall into identifiable patterns. The five different understandings and key concepts associated with them are listed in Table 1.1.

Type of Understanding	Cognitive Tools
Somatic (pre-linguistic)	Bodily senses; emotional responses and attachments; rhythm and musicality; gesture and communication; referencing; intentionality
Mythic	Story; metaphor; abstract binary opposites; rhyme, meter and

(oral language)	pattern; joking and humor; forming images; sense of mystery; fantasy; games, drama and play
Romantic (written language)	Sense of reality; extremes and limits of reality; association with heroes; wonder; humanizing of meaning; collections and hobbies; revolt and idealism; context change
Philosophic (theoretic use of language)	Drive for generality; processes; lure of certainty; general schemes and anomalies; flexibility of theory; search for authority and truth
Ironic (reflexive use of language)	Limits of theory; reflexivity and identity; coalescence; particularity; radical epistemic doubt

Table 1.1 – Understandings and cognitive tools upon which IE is based. Adapted from [11].

Narrative is one of the most powerful and essential cognitive tools suggested by IE. Narrative can provide the conceptual framework that the National Research Council identifies as important for effective learning; it is highly influential in learning new concepts: "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?' They experience events through the protagonists…"[12] Narrative allows emotional as well as intellectual association with given knowledge, and helps learners organize knowledge into a useful framework.

Narrative has already been shown to be effective in engineering education. The Museum of Science in Boston, Massachusetts produces a series of children's books that deal with engineering and technology, called *Engineering is Elementary*.[13] The *Engineering is Elementary* website describes the work of each book:

> Storybooks featuring children from a variety of cultures and backgrounds introduce students to an engineering problem. Students are then challenged to solve a problem similar to that faced by the storybook character. Through a hands-on engineering design challenge, students work in teams to apply their knowledge of science and mathematics; use their inquiry and problem-solving skills; and tap their creativity as they design, create, and improve possible solutions. In the end, students realize that everyone can engineer!

The *Engineering is Elementary* format uses narrative as an engaging device to attract students to engineering, and assist them in gaining significant knowledge through their interactions with the course material. As of 2010, *Engineering is Elementary* had reached 1,781,890 students in every state[13]. However, *Engineering is Elementary* is aimed primarily at elementary aged learners; there exists no similar resource for middle school learners, another important age group to reach.

To meet this need, the authors of this paper developed *Talk to Me,* which applies narrative as a cognitive tool to engage middle school learners with engineering. The core of *Talk to Me* is a young-adult novel that weaves engineering concepts into a plot that IE theory proposes is relevant and interesting to middle school learners. The novel serves as a springboard for a series of activities that utilize cognitive tools specific to middle school level understandings. These tools allow learners to deeply learn certain core concepts and ideas about engineering by engaging with the material and the trajectories of the characters, as well as the engineering

concepts and problems that appear in the novel and on the site. The most appropriate cognitive tools for the *Talk to Me* audience are those for Mythic, Romantic, and Philosophic understanding.

Mythic understanding generally coincides with the learner's development of language. Language develops at the same time as other "modes of sense-making" that help learners organize their worlds.[9] Learning is no longer predominantly coded by genetics at this stage; it is no longer easy, and must occur through outside sources. Mythic learners begin to see the world in terms of binary structures, finding meaning in the intermediary between such dualisms as "hot" and "cold," "male" and "female," etc. Mythic learners are also fascinated by fantasy and abstract thinking, and can utilize metaphors, rhythm, and narrative as tools to learn and remember. Mythic understanding is based on the universality of myths in different cultures, and the traditions and themes that these myths bring with them.

The transfer to Romantic understanding occurs as learners begin to develop literacy. One of the defining features of Romantic understanding is the mixing of mythic and rational: "Imagination is crucial to preserving the capacities of Mythic understanding, but imagination is not in any sense in conflict with developing rationality and its view of reality, seen in the light of common day."[9] Many elementary and middle school learners are entranced with the *Guinness Book of World Records*. Egan cites this as an example of Romantic learners' fascination with the limits and extremes of reality. Romantic learners are also interested in transcendence within reality, and how heroes might interact with reality. They display a passion for hobbies and collecting, and a humanized knowledge that focuses on individuals: "Romantic understanding in particular is constructed by seeing the object of study in the context of someone's or some people's thoughts, intentions, hopes, or fears."

Mythic and Romantic understandings become partially incorporated into Philosophic understanding as the latter begins to develop around age 15. Egan writes that "a proper education today requires that individuals accumulate and recapitulate the intellectual capacities represented by each of these kinds of understanding [Mythic, Romantic, Philosophic], and deploy them together." Philosophic learners enter into more complex systems of thinking; however, their development must be encouraged and supported, because Philosophic understanding does not often develop unaided. The development of Philosophic understanding has been linked to the evolution of complex and abstract written language: it "requires not only a sophisticated language and literacy but also a particular kind of communication that in turn requires particular kinds of communities or institutions to support and sustain it."[9] Learners with Philosophic understanding often crave generality in language; so-called portmanteau words that define broad concepts (such as "society" or "the environment") are used frequently to draw the fragments of Mythic and Romantic understandings together into a cohesive whole. They also begin to understand themselves within a greater context of history and society, and develop an overconfidence in their own beliefs and theories, carrying the attitude that they know everything there is to know. Philosophic understanding is driven by a quest to create general schemes of organized knowledge and to fit new pieces of knowledge into those schemes; "In the inescapable and irresolvable difference between reality and our ideas about it lies the fuel of Philosophic inquiry."

By incorporating a conception of these different understandings and the cognitive tools that accompany them, *Talk to Me* aims to capture the imagination of learners, and spark their interest in engineering. The goal of *Talk to Me* is to engage and interest middle school learners, particularly girls, with the subject of engineering, promoting deep learning. It is being developed as a response to teacher-need for engineering curricula that effectively engage learners with engineering. The use of narrative functions on two different levels to accomplish this goal: the storyline immediately engages learners, and also provides a framework for learning with understanding.

3. Applying Imaginative Education to Design *Talk to Me*

Talk to Me implements the Mythic and Romantic cognitive tools identified in IE through a young adult novel and interactive website. The website is available free of charge at www.talk2mebook.com and contains the novel, several tie-in activities (currently Artificial Intelligence, Design, and Ethics), and a blog. Each of these elements has been carefully planned in relation to IE. The following sections highlight the use of IE in *Talk to Me*, and how specific cognitive tools are used to promote deep learning.

Novel

The core component of *Talk to Me* is a young-adult mystery story with a cast of five main characters. The protagonist is Sadina Reyes, a fourteen-year-old girl who is searching desperately for proof that her mother is innocent of a crime. Sadina's younger sister Maddie knows who really committed the crime, but has a disorder called selective mutism that prevents her from talking. Sadina teams up with her friends to quickly find a way to help her sister communicate. The team learns about brainstorming, respect, teamwork, and communication (all elements of the engineering design process); experiences ethical dilemmas that have parallels to engineering ethics; and explores concepts of artificial intelligence.

The novel draws on two main cognitive tools: narrative and mystery. IE emphasizes narrative as one of the most central keys to learning, at any age. Individuals typically have an emotional response to a story; the reader engages with the writing on a visceral as well as an intellectual level. Humans also "storify" events "in order to understand them in a particular way."[9] By condensing a given series of occurrences into an organized succession, humans can make sense of an event, and organize it logistically. Research also shows that the use of stories to frame any curriculum results in a deeper and more coherent understanding of *all* material.

One of the most engaging narratives for Mythic learners is mystery. Egan writes that, "Mystery is our sense that there is more than we can see and hear and experience in our environment. By opening our minds to this wider, stranger, and less easily accessible world, we create the first tool for its exploration."[10] Mystery makes apparent that humans do *not* know everything about the world and sparks an interest in further intellectual exploration to help "solve" parts of the mystery. In 2005, a group of roughly 100 high school students participating in the Smith Summer Science and Engineering Program were surveyed about what they would want to see in a novel; an overwhelming majority said that they would enjoy a mystery story. This coincides perfectly with the theory of IE, and reinforces the use of mystery as an engaging

element. By framing engineering within the context of a mystery, learners are encouraged to further explore engineering.

Thus *Talk to Me*'s structuring of engineering within the framework of a mystery story is designed to be highly engaging. The characters of the story utilize certain engineering concepts in order to help them solve a mystery, engaging Mythic understanding on two different levels. When placed within the context of a mystery novel, engineering loses both its "scare" factor and its traditional rigid association with math and science disciplines. A young-adult novel that just happens to involve engineering is inviting to many girls who might otherwise shy away from what they view as an unapproachable and technically complex discipline. While engineering is unarguably based in mathematics and science, and thus frightening to certain groups of students, inviting learners to explore engineering in a welcoming, non-intimidating, manner may completely change the perspective those learners have of the field. Indeed, women are often attracted to career fields that help society, and many view engineering as a solely technical field.[6] Helping learners understand the wide-scale impact that engineering can have on society is therefore an essential first step in engaging women with engineering.

The novel's characters are also important to its success. The main character, Sadina, is a dynamic but relatable young woman. She and her friends provide a peer-level connection for middle school learners. Learners become vested in these characters and their trajectories, and are interested in discovering as much as they can about them. This is integral to the presentation of the website and activities, as an interest in the characters encourages learners to pursue them through the various activities. The NRC writes in *Learning Science in Informal Environments*[14] that it is important for students to *perceive* of themselves as scientists, regardless of what stereotypes might otherwise tell them. By identifying with the characters of the novel and their roles as engineers, students are envisioning themselves as engineers, taking the first critical step toward engaging with engineering.

Website

The *Talk to Me* website itself[15] is structured to feel graphically inviting. The first page brings the viewer into Sadina's room, where the desk is visible, with a collection of objects upon which to click (*Figure 3.1*). A speech bubble from Sadina contextualizes the page, and a description of the novel appears when users hover over the book's image on Sadina's desk, providing framing tools. The website serves as the central location for access to the novel, the blog, and the three current activities – Artificial Intelligence, Engineering Design, and Engineering Ethics. These three activities form the second core component of *Talk to Me*. They draw on the concepts and characters introduced in the book, but can also serve as standalone activities.

Figure 3.1 – Screenshot of Talk to Me *homepage*

Artificial Intelligence

Artificial intelligence (AI) is an engaging and dynamic field of engineering that has particular relevance for framing engineering according to the framework of Imaginative Education. Learners in both the Mythic and Romantic stages of understanding are developing binary understandings and a fascination with the extremes and limits of reality.[9] The questions that frame the AI activity are formulated according to these understandings, placing the activity within a context with which middle school learners can grapple. For instance, Think, Inc. (described below) asks the question, "Do you think chatterbots will ever pass for humans?"

The AI activity is set at Rio's (Sadina's friend) house; different rooms host different components of the activity. The design of this page, like the entire website, allows learners to explore and discover new things; it places the engineering work in a non-traditional media and format. There are three main components to the AI activity (see Table 3.1).

Component	Description	Relation to IE
"Rio's Dream"	Simplified comic book version of Daniel Dennett's "Where Am I?" story, a philosophical exploration of the mind/body duality	Narrative; limits and extremes of reality
"The Imitation Game"	Brief introduction to a simple party game that sets the stage for Alan Turing's Turing Test	Binary structuring; abstract thinking
"Chatting with Chatterbots"	Tips and links to chat with web-based Chatterbots, online computer programs that strive to converse like humans	Limits and extremes of reality; humanized knowledge

Table 3.1 - Components of AI activity

All three components work together to introduce complicated AI concepts to middle school learners on a basic level, while simultaneously encouraging them to explore further. Attached to every individual component are two links: "What's the Connection?" and "Think, Inc." Both pages provide further questions and links that set the stage for the development of deeper understandings. "What's the Connection?" and ""Think, Inc." appear on nearly every component of all three activities currently on the site.

One of the most engaging components of the AI activity is the "Chatting with Chatterbots" activity (*Figure 3.2*). Consistently an attraction to learners interacting with the website for the first time, the ability to carry on a conversation with a computer is immediately engaging to middle school learners. This ties in to Egan's concept of Romantic Understanding, as learners begin to grapple with the extremes and limits of reality, and what it means to transcend the idea of reality. The chatterbots also provide a form of humanized knowledge. Egan writes that "Romantic understanding in particular is constructed by seeing the object of study in the context of someone's or some people's thoughts, intentions, hopes, or fears" (Egan, *The Educated Mind*, 93). The chatterbots are contextualized as an ongoing quest to develop a computer that can converse in a manner identical to humans, framing AI as a human pursuit. The AI activity allows learners to explore the extremes and limits of intelligence and technology, while simultaneously seeing the very human creators of this technology.

Figure 3.2 – "Chatting with Chatterbots" in AI Activity

Engineering Design

Engineering design is a concept foundational to engineering and state educational frameworks. One of the most important steps in providing an alternative, highly engaging curriculum such as *Talk to Me* is making sure that teachers actually use it; already pressed for time, many teachers cannot add yet another unit into their classroom. Therefore a successful strategy for changing the engineering education must *replace* what is already in the curriculum.

The Engineering Design activity helps teachers comply with the Massachusetts Science and Technology/Engineering Curriculum Framework[16] and other standards. The activity focuses on the use of the design cycle both in engineering and day-to-day life, and aims to address the ways in which the engineering design process works and how individual leaders and teams can function in this process. Table 3.2 lists the components of the Engineering Design activity.

Component	Description	Relation to IE
"Chattercat in 8 Easy Steps"	Interactive overview and graphic of the design cycle that links what happens in the novel to the steps of the design cycle	Narrative
"Dress to Impress"	Relates the design cycle to making other decisions – in this case, buying a new pair of jeans	Narrative; broad-based perspective on engineering
"What Kind of Team Player Are You?"	Presents different styles of leadership (connected to the major characters of the novel)	Games

Table 3.2 – Components of Engineering Design Activity

The two design-cycle based activities of the Engineering Design activity help contextualize the engineering design cycle by making the cycle a concrete reality rather than a series of abstract terms (*Figure 3.3*). The design cycle is associated with the novel itself by identifying the characters' use of the cycle. Learners interact with the plot and the characters to a high degree in the Design activity, even aligning themselves with the characters themselves in the leadership activity.

Figure 3.3 – Engineering Design Cycle in "Chattercat in 8 Easy Steps"

Engineering Ethics

The Engineering Ethics activity provides a context to engineering that helps learners understand engineering as a discipline highly integrated with society, culture, and everyday life. The activity also draws in large part from the novel, in which both Sadina and her mother have to face and make tough ethical decisions. Organized like Sadina's diary, with each day's entry leading to a different activity, the format itself draws upon the idea of narrative (*Figure 3.4*). The components of the Engineering Design activity are listed in Table 3.3, below.

Component	Description	Relation to IE
"The Loyalty Quiz"	A short quiz that helps learners identify the balance between being loyal to their friends and making wise decisions	Games and play
"6 Keys to Acting Ethically"	Learners hunt for six "keys" in a treasure map; each key identifies a step in making an ethical decision	Games and play
"Discover Your Ethical Style"	Instructions and layout for folding an origami box upon which learners answer questions about their ethical "style"	Games and play
"Case of the Unstable Building"	Choose-your-own ending story that deals with the true case of the Citicorp Center	Extremes and limits of reality

Table 3.3 – Components of Engineering Ethics activity

The Engineering Ethics activity contains the "Case of the Unstable Building." This activity is a challenge even to older students, because each step of the activity requires a hard ethical decision. With a difficult activity, it is important to ensure that the target age group will still find it accessible. This is done by framing the activity within a real-life situation, the Citicorp Center, which deals with the extremes and limits of reality. The activity prompts a number of other questions about buildings, such as: how tall can a building be? Ultimately, the Engineering Ethics activity helps learners establish a strong ethical framework from the outset and form a set of beliefs that will help guide them through their engineering work, as well as all other interactions.

Figure 3.4 – Landing page of Engineering Ethics activity

Blog

The final major component of the website is a blog in which two Smith College undergraduates frequently post entries. One student is a current sophomore double majoring in Anthropology and Engineering; she shares specific insights from her various engineering classes, explaining projects and concepts in an understandable manner. The other student is a first year whose major is undecided, but who is taking Engineering 100 (the introductory level engineering course at Smith). While she may not ultimately pursue engineering as her major, the second student shares her initial experiences with engineering, the things she is learning in the introductory course, and the factors that go into her decision making process regarding major selection.

The concept of the blog is based on the theory that by creating role models in science and engineering, girls are more likely to consider those fields when they make career choices. Buck et al.[17] cite a large amount of current research that "does show that students are more likely to enter a profession when they are able to identify a role model in that occupation (Betz, 1994; Hackett & Betz, 1981; Lent, Brown & Hackett, 1994; Zirkel, 2002)". Buck et al. also find that in online mentoring, "getting people online is not enough; attention must be paid to building online conversation spaces, activities, support and facilitation to make these mentoring experiences work." Researchers have identified a number of guidelines for effective scientific role modeling. Table 3.4 (adapted from [17]) details some of the guidelines that the *Talk to Me* blog follows.

Guidelines for effective scientific role modeling
• Science roles models should show that they are not one-dimensional: they should share interests outside of science, and different sides of their personalities • Science role models should also share sections of their personal lives to help contextualize themselves within a greater community • Science role models should not appear perfect: they should acknowledge imperfections and mistakes, both in themselves and in other scientists • Science role models should demonstrate their love and passion for science, and show off their scientific knowledge • Interaction between the science role model and the student should occur often

Table 3.4 – Guidelines for effective scientific role modeling. Adapted from [17].

The *Talk to Me* blog includes descriptions of both success and failures in projects and labs, illustrating that engineers are not perfect. It allows students to comment and ask questions, furthering the interaction between the bloggers and learners. It also shows different sides of the bloggers' lives, including interests such as activities, television shows and other areas of study. All of these are part of what makes female students see engineers as role models, which in turn makes them more likely to see engineering as a possible career.

It is important to note that these activities, and the blog, do not – as of yet – aim to teach learners all there is to know about engineering. Rather, learners are introduced to the field in an inviting manner; they gain an interest in engineering without being overloaded with concepts and exercises. Learners who are interested in what they are learning are inherently prepared to learn more.[9] Therefore, by providing an accessible and inviting entry method into engineering, *Talk to Me* aims to encourage girls to pursue engineering at a higher level.

4. Teacher Use of *Talk to Me* Website

Talk to Me was launched in fall 2010, so there is currently limited data on its use. An early version of the website was pilot tested with a group teachers from Springfield Public Schools in summer 2010. The University of Massachusetts Donahue Institute conducted an independent assessment of the teachers' reactions to and suggestions for the website. The *Talk to Me* project also had a booth at the USA Science and Engineering Festival in October 2010, where an updated and expanded version of the website was demonstrated to numerous visitors – students, parents, and educators. Anecdotal evidence from this experience provides a useful gauge of middle school learners' reactions to the site.

Summer 2010 Professional Development Workshop

Summer 2010 marked the first pilot study of *Talk to Me* with a group of elementary, middle, and high school teachers from the Springfield, Massachusetts public school system. This high needs community was the target of a two-year National Science Foundation MSP-Start Partnership among Springfield public schools, Springfield Technical Community College (STCC), and Smith College. The three institutions worked together to create a series of summer professional development workshops, entitled "Drafting a Blueprint for Teaching Tomorrow's Engineers Today."[18] These two professional development workshops were composed of two-week summer sessions in both 2009 and 2010. In the summer 2010 workshop, instructors

introduced concepts of Artificial Intelligence to the teachers attending. *Talk to Me* was presented as a tool to help teachers integrate the concepts of AI into their classrooms.

Table 4.1 lists the day-by-day activities of the teachers in the AI portion of the summer 2010 PD workshop.

Day 1	• introduction to Alan Turing
Day 2	• introduction to *Talk to Me* • visit with author (Sonia Ellis) • Imitation Game • read Daniel Dennett's "Where Am I?"
Day 3	• Chatterbot activity and discussion • introduction to Kieran Egan and the use of story
Day 4	• planning time for day with STCC Robotics Camp students
Day 5	• day at STCC, working with Robotics Camp students and *Talk to Me*
Day 6	• construction session (no AI work)
Day 7	• lecture on machine consciousness and the Chinese Room story
Day 8	• reporting out on concepts and ideas gained from workshop

Table 4.1 – AI portion of summer 2010 profession development workshop

Participants spent about three hours every afternoon learning about AI and *Talk to Me*. In the mornings, participants completed workshops on construction. Though some participants from the 2009 workshop also participated in 2010, the latter workshop had a number of new participants. Importantly, teachers stated that they had learned more from the AI section of the workshop than any of the other sections.

The initial version of the *Talk to Me* website used for the 2010 PD workshop contained only the Artificial Intelligence activity. The teachers' responses were a major tool in helping frame the site's further evolution and development. Teachers were given certain activities to focus on, as well as given time to explore the site on their own. The Donahue Institute analyzed the teachers' use of the site and conducted pre- and post-workshop studies to determine knowledge gained, thoughts about the workshop, and thoughts about *Talk to Me*.

Overall, the study showed that teachers developed a deeper understanding of engineering and the ways in which they could bring engineering into their classrooms in an engaging manner. Teachers also responded positively to current and future use of *Talk to Me* with their students. The final teacher survey demonstrated that:

- Over 85% "strongly agreed" or "agreed" that if the current activities on the TTM website (AI, design, ethics) were all fully operational they would use TTM in their classroom.
- Over 85% "strongly agreed" or "agreed" the content of the TTM website is more likely to engage students in engineering than what was currently available for them to use.
- Over 92% "strongly agreed" or "agreed" the characters and story of the TTM website are more likely to engage students in engineering than what was currently available for them to use.

- Over 92% "strongly agreed" or "agreed" the look and feel of the TTM website is more likely to engage students in engineering than what was currently available for them to use.

In addition to using the site on their own, the teachers had the opportunity to use *Talk to Me* to create a lesson plan for a group of middle school students at a summer robotics camp held at STCC. The teachers were given an afternoon to brainstorm and collaborate to create a lesson plan; *Talk to Me* became an integral part of this lesson plan. The teachers began with the Imitation Game, then allowed the students to access the website. The teachers then wandered among the students as they used the website, encouraging the students to use different parts of the site, to try out the chatterbots, etc. One teacher also made a presentation on Alan Turing, lending the day some factual background.

Both the teachers and the students at STCC found this exercise rewarding. One teacher wrote that he or she, "Enjoyed working with colleagues to plan a lesson for the students at the Robotics Camp at STCC." Another wrote that he or she, "really like[d]…working with the Talk to Me website and going to STCC to see what kids were doing in Robotics Camp." Teachers found overall that the students seemed to enjoy the *Talk to Me* activities and stayed on the website, rather than going to other sites. They also engaged with the *Talk to Me* storyline, which the teachers presented through a short skit. Teachers remarked that the novel was age appropriate and interesting to learners of any gender; one teacher said that a student had asked where he could buy the book, so he could read all of it.*

The teachers indicated that the AI material they were sharing with the students was "pretty heavy duty" for them and difficult to get across in a one-day workshop. Nevertheless, several of the teachers felt that the activities managed to get the students thinking about the central question, "Can computers think?" The only major concerns regarding the use of *Talk to Me* centered on logistical issues. With the group of educators ranging from elementary to high school teachers, many felt that it would be important to delineate certain activities for certain age groups, so that sections were not repeated. While the project is aimed at middle school learners now, this is certainly an element of expansion to be considered for the future. It is also difficult within the Springfield school district to secure reliable access to computers and Internet connection. This raises a difficulty that needs to be addressed before *Talk to Me* can be fully implemented in the Springfield school district. However, some teachers are able to gain access to computers.

The teachers also discussed different ways of using *Talk to Me* in the classroom, taking the curriculum into their own hands. The idea of using *Talk to Me* for interdisciplinary learning was popular. Teachers discussed incorporating it into English language arts (ELA), mathematics, and history classes, as well as science and technology classes. They noted that important vocabulary words could be drawn out of the story and used as educational tools in both ELA and science classrooms. One teacher said, "I like that *TTM* incorporates science/engineering as a concept. I also like the ethical subplot that could be used in an Advisory class. Finally, the well-written plot can be used in ELA class. This interdisciplinary

* As previously noted, the novel is available on the website, free of charge.

approach will work well in my school." The idea of using *Talk to Me* throughout the curriculum is an idea that fits very well with Imaginative Education: with a unifying factor throughout all classes, learners might be better able to contextualize the information that they are learning, and put it to meaningful use.

Though one teacher noted that *Talk to Me* is "sellable with the kids" and that its content and metaphors would transfer well to an engineering class, other teachers noted an increased need for interactive elements on the website, such as quizzes and games. Their identification of this as a tool for deeper learning demonstrates the importance of play as a cognitive tool. Egan notes that many have identified play as an important, even essential, stage of development; the ability of players to take on different roles makes play "a cognitive tool of immense value and varied forms."[10] While what Egan terms electronic play is considered to detract from physical play, the engaging aspect of games remains high; therefore, it would be important to balance games on the *Talk to Me* site with offline activities. Open-ended responses revealed that teachers enjoyed the interactive features and the narrative component of *Talk to Me* most, because they felt that there were the features most likely to engage students.

Another important element the teachers highlighted, particularly relevant to *Talk to Me*'s implementation in Massachusetts, was the need for *Talk to Me* to be designed around the Massachusetts Science and Technology/Engineering Curriculum Framework. One teacher stated that the, "Current version [would fill classroom needs], yes – future version around standards, even better. I would tie in standards that apply to the other disciplines as well (when you do it) Math, ELA, Social Studies (ethics), etc. I really like the fact that the story ties in so many science vocabulary words that the kids need to learn. I'll definitely use it." Another teacher noted that, "It would definitely get my students talking! A future version tied to the National Standards will probably be best!"

USA Science and Engineering Festival

The USA Science and Engineering Festival culminated in a two-day exposition on the National Mall in Washington, DC in late October 2010. *Talk to Me* had a booth at the exposition, and received a large amount of foot traffic. Visitors to the booth were encouraged to sit down and try out the website, browse the book, or talk to any one of the team members to find out more about the project (*Figure 4.1*).

Figure 4.1 – Talk to Me *booth at the USA Science & Engineering Festival*

Cards were handed out that featured three of the five characters from the novel, with the website and project information listed on the back. Several learners immediately identified with the characters on the cards. A few younger students were intent upon getting the full set of cards, which connects intriguingly to a core component of Romantic understanding: collections and hobbies. Egan writes that "Students commonly put immense intellectual energy into collecting a set of something…This urge to securely understand something can be used extensively in education."[10]

5. Discussion

The data in Section 4 present information relevant to advancing the *Talk to Me* project and analyzing its potential effectiveness with middle school learners. This was a pilot study and more research is necessary; however, the teachers provided positive and important data. For *Talk to Me* to be successfully implemented in the schools, it must have teacher support. Therefore, the ability to show it to teachers early in its development allowed them to give input, and gave the project team a better feel for how teachers interact with the material. The opportunity for feedback also encouraged teachers to have a voice in the project. Therefore the initial pilot testing of *Talk to Me* with the Springfield public school teachers was successful.

The high percentage of teachers who stated that they would plan to use *Talk to Me* in their classrooms was perhaps the best success. If teachers are willing and excited to use *Talk to Me*, then they will transfer this excitement to their students. Teachers also said they had learned more from the AI section of the PD workshop than any of the others. This could indicate low background knowledge of AI, but also indicates that the techniques used to teach AI were strong and effective. These strong and effective techniques are the same ones found in *Talk to Me*, and therefore can be expected to be successful with pre-college learners.

One of the main concerns that teachers brought up is the logistics of actually being able to use *Talk to Me* in the classroom. Springfield Public Schools have a limited number of computers, and Internet access isn't always reliable. Additionally, certain sites will be blocked, and if learners need to access links off the *Talk to Me* page, those links would need to be cleared with the school system. One possible solution for this problem, a problem not unique to the Springfield school district, is the interdisciplinary use of *Talk to Me* that the teachers suggested. Learners could read the novel in ELA classes, work on the scientific vocabulary in science classes, and use the website in technology classes. This would necessitate that teachers plan lessons cooperatively, something that several of the participants in the PD workshop indicated is not common to the Springfield school system. Therefore, to successfully implement *Talk to Me* in this district, several steps need to be taken:

- The age/grade level that the project will initially be aimed at needs to be solidified, so that there is limited repetition of the activities. Currently, *Talk to Me* is suited to a middle school learning level.
- Technology concerns need to be addressed. Communication with leaders in the district about computer and Internet access, as well as website blocking, needs to occur. While it might be difficult to add more computers, partitioning *Talk to Me* into different sections for use online and offline is a possible solution.
- In this vein, interdisciplinary discussion between teachers should be encouraged. Teachers from different disciplines should be given the time to work together so that they are able to examine how their various classes might fit together best. Indeed, this does not apply only to *Talk to Me* – any manner in which classes might fit together would be beneficial for learners.

The other major element that teachers identified as an area for improvement was compliance with the Massachusetts Science and Technology/Engineering Curriculum Framework.[16] These standards and those for other subjects provide guidelines for teachers to follow in all of the disciplines they teach; students must have a certain amount of knowledge in order to take the Massachusetts Comprehensive Assessment System (MCAS). This places demanding time limitations on teachers, giving them a large amount of material to cover in a short time. Therefore, the more engaging the material they can use, the better. If *Talk to Me* could be used to help teachers comply with the engineering section of the Massachusetts standards, it would function as a time saver as well as a better educational tool. Thus development of *Talk to Me* has and will continue to keep these standards in mind. Since these frameworks are not unique to Massachusetts, their inclusion in the project will allow more teachers in more states to more readily adopt *Talk to Me*.

There are a number of other developments for *Talk to Me* that will occur in future iterations of the project. These are designed to increase its accessibility and add to the depth of activities and amount of information available on the site. The next stage of development for *Talk to Me* will begin with a novel, a sequel to the original. The same characters that appear in the first novel will continue to discover how engineering interacts with middle school life in the second novel. Steps will be taken to heighten access to the book; it will be available online not only as a PDF, but also as a downloadable version for e-reader devices, and as part of a highly interactive online reader tool. The connection between the books and the activities will be

strengthened by allowing users to access the activities directly from correlating sections of the book, and even play some short games and quizzes within the pages of the book itself.

The addition of new activities is another core element of the next stage of *Talk to Me*. Two additional activities will be based on Sustainability and Bioengineering, both areas of engineering that research has shown to be particularly interesting to middle school age girls. Karen Panetta, an engineering professor at Tufts University, claims that "the chemical and biomedical engineering fields are by far the most popular for women, who understand the social mission of these fields is to help individuals by using technology to cure diseases or develop assistive technologies"[6]; the same might be said to apply to the field of sustainable engineering. Like the existing activities, both will be carefully framed by narratives guided by IE. The sustainability activity will follow the narrative of Hurricane Katrina and its aftermath. The activity's leader, Monica, will ask learners to analyze their own energy use, as well as question and understand the definition of sustainability itself. Learners will ultimately relate sustainability to engineering, designing a building that incorporates sustainable features. The narrative of the bioengineering activity will focus on new developments in prosthetic limbs and nanotechnology. Design elements and real world situations will be incorporated, to help learners understand how bioengineering functions within the wider world. Careful research and discussion with educators, informal education professionals, and students will be conducted to determine successful topics for other new activities. Possible units include one about learning and different theories of education, and one about computer programming and software engineering.

In addition to these new activities, new elements of interactivity will be added to the website. Most important among these is the use of a portfolio tool that functions as a mechanism for knowledge building. The portfolios will be composed of quiz results, ideas, and designs created throughout the site. Serving as a profile page for the user, the portfolio will also be customizable. Highly monitored forums will allow users to interact with each other, and leaders such as Girl Scout troop leaders, afterschool activity directors, and teachers, will be able to create private group forums for students that will help them engage with both their classroom and extracurricular work. Through collaboration and discussion, users will interact with the material on an even higher level, while simultaneously creating a portfolio that will contain designs and ideas that have potential to serve them later in their academic career.

These portfolios and forums are based on recent educational research concerning knowledge building. New problems facing future engineers will need to be solved through the production of new knowledge. Though some of these new solutions will be formed through innovative use of existing technical knowledge, many will be formed through collaboration with peers. Knowledge building environments aim to prepare learners to interact with each other in this formation of new knowledge. Both the portfolios and online forums on the *Talk to Me* site will serve as knowledge building environments. Each forum will be prompted with a question, such as "Do you think chatterbots will ever pass for humans?" Learners are encouraged to generate and post ideas, which eventually formulate themselves into working groups and concepts that function collaboratively. The forums rely on the use of discourse as an important knowledge building tool. Knowledge building is the subject of much research and development[19, 20], and has been used in a number of different educational contexts. Knowledge

building helps learners address authentic problems and ideas, work productively with others to form new ideas, and learn how to use authoritative resources.[21] Knowledge building theory also assists in motivating learners by providing a knowledge problem to be solved, and a community of which to be a part.

The final step to help increase availability of the site will be to create a mobile phone application. Though the novel and website are already accessible on mobile devices, the creation of a specific application would work toward the goal of allowing the greatest number of users to access the novel, site, and activities, in the greatest number of venues.

Ultimately, the data from the teachers provided an initial positive response, and a number of ways in which to move forward with the project. Though further research is required, the pilot testing was important to validate the importance, necessity, and niche for *Talk to Me*. The enthusiastic response that the teachers provided was important both for them and for the project; their input will help tailor *Talk to Me* to teacher needs, and allow the project to reach the maximum number of people, in order to accomplish its goals.

6. Summary and Conclusion

There is a clear need to prioritize engineering education; all students should be engaged in engineering at some point in their educational trajectory. This need is particularly relevant for female students. To accomplish this, engineering education must be effective in engaging students and encouraging them to learn deeply. The theory of Imaginative Education provides a useful toolset with which to do this. *Talk to Me* utilizes the cognitive tools of IE to engage middle school learners, particularly girls, in engineering.

Though research data to this point is limited, initial investigations demonstrate a positive response. Teachers from the Springfield public school system engaged with the beta version of the website, and indicated that they both could and would incorporate it into their classrooms in some format. Additionally, students at the STCC robotics camp indicated interest in the website and the activities, and engaged with the plot line of the novel.

Preliminary results appear to support that the theory of IE is an effective device for engaging students in engineering. The toolset it provides is tailored to the appropriate age levels, but also allows for flexibility within a curriculum. Likewise, the *Talk to Me* site can be utilized in many different ways; teachers can pick and choose elements of the site that they feel are best suited to their individual classrooms, adding a level of customizability.

However, future research is needed as the project moves forward. In particular, analysis of student use of the website is needed both to better tailor the navigability and functionality of the website, and to understand better how learners will utilize the different portions of the site. Consultation with educators, informal education professionals, administrators, and students themselves will serve as an important guide for additions and modifications to the project.

Overall, the pilot version of *Talk to Me* has proven to generate interest and enthusiasm among teachers, an important element in wide-scale implementation of the project. This

enthusiasm suggests that IE can be a powerful tool in engineering education. *Talk to Me* might prove to be a first step in engaging young women in engineering, and encouraging them to pursue higher-level engineering education and professional engineering. It can do this by engaging learners in engineering, providing them with a conceptual framework, and promoting deep learning. With a deep understanding of the underlying concepts of engineering, learners can apply engineering to their daily lives and cultivate an interest in pursuing further education in engineering.

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