Social Robot Teaches Cybersecurity

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Abstract
Social robots have recently been gaining attention in the education field. Given their capabilities, researchers can use social robots in various ways that support human-robot interactions. In this paper, we present an interactive cybersecurity education program to teach children about foundation cybersecurity concepts using a social robot. To create child-robot interactions in cybersecurity education, we devised three processes. First, in collaboration with practicing teachers we developed an interactive story to support student engagement and learning of cybersecurity concepts. Second, we prototyped animations for the story on the social robot. Third, we use a mixed-methods approach to pilot test our cybersecurity education program. Our research highlights the potential of social robot use in education, both for child-robot interaction and K-12 cybersecurity education.

Author Keywords
Social robots; K-12 education; STEM; Cybersecurity education; interest development; Collaborative learning

CSS Concepts
• Human-centered computing→Empirical studies in HCI; • Social and professional topics → Professional topics → Computer education→ K-12 education; • Applied computing → Collaborative learning.

Figure 1: Zenbo is a social robot designed and manufactured by ASUS. [11]

Figure 2: Fifth graders at The College School, located on UD's Newark Campus, interact with Zenbo the social robot source:https://www.udel.edu/udaily/2020/february/teaching-tools-cybersecurity-kids/

Introduction

This generation of children is the first to grow up with digital media and technologies so deeply embedded in their lives. Recent data indicate that children ages 8-12 spend approximately six hours online consuming digital media on computers, tablets and smartphones [14]. Many children now have Internet access in their bedrooms through wireless routers and handheld devices. At the same time, online threads are becoming more sophisticated, damaging, and potentially dangerous, making children and their families vulnerable to online risks [15]. For instance, as children make greater use of technology, sensitive data (e.g., passwords) are stored on the devices making them targets of cybercrime.

Educating children at an early age is one way of addressing the dangers that lurk online and safeguarding against them. The Computer Science Teachers' Association (CSTA) and the International Society for Technology in Education (ISTE) acknowledge digital citizenship as a key competency of this new generation of students. Yet this effort does not provide actionable guidance for education. The field desperately needs *models* of K-12 programs that aim to both prepare and generate interest in cybersecurity careers among current students. A student population of particular interest is upper elementary age students. This age group represents a prime population for generating interest in cybersecurity education because research indicates that it is during elementary and middle school years that students become aware of social stereotypes and make decisions related to future engagement with computing fields [1,2].

In this paper, we describe our iterative development of a promising approach to cybersecurity education that utilizes interactive storytelling to advance students' learning of and interest in key cybersecurity concepts. We also discuss our plans for pilot testing this approach. Storytelling is a powerful means to advancing student learning because it can take complex ideas and present them in simpler and actionable steps [3]. The stories developed in this work address three cybersecurity concepts included in the ISTE and CSTA standards: *safety, privacy and security*. We deliver these stories through the use of a social robot, Zenbo. The use of physically embodied robots as learning companions can provide students with an interactive experience where they can influence the storyline through actions, resulting in greater engagement and desire to continue interacting with the system [4,5].

Related Work

Much research has been conducted in using social robots to support interactive storytelling in children across K-12 grades [7,8]. To date, researchers found that incorporating robots in interactive storytelling supports user engagement and serves as an aid in the instructional process [6,7,8]. Moreover, researchers have found evidence that the physical presence of a robot compared to a video-represented robot with accompanying voice can result in greater cognitive learning gains for participants [9]. The use of the social robot in this case, could act as a learning companion and tutor that helps supplement existing cybersecurity lessons and curricula. Importantly, social robots can *personalize interactions* with students over multiple encounters through adaptive learning algorithms [10].

Figure 3: Captain Cyber Story

Figure 4: Little Red Riding Hood

Social Robot

Social robots are autonomous robots that interact and communicate with humans by following social behaviors and rules attached to a role (see Figure 1&2). With social behaviors introduced, social robot could fundamentally reshape how we interact with machines.

In our work, we use Zenbo [11] as our social robot platform. Zenbo is an off the shelf robot for home and office use, which provides educational, personal assistance, entertainment, senior citizen healthcare, and other functions through voice and touch interactions.

Approach

There are four inter-related goals that are driving this work, including: (a) iteratively design a collection of interactive stories addressing key cybersecurity concepts; (b) prototype the stories on the social robot Zenbo; (c) increase children's knowledge of key cybersecurity concepts and understanding of the importance of cybersecurity; and (d) create instruments for monitoring project goals and participant outcomes. The work will be situated in formal and informal settings (e.g., elementary schools, libraries, etc.) in the United States.

Interactive Story Design

To increase the engagement of students in cybersecurity education, we designed an original story series based on a comic superhero and recreated a popular Grimm's fairytale. The story narratives are anchored in the ISTE and CSTA standards for *safety*, *privacy*, and *security*.

The first story features a superhero called Captain Cyber who lives in cyberspace and protects students as they use the Internet by teaching them about cybersecurity. In this story, we have two additional main characters named Louisa and James (see Figure 3). They are in 4th grade and have been best friends since they were five years old. They enjoy playing an online game together on the Captain Cyber website. The story starts on the day that a new Captain Cyber game is released. As the friends prepare to play the game, they are faced with a login issue after James enters his username and password. It seems that the website looks different and may be a *phishing* site. The two friends are then pulled into the video game and meet their long-time hero, Captain Cyber. Captain Cyber teaches the friends about phishing sites, what to do to identify a phishing site, and encourages the friends to ask an adult for help with navigating these sites. Throughout the story, students have opportunities to respond to questions related to the cybersecurity topic that is being explored. Below we present one such example:

Louisa and James both go online to Captain Cyber's website and enter their username and passwords. Louisa is able to log in with no problem but James notices something strange when he gets past the log in page.

WHAT SHOULD JAMES DO?

A. GET OFF THE SITE AND ASK A PARENT FOR HELP

B. CONTINUE ANYWAY

IF CHOOSE A: That is correct! If something seems different about a website that you usually use, check in with an adult to make sure there is not a problem with the site.

IF CHOOSE B: That is NOT correct! If something seems different about a website that you usually use, do not continue to the site. First, check in with an adult to make sure there is not a problem with the site.

Our second story is adapted from the well-known fairytale--Little Red Riding Hood (see Figure 4). In this story we embed lessons concerning *password safety*. Little Red Riding Hood is told to remember the password to get into her grandmother's house and is warned to not share personal information with strangers that she may meet on her trip to her grandmother's house to deliver food. Like the Captain Cyber story, opportunities are provided throughout the story for students to respond to questions on the cybersecurity topic that is being covered. Below is an example from this story:

"Oh, hi wolf!" says Little Red Riding Hood. "I am going to my grandma's house; she isn't feeling well and I'm bringing her some food."

"Oh, that's very kind of you," says the wolf, "you know what? I saw some flowers a little way back, and I bet she'd love some! Flowers always help me feel better.

WHAT IS YOUR GRANDMA'S FAVORITE TYPE OF FLOWER?

A. MY GRANDMA LOVES ROSES

B. I DON'T WANT TO TELL YOU

If CHOOSE A:

"She loves roses!" says Little Red Riding Hood, she loves them so much that you have to say rose to get in her house."

The wolf then runs to grandma's house and uses the rose as the password to get in and take all of grandma's personal belongings while she sleeps.

IF CHOOSE B: That is correct! You should not tell the wolf your personal information.

In our third story, students learn about safety when *sharing information online*. Louisa is home sick from school and starts talking online with someone she believes is another child from her neighborhood. In this story, her father intervenes and talks about rules for online safety. Again, we provide opportunities for students to interact throughout the story. An example of this follows:

SHOULD LOUISA RESPOND TO THE PERSON NOW THAT SHE KNOWS IT IS NOT JAMES?

A. YES, IT IS THE NICE THING TO DO

B. NO, YOU SHOULD NOT TALK TO STRANGERS ONLINE

IF CHOOSE A: No, you should only talk to people you know online. Let's see what Louisa does.

IF CHOOSE B: That is correct! You should only talk to people you know online. Let's see what Louisa does.

Program Development

To determine the salient content and infrastructure for the intervention, we conducted focus groups with practicing teachers. A total of four teachers were recruited to participate in six focus groups (1.5 hours each). As part of these focus groups, teachers provided feedback on the quality of the stories and suggestions on how to modify stories to support student engagement and learning. Through an iterative process, we have used teacher feedback to make improvements to the stories and have explored the best ways to use the stories as part of classroom instruction. Examples of

changes made to the stories include adding clarifying language for words like "phishing", reducing the speed of the narration of the story, and adding more opportunities for students to interact with Zenbo through questions. We also plan to pilot the stories with students to gain further understanding on whether students find the stories engaging and informative.

A student sample size of approximately 30 students in grades 3-5 will review the revised stories delivered on Zenbo and will provide feedback based on probing questions and observations to determine their level of engagement and understanding. By including teacher and student feedback at this stage of our work, we hope to increase the feasibility, social validity, and sustainability of the intervention.

Pilot Study

In our next phase of work, we will use a mixed-methods approach to support the pilot testing of our cybersecurity education program. An advantage of mixed methodology is that the methods complement each other and allow for a more robust analysis than otherwise possible [12]. We will employ a multistage evaluation mixed methods design [13]. A multistage evaluation design will allow us to evaluate the success of the use of Zenbo as part of cybersecurity education in upper elementary classrooms.

We will pilot the integration of Zenbo into formal 3rd -5th grade classroom environments. Implementation will occur in 3 schools as part of their technology/library class. We will conduct two student pilot study groups per school for a total of 6 groups and will examine students' perceptions of working with Zenbo. We programmed Zenbo to interact with the students by telling the stories and leading the discussion with children about the story. A pretest/posttest design will be used to examine student knowledge and application of cybersecurity concepts as well as student interest and participation in computing. Teacher and parent consent as well as student assent will be collected prior to initial data collection. Participating students will complete a pre-test measure of their application of cybersecurity concepts and attitudes toward computing one week prior to the intervention, and after the intervention to assess changes to the application of and attitudes related to these concepts. To examine changes in knowledge, students will take a pre-test on the cybersecurity topic to be covered in that lesson prior to interacting with Zenbo and follow with a post-test of the same concept. Further, we will conduct interviews with teachers on the sustainability of Zenbo in their classroom instruction.

Conclusion

In this paper, we present an innovative approach to teaching cybersecurity concepts using interactive stories delivered with the Zenbo social robot. We conducted several focus groups with local elementary school teachers to iteratively refine the interactive stories. Three stories have been developed to address key cybersecurity concepts included in the CSTA and ISTE standards for K12 students, namely safety, privacy and security. We have programmed all three interactive stories on Zenbo, to provide a personalized learning experience for participating children.

In the next phase of our work, we will evaluate the effectiveness of our approach using a mixed-method research design. We plan to conduct a multistage evaluation of both teachers and students focusing on classroom implementation of cybersecurity using Zenbo.

We will examine students' learning of cybersecurity concepts, interest towards cybersecurity, and engagement level.

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