Decoding Teacher Perceptions of the Usability and Feasibility of a Technology Enhanced Cryptography Curriculum

Purpose

The purpose of this study was to explore the perceptions of a group of afterschool program educators regarding the feasibility and usability of a technology-enhanced curriculum designed to introduce elementary age children to cryptography and cybersecurity.

Perspectives and Frameworks

Cybersecurity is a major challenge in the flat, global society of the 21st century and so it is very troubling that the US is experiencing an extreme shortage of cybersecurity professionals (National Academy of Sciences, 2018). This shortage is directly related to the insufficient number of students graduating with STEM majors and is described as an existential threat to homeland security in national reports. Universities and community colleges are starting to rise to the challenge of preparing cybersecurity specialists; however, this problem remains largely unaddressed at the K-12 level, particularly in elementary grades when disciplinary dispositions and career aspiration begin to form (Tran, 2018).

Cryptography exists at the intersection of linguistics, mathematics, computer science, psychology, software engineering, electrical engineering, communication science, quantum physics, and many other fields. Given the diverse and societally important applications of cryptography and cybersecurity, our project addresses this challenge by engaging young children in making and breaking codes, which will help them develop morphological and symbolic systems awareness skills and appreciation of cryptography and cybersecurity education pathways and careers. Cryptography is the backbone of cybersecurity (Paar & Penzl, 2010), and the skills underlying the basic encrypting and decrypting practices in classic cryptography parallel the skills children must develop to gain morphological awareness and become successful readers, writers, and symbolic analysts. Morphological awareness is the recognition, understanding, and use of word parts, or morphemes, that carry significance – a critically important but often overlooked component of K-12 education (Henbest & Apel, 2017). Cryptography relies on the ability to understand, deconstruct and reconstruct morphemes and, more recently, mathematical algorithms (Swenson, 2008), and may thus serve as a new, exciting, and societally important context for improving morphological skills, appreciation of cybersecurity, and development of identity in STEM.

The design, development, and implementation of the curriculum and technology in our project are informed by the current research on the design of integrated, technology-enhanced STEM learning environments (NRC, 2014; Sandoval, 2014), Common Guidelines for Educational Research and Development (2013), STEM teacher professional development (Loucks-Horsley et al., 2009), and expanding underrepresented minority participation in STEM (NRC, 2011). Our interdisciplinary learning design collaborative of K-12 afterschool teacher leaders, education technologists, special educators, computer scientists, and STEM education researchers are working to design, implement, study, and evaluate a 6-week, 24-hour program of cryptography and morphology focused and touch-screen technology-enhanced as well as "unplugged" activities for upper elementary students (grades 3-5) in strategically selected afterschool programs. These activities will also help students develop scientific habits of mind (e.g., curiosity, informed skepticism), acquire and employ STEM practices (e.g., developing and using models, analyzing and interpreting data), foster computational thinking (problem decomposition, pattern identification, conditional logic, systematic information processing) and enhance their understanding of relevant NGSS crosscutting concepts (e.g., patterns). Curriculum activities will be designed to reflect the Common Core State Standards (CCSS).

For example, consider an activity that introduces children to substitution cipher, a classic method of encryption by which units of plaintext (original message) are replaced with ciphertext (encrypted message), according to a fixed system where the units are single letters or groups of letters. The technology scaffold (tablet app) provides on-screen tools and touch-gesture affordances to guide learners to a) examine the encrypted message, b) fill in the substitution table (Table 1) that contains plaintext alphabet in the top row and ciphertext (substitution) alphabet in the bottom row, and c) use the ciphertext to decrypt the message. Ciphertext in substitution codes is created by first writing out a keyword (in this case, "zebras"), removing the letters Z E B R A and S from the alphabet, and then writing all the remaining letters in the alphabet in the usual order.

Table 1: A substitution cipher activity

Ciphertext alphabet:	ZEBRASCDFGHIJKLMNOPQTUVWXY	SIAA ZQ LKBA. VA ZOA RFPBLUAOAR!
Plaintext alphabet:	ABCDEFGHIJKLMNOPQRSTUVWXYZ	FLEE AT ONCE. WE ARE DISCOVERED!

To encourage adoption and facilitate dissemination, the entire curriculum is available online in the form of an interactive, touch-friendly app. Given the young audience and the visuospatial nature of many of the activities, the app use the "tiles" user interface design metaphor and mobile design patterns that have been shown to be usable and effective on mobile touch-screen devices (Neil, 2014). Age-appropriate touch-gestures such as tapping, dragging, and swiping will be implemented using mobile touch technology design guidelines (Wroblewski, 2011). Additionally, a comic book is used to frame all activities into a cohesive curriculum. The comic book presents 4 main characters (3 elementary age girls and a boy) who find themselves in a cyberworld and have to embark on multiple adventures and solve puzzle to get out of it.

Method

This project uses a design-based research approach (Brown, 1992; McKenney & Reeves, 2019) because it improves educational practice through iterative analysis, design, development, and implementation as researchers and practitioners collaborate in real-world settings to develop contextually sensitive design principles and solutions (Brown, 1992; Common Guidelines for Educational Research and Development, 2013). The focus of our design-based research program is to conduct a systematic investigation of the effective conditions for designing and implementing touch-screen enhanced visuospatial learning curricula that foster STEM education and exploration of STEM careers using the unique context of cryptography. The study reported in this AERA presentation focuses on the following specific research questions:

How is the cryptography focused technology-enhanced curriculum perceived by informal educators who will be implementing it in the afterschool programs? What is perceived usability of the app, implementation guide and the curriculum? What is perceived feasibility of implementing apps?

Study participants were 8 afterschool educators (7 female and 1 male) 24 to 57 years old and with teaching experience ranging from 3 to 26 years. Each educator was asked to review the curriculum (activities and comic book) on the tablet app using the provided print copy of the implementation guide. Feedback was provided using individual Zoom interviews, a Zoom focus group, and written comments. Thematic analysis was used to analyze and converge data from all data sources (Braun & Clark, 2006). Specifically, we followed the following 6 steps in our analytic process. First, the core team of researchers became familiar with the data, generated initial codes (e.g., “transitions”, “vocabulary”), searched for themes, reviewed themes, defined and named themes, and produced a final report.

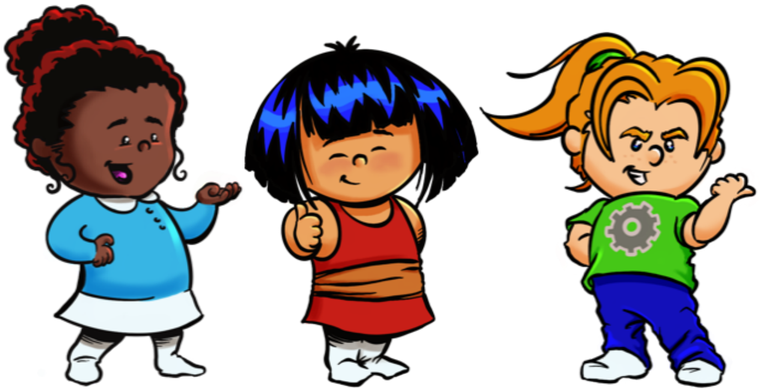
Results

Four key themes emerged as a result of collaborative interpretation of qualitative data from all sources in this study. These themes are discussed below. More detail will be provided during the presentation.

The comic book serves as a useful tool to link all activities in the curriculum. The curriculum consists of six three-hour modules that address pictorial, verbal, and numeric codes, cybersecurity, and a variety of strategies for encrypting and decrypting information. Each module has its own focus but the participants agreed it was important to integrate all modules into one cohesive narrative with game-like features – such as identifying with charismatic story characters, completing missions, collecting artifacts, and solving a major problem. Several participants commented that while the story in the comic book was appropriate and engaging for the target student population, the design of the characters was not and the designers should have done a better job introducing the characters to the students early in the curriculum (Figure 1).

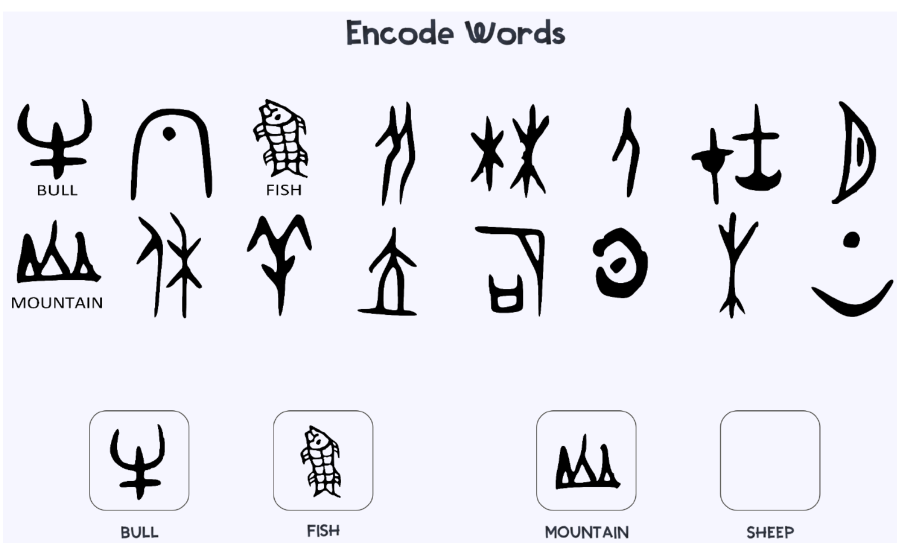
For example, Tonika shared: “I think the representation of the characters in the comic book is a little juvenile for 3rd -5th grade students. To me, the characters look younger than the targeted audience… This may be a turn off for some older students.”

Figure 1. Comic book characters.



The curriculum should engage children emotionally, cognitively, behaviorally, and socio-culturally. Overall, participants agreed that the curriculum provides a good spectrum of technology-enhanced and unplugged activities to engage students' minds, bodies, and emotions. Mary expressed that "The children are exposed to a variety of teaching/learning strategies. This helps students not to lose interest." Most participants felt like introducing children to the Navajo culture as well as Adinkra (West Africa) and Chinese culture and symbology would serve the purpose of engaging children both emotionally and cognitively because the cultures are very different and interesting in their own ways. Several participants commented on the importance of the cultural relevance of symbology and morphological awareness in cryptography, such as in the learning experiences of designing West African Adinkra clothing, exploring the role of the Navajo language and Navajo Code Talkers during World War II, analyzing ancient Chinese writing and artifacts and so forth (e.g., Figure 2).

Figure 2. Tablet drag-n-drop activity on decoding ancient Chinese characters.



Cognitively, exposure to a variety of symbols used in different modern and ancient cultures would engage students in the practice of symbolic system awareness. Behaviorally, children are asked to either use a variety of touch gestures to solve puzzles in the tablet app or engage in unplugged activities that require a lot of movement (e.g., Morpheme Race). Thus, as, Sandra put it, “there will really be no time for them got bored.”

Implementation guide was useful and easy to follow but needed additional scaffolds. Design of the implementation guide for afterschool educators was a significant effort for the project because it was important that teachers are provided with adequate support in a) implementing activities they have never done before with their students, b) conducting implementation of the curriculum with appropriate fidelity (Carroll, 2007), and c) developing a good understanding of cryptography and cybersecurity and their role in our society. The educators in our sample commented that activities appeared easy to implement partly because teacher prompts and discussion questions were provided in the implementation guide. Mary shared that the time devoted to each curriculum module may need to be adjusted depending on whether tablet activities were to be implemented individually, in small groups (pairs, tryads) or as a whole class. Some educators had concerns with the implementation of the unplugged Navajo treasure hunt activity because it involves taking students to the school yard and searching for a Navajo petroglyph (rock carving/painting). A concern was expressed that children in elementary grades may have trouble handling rocks and perhaps the activity should use foam replicas of rocks. Importantly, most educators agreed that the implementation guide did not ask too much of the teacher.

Planning implementation is challenging due to the uncertainties related to COVID-19. As expected, all educators in the sample expressed concerns regarding the implementation of the curriculum, and particularly its unplugged activities, given the reality of COVID-19. According to Dakota, “the hardest part for us will be due to Covid-19 and not being able to have kids from different groups meet to participate.”

Significance

The data and insights presented in this session together with the technology and curriculum design decisions that underlie educator and student experiences will provide useful implications for the design, practice, and research on instructional technology in informal learning. Informal educational environments have unique affordances and constraints that a technology or curriculum designer must keep in mind. The session will address specific the implications for the design of technology and curricular models with similar goals and scope, and recommendations for usability and feasibility studies with young children in after school programs.

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