My:Talkies: Designing a Craft Kit to Support Learning about Communication Devices through Making

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ABSTRACT

My:Talkies is a tangible learning kit for teaching basic concepts of communication devices through expressive making with children (ages 11-14). The My:Talkies prototype comprises of a pair of two paper templates for embodying the communication entities, micro:bit boards, and paper potentiometers for analog to digital encoding. Through pilot studies with eight children and expert review sessions with ten out-of-school educators, we report the design affordances of our prototype and implications of design for future revisions. We found that the kit supported youth in learning through making with personal narratives to grasp abstract concepts such as transmitter/receiver and encoding/decoding. In the expert review, out-of-school educators positively evaluated that the kit is easy to use, good for teaching communication devices, and recommendable to others. The paper concludes with a discussion on the future work informed by observation from the pilot study and design suggestions from the educators.

CCS CONCEPTS

• **Human-centered computing → Interactive systems and tools**.

KEYWORDS

Tangible computing; educational technology; maker education; craft-based learning

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1 INTRODUCTION

Digital communication devices such as cell phones are used as everyday technologies in the lives of youth. Despite their pervasiveness, it is challenging to teach and learn how communication devices work–namely, how these technologies are made of combinations of hardware & software and inputs & outputs, and how they send and receive data and information to each other because this is largely invisible.

Educators working in out-of-school learning environments such as science centers, maker spaces, and community workshops are responsible for selecting and mediating hands-on activities to support children's curiosity and learning. In these settings, educators organize learning of children in educational programs such as drop-in making sessions where hundreds of children participate in a given day; or week-long and daily hands-on learning activities for cohorts of 10 to 20 students during summer months. Such activities require educators to plan for materials and activities to maintain children's interest and engagement in learning and making. Educators face challenges when trying to balance the costs of these materials and still provide authentic hands-on tools and programmable materials.

Here, we present My:Talkies as a hands-on learning kit prototype intended to introduce basic concepts of communication devices in out-of-school learning environments. In designing My:Talkies, we aimed to make the kit: (1) age-appropriate for youth (ages 11-14), (2) low-cost to serve a large number of youth, (3) tinkerable to encourage exploratory construction, and (4) expressive to invite creative storytelling. Our goal is to address the central research question: *How can we design a kit to support children's learning through making about communication devices for out-of-school learning environments?* To investigate this, we conducted a pilot study with eight children where we investigated what they could make with My:Talkies kit prototype. We evaluated the kit through expert reviews with ten out-of-school educators where we also drew upon their insights for our design revision of the kit and the overall activity.

2 RELATED WORK

Maker-oriented approach to learning is a promising way to combine storytelling, art, and craft with digital tools and STEM disciplinary practices for interdisciplinary tangible learning [3]. In designing My:Talkies, we reflected upon Blikstein's design implication for intrinsically valuable making experiences for students from diverse backgrounds, specifically, *powerful expressiveness and learnability in making* [4]. We wanted to afford children-led exploratory construction with their storytelling, connecting to the knowledge of communication devices [14]. Eisenberg et al. [9] argued low-tech craft materials, such as paper, can shift the landscape of educational technology as those are increasingly blended with programmable electronics which are becoming small, thin, and inexpensive. A number of craft-based learning technologies have shown how paper and paper-like craft materials can be extended to innovative engineering media [5, 20, 21]. Our work is inspired and informed by the prior work that bridges the accessibility and rich expressivity of using paper to promote inclusion and diversify computational participation [16].

Ubiquitous computing pioneer Mark Weiser predicted that technologies would pervade our everyday lives [25]. True to this vision, children are surrounded by a variety of computing technologies and communication devices. Noting its importance, the K12 computer science standards include the need to understand communication devices and how they function [22]. In educational settings and maker spaces, communication devices take the form of tablet computers, cell phones, and programmable DIY circuit boards from various companies (e.g., Raspberry Pi [11], Teknikio [24] , or Arduino [1]) that can be made into communication devices for sending and receiving data. These technologies enable users to build communication devices easily from onboard radio antennas or existing Bluetooth functions that can be programmed using web-based block code editors. To engage students in STEM learning, researchers have suggested toolkits with maker-oriented and personal interest-driven approaches in learning communication devices [12, 17]

The use of storytelling has been a powerful approach for sharing knowledge and engaging children's learning and development. Traditional and digital storytelling helps youth connect their experiences and imaginations to intended lesson or instructional goals [13, 18]. Storytelling as a means for inclusive learning serves as a vehicle for helping children with different abilities develop and find their place in the world [2, 8].

In line with the growth of interest in STEM learning programs, out-of-school settings have offered STEM-relevant learning opportunities in many different formats [6]. A hallmark of out-of-school learning experiences is that they support interest-driven learning so children can choose what and when to learn [10].

3 MY:TALKIES

My:Talkies is a tangible learning kit that consists of paper templates to make messenger models, custom paper potentiometer parts, and micro:bit boards (Figure 1.(A)). Using the paper template, one can assemble parts to construct a base messenger model attached to a paper potentiometer (Figure 1.(B)). A micro:bit board is embedded inside of the base model and the board's LED matrix can shine through when powered.

My:Talkies aims to introduce basic concepts of communication devices. Drawing from computer science content standards [23], we identified our goal in this prototype as understanding computational communication devices in more detail–forming abstract ideas about specific components (e.g., input and output), specifically focused on transmitter & receiver, and encoding & decoding messages.

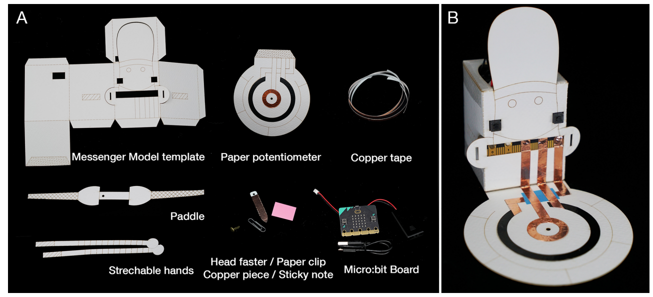

Figure 1: (A) My:Talkies kit components, and (B) assembled base model of My:Talkies

3.1 Design Considerations

Our designs are inspired by prior work in learning by making, computational crafts, storytelling for inclusive learning, and our own experiences building and iteratively testing physical computing materials.

- Age-appropriate: We selected micro:bit board as the microcontroller of My:Talkies because it can be programmed using MakeCode [19]. Microsoft MakeCode is a block-based coding environment that is a free and open source platform for beginners.
- Low-cost: Micro:bit board supports wireless communication equipped with multiple hardware components such as LED matrix, speaker, microphone, and sensors. This means, one board purchase (approximately $20) enables creating communication devices with inputs and outputs without adding external hardware components.
- Tinkerable: We designed My:Talkies' paper templates to make a messenger model and a potentiometer with paper and craft-friendly materials (e.g., copper tape and Velostat [7]) that are easy to cut and modify using any sort of craft cutting tools to encourage exploratory construction.
- Expressive: To invite storytelling through expressive making, My:Talkies messenger model template design visually implies a character while leaving a space for children's imaginations on their own characters. That is, we aim to find a right balance between providing a scaffolding medium for starters, yet enabling diverse, creative outcomes. We also encourage youth and museum educators to add in objects or craft materials of their choice to making.

3.2 A Pilot Study with Youth

We conducted a pilot study with youth to build our preliminary understanding of what children could make with My:Talkies kit prototype. We structured two sessions with each taking four hours on Saturdays. Eight middle school students (ages 11-14; 5 male, 3 female), five identified as African American, two as Caucasian, and one as Middle Eastern, from the Metro Atlanta region participated. All, but two of the participants picked up a kit from researchers and signed consent and assent forms. The two received the kit by airmail and followed a remote consent and assent process prior to the workshop. All participants had access to a laptop or personal computer with internet and a webcam to use for the virtual workshop. Participants were given a kit materials with a micro:bit technology set which they could keep beyond the workshop. Two graduate students co-facilitated the workshop while two researchers documented. We presented My:Talkies as an early prototype that seeks further improvement and asked for their ideas to advance the kit and the activities.

3.2.1 Procedure. The workshop is designed to introduce basic concepts of communication devices–transmitter & receiver, encoding & decoding–through expressive making. To introduce the concept of transmitting and receiving, we introduced a pair of micro:bit boards, one as a transmitter of inputs and the other as a receiver of outputs. We demonstrated how transmitting data from inputs (e.g., blowing into microphone, pressing buttons, shaking an accelerometer, changing switch position, etc.) influences the outputs on the receiving micro:bit (e.g., LEDs, speaker). To introduce the concept of encoding and decoding, we designed an activity where participants made and coded a "Pick-A-Message" using the paper potentiometer of the kit (Figure 2). We demonstrated how to read the resistance values corresponding to the position of the dial and divide the range of analog values that potentiometer made by the number of the messages. For example, given a range of analog values from 500 to 1100, if one has two messages to send, then one message could be assigned to the range from 700 to 800, and the other from 800 to 1100.

3.2.2 Results. Participants made a wide range of creations with the kit and the completion levels were varied. Many youth shared frustrations with copper tape because it tore easily and was difficult to adhere to their designs. This issue prompted us to find an alternative material to take the place of copper tape. In terms of the outcomes, Table 1 shows researchers ratings to evaluate to what extent students completed making My:Talkies messenger models (Model) and potentiometer dials (Pot), demonstrated understading concepts like transmitter & receivers (T & R) and encoding and decoding (E & D), engaged in programming their My:Talkie (Code), and finished their projects (Done). While most students (N=6) reflected a good understanding of transmitter/receiver, less students (N=3/6) demonstrated their understanding of encoding and decoding. Participants who were interested in crafting tended to engage in activities more actively than others. Here, we report two cases to share students' creations through expressive making with storytelling (Figure 3).

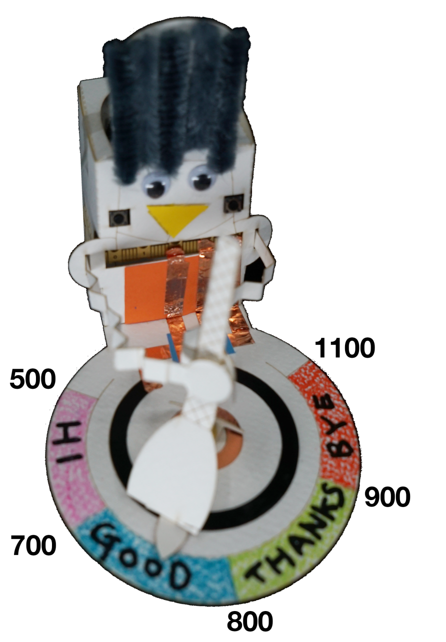

Figure 2: Pick-A-Message application example

B1 mentioned that he visited an aquarium and got to pet a flowerhorn fish, a fish with a distinctively large and colorful head. Because he aspired to have a pet of his own, he instantly started drawing the flowerhorn and himself when we asked to design the characters for their communication devices. His fish was the transmitter and he was the receiver. He encoded four messages on the paper potentiometer for the fish. The messages were "food" with a smiley face, "maintenance" with a sad face, "friends" with two faces, and "obstacles" with a beeping sound. He demonstrated his understanding of encoding and decoding when describing his project, telling us "the first one, 150 to 310 was food."

G1 and G2 are sisters who were deep into the video game-based fan fiction called *SCP*. They introduced the SCP stories as a kind of cultural phenomenon among youth. Using four available messenger model templates from two kits, they made communication devices representing four characters from the story: a demon, two soldiers, and a sergeant. Their collaborative project depicts a confrontational scene between a demon and soldiers. G1 and G2 demonstrated increased understanding of transmitting and receiving, saying "This is the transmitter. And this one is the receiver. And I made it so when it turns on, it keeps sending a number forever. This one is sending the number and then this one's receiving it." The sergeant was a transmitter and demons and soldiers were receivers. If they move the sergeant's dial to the left part of a potentiometer, it was designed to send a "Halt" message to a demon. Likewise, if the dial is in the right part of the potentiometer, the sergeant was supposed to send "Attack!" to the soldiers.

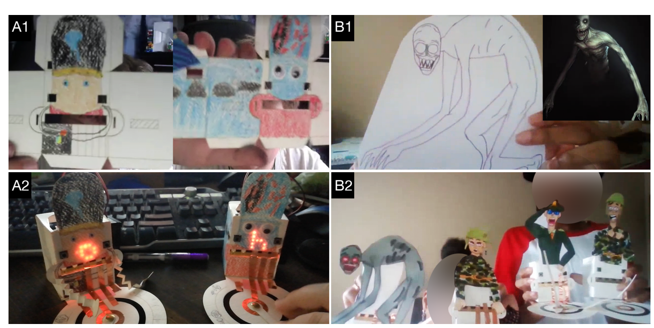

Figure 3: Students' creations of communication devices: (A1-2) for himself as a future marine biologist and his fish; and (B1-2) for a gaming scene with a demon and soldiers

Table 1: Summary of Outcomes

ID	Project	Sender & Receiver | Messages	Model	Pot	T&R	E&D	Code	Done
G1	Demon Security	Sergeant/ Demon | Halt / (Screaming sound)	5	5	5	5	5	5
G2	Demon Security	Sergeant / Soldier | Attack! / Yes sir	5	5	5	5	5	5
B1	Fish Care	Fish / He | I need food/ friends/ Maintenance/ Plants	5	5	5	5	5	5
B2	Game Availability	He / Friends | Can you join the game? Yes / No	5	5	5	3	5	4
G3	Pizza Messaging	She / Her mother | I'm hungry/ I need pizza	5	5	5	3	3	4
B3	N/A	He / microbit (did not define the character)	5	5	5	1	4	2
B4	N/A	Completed the assembly and interested in hardware	5	5	3	1	1	1
B5	N/A	Ccompleted the assembly only. Wanted more time	5	5	1	1	1	1

4 EVALUATION WITH OUT-OF-SCHOOL EDUCATORS

Our design considerations for the My:Talkies prototype were based on prior practices in the field and our experiences as designers and maker educators. To evaluate our prototype and gather insights for the next design revisions, we invited ten out-of-school educators to provide their expert reviews and design suggestions.

4.1 Recruitment & Procedure

Ten educators were recruited by sending emails to children's out-of-school STEM maker programs, museums with established maker programs, and community workshops. Educators had a range of prior teaching experiences from 2 years to 25 years working in STEM programs and agreed to participate in expert review sessions and surveys.Two additional educators voluntarily joined the expert review sessions with their peers and also submitted a survey, bringing the total number of participants to twelve.

Prior to the expert review sessions, we sent out an online survey to evaluate our kit prototype. All educators also received the My:Talkies kit including two templates and two micro:bits along with craft materials. Along with assembly instructions, digitally accessible video, and print-based tutorials, educators were asked to explore the kit on their own and fill out the expert review form. Then, one to two weeks after receiving the kit, an hour-long virtual session was scheduled. Similar to a format of a focus group with peer conversation, each of five sessions was attended by two to three educators. (Due to a late scheduling conflict, one educator had to participate individually.) Each session consisted of value ranking (via Google's collaborative digital whiteboard Jamboard [15]) and semi-structured interviews to (1) review the My:Talkies prototype and (2) to draw their insights for our design revisions of the kit and the activity.

4.2 Results

4.2.1 Survey. The survey component of the expert review consists of 16 questions that asked about the kit's ease of use, use in learning and practice, and overall satisfaction using ratings 'Strongly disagree, Slightly disagree, Neither disagree nor agree, Slightly agree, Strongly agree' options. Two additional open ended questions allowed educators to elaborate more about the positive and negative aspects. Twelve expert review forms were collected and analyzed. Initially twelve people were recruited and participated in the survey, but two of them were not able to join the expert review sessions where we conducted values ranking activity and semi-structured interviews.

In the 'Ease of Use' category, 83% of respondents answered 'Slightly agree or Strongly agree' to the question of 'The kit is easy to make and user friendly.' However, the answers were evenly spread for the question of 'I can use it with minimal instructions' and 'I can use it successfully every time' In the 'Processes and Practices' category, 66% of respondents answered 'Slightly agree or Strongly agree' to the question of 'The learning objectives are clearly matched to the design of the kit' and 'It helps me learn the concepts of sending and receiving messages easily.' In addition, 91% of respondents answered 'Slightly agree or Strongly agree' to the question of 'I am encouraged to explore more about coding with MakeCode', 'I could imagine using this with my own students.' Lastly, in the 'satisfaction' category, all respondents answered 'Slightly agree or Strongly agree' to the question of 'I would recommend it to another organization or friend.' 66% of respondents answered 'Slightly agree or Strongly agree', 12% to 'Neither disagree nor agree', 12% to 'Slightly disagree' to the question of 'I am satisfied with it. Overall, the survey shows that the kit is easy to use, good for teaching the concept, and recommendable. However, the survey also showed the need for the development of better instructions and more robust paper templates for repeated use. These issues are discussed in more detail in the later semi-structured interview.

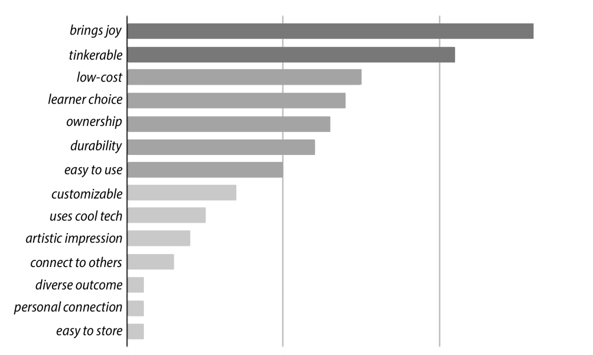

Figure 4: Values ranking for a STEM learning kit rated by out-of-school educators in the expert review

4.2.2 Values ranking. We added values ranking activity to understand underlying criteria that educators might have considered in their evaluation of the kit as well as to get their guidance on our design revision of the kit. We did not limit value considerations to be only centered on our kit. Instead, we encouraged educators to think about a broader context of general tangible learning and making kits.

Using Google Jamboard, educators were asked to identify their top 5 learning values for a STEM learning kit then rank them from highest priority to least. They dragged and dropped pre-populated words that included designer values as well as had the option to create new words. Across the 10 educators, the responses were pooled then tabulated. We quantified the answers on a scale of 1-5 with 1 being least important and 5 being most important. The highest was 'bringing joy' with 26 points and the next highest was 'tinkerable' with 21 points. Figure 4 shows the overall rankings of values. Through this elicitation activity, we learned that out-of-school educators value: bringing joy, tinkerable, low-cost, learner choice, ownership, durability, and ease of use.

These representative educator comments captured how they view the highest ranking of "joy":

> *Educator1: "For it to be a fun and enjoyable experience is often a high priority. And want people to walk away, more fulfilled"*
> *Educator2: "The message that I want to send to students is I want to hook them with something that they're interested in. And I want them to derive joy from the experience, because that is really important. And that really is the launching pad for, for something beyond the activity, right? If the activity in and of itself brings joy, then they will be intrinsically motivated to seek and pursue learning beyond the activity."*
> *Educator3: "You know, if you're not getting joy out of the experience, you're turned off from it. So that, to me is one of the most essential pieces if I'm not finding excitement, and you know, and to me, this comes down to you know, joy."*

4.2.3 Interviews. Ten educators were asked about (1) if they want to use My:Talkies kit in their programs and (2) if so, why. Each session was recorded then transcribed using automatic transcription service otter.ai. These transcriptions were thematically coded across three main categories - Teaching, Facilitation/Instructional Parameters, and Implementation at Scale – using Dedoose by two researchers. Code application disagreements and subcode refinement were moderated by a third researcher for two rounds of code applications on a single transcript, before a third and final round of coding was applied to the remaining transcripts.

In summary, expert educators were enthusiastic about using My:Talkies in their informal science education contexts, but voiced concerns about durability. When asked if they would use My:Talkies in a workshop or camp, educators saw the papercraft aspect of My:Talkies as an opportunity for engagement through storytelling, learning through expressive making with agency that would contribute to a sense of ownership. In addition, the low cost of the kit was appreciated as it could enable their programs to serve more students and let them "make and take" their projects to home. Educators at high traffic and high head count museums voiced concerns about durability of papercraft materials and anticipated that students' fear of ruining their models could inhibit their ability to progress to the engineering and programming stages of My:Talkies.

4.3 Suggestions

4.3.1 Leaving a space to go beyond the given kit. When we asked how to improve the craft element of My:Talkies, educators with extensive papercraft experience pointed out that the template design shouldn't be overly scaffolded. That is, students should have agency throughout their exploratory construction even if it could lower the final quality of students' creations using the kit and increase risks for their struggles in the process of using My:Talkies kit. This suggestion also reminded us of value ranking results where educators prioritized providing tinkerability, learner-choice, and ownership. This feedback was expressed well by one educator about this tension between scaffolding storytelling through a character and allowing students to own their story for My:Talkies communication entities.

> *Educator4: "There was a little too much detail where it felt like it, it was somebody else's, in some ways that like I wanted it to be a little bit more generic. And like, you know, I saw these eyes and then I was like are these also eyes and then like, this is a pretty specific hand and pedal thing. And so I just felt like it was, it was directing the activity a little too much in like the vision of the person who had created this."*

4.3.2 Thinking of ways to lower the cost even further. Educators emphasized the importance of low cost with budgets ranging from less than one dollar up to $25 per student. Accordingly, the price of a micro:bit was the largest barrier in low-budget based museums to let students take their creations. Educators suggested that this issue could be addressed by program facilitation. For instance, micro:bits would need to be subsidized by students by charging a technology fee, or students can take only their paper models without micro:bit boards.

4.3.3 Enabling early success achievement. Educators were concerned that the beginning of the making with My:Talkies kit could be challenging for many children. Based on their hands-on experiences, some educators mentioned that it took too long to feel like they got a "win" or positive feedback from their My:Talkies creation. This becomes an issue because early frustration could cause students to disengage, especially in settings lacking sufficient hands-on support and facilitation. Educators suggested that the activity structure needs to be improved to let children quickly feel like they are making positive progress especially at the early stage of the activity.

5 LIMITATIONS AND FUTURE WORK

Our pilot study was conducted with a small sample of participants (8 youth, 12 educators) during COVID-19. Youth participation lasted only 4 hours as a one-day fully online workshop, educators submitted a single survey and participated in one hour review sessions. Increasing the sample size and extending the study duration may show us different results on usability of the kits, engagement level, or learning outcomes. Each My:Talkies paper template was pre-cut to be assembled into a single character. Future designs could explore more open design templates to further support more ownership and children-generated stories and projects. With these in mind, we plan to conduct iterative testing using modified versions of My:Talkies with in-person small groups of users to more closely examine their making process as well as conduct longer workshops with more youth (for instance, as a weeklong-workshop in a face-to-face setting.) With more time to explore and build, youth could incorporate more communication options through coding different outputs for sounds and music or light patterns and letter messages on the micro:bit. On a related note, although we received valuable feedback from both youth and educators, we felt their voices could be further amplified by inviting them as co-designers into the process. We plan to engage more children and educators through co-design activities for future design revisions.

6 CONCLUSION

Communication devices are becoming indispensable to our lives and we need more learning resources to prepare the next generation for a better understanding of how they work. My:Talkies is a craft-based kit to introduce basic concepts of digital communication devices through expressive making. It enables children to design their own communication device with interest-driven stories. With our initial designs, children could understand abstract concepts of communication while making a personal story with My:Talkies messenger model templates even in a short workshop. Out-of-school educators evaluated the kit as easy to use and good for teaching communication devices from the expert review, but also offered an abundance of ideas for future iterations to improve the design for children and implementation in out-of-school learning environments.

7 SELECTION AND PARTICIPATION OF CHILDREN

In this study, we recruited eight children (ages 11-14 years old; 5 male, 3 female) in collaboration with a university-based K-12 STEM outreach program. No participants were excluded from the study. Researchers shared the goals of the workshop on a website, a PDF flyer, and by telephone or in-person with their parents to describe the goals and purpose of research project. Parents reviewed and signed consent forms while children signed assent forms that described the research, data collection (e.g. observations, video, interviews, student-created projects, design journal, text chats), and our process to maintain their confidentiality. We explained to parents how the data would be kept in a secure location and data would not be shared outside of our research team. Participants were informed that we would use pseudonyms if we referred to their experiences in any external publications. All the making supplies were provided. Participants were not paid any incentives to join, but could keep all the micro:bit technology components and making supplies provided to them. Participants did not need prior experience to participate but required access to a laptop or personal computer with a webcam to use for the virtual workshop. The research study was approved by Georgia Institute of Technology's Institutional Review Board prior to the study.

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