IoT Props into Creative Writing: Designing Narrative-Based Maker Activities for Children

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ABSTRACT: Project-based making activities with the Internet of Things (IoT) toolkits allow learners to make interactive and tangible products by integrating internet and computing devices embedded in everyday objects. This study presents a workshop experience with a designed curriculum incorporating crafting, coding, and creative writing with IoT toolkits for students to work on interactive IoT-infused storytelling activities. We conducted a qualitative study through a week-long maker workshop in the middle school classroom. We examined students' learning to understand how they integrated IoT crafting with creative writing. Ultimately, we discuss design implications for improving IoT-crafting workshops with creative writing for children. Additionally, the findings inform the future design of a STEAM workshop to broaden STEM participation and enhance learning.

Introduction

The growing demand for engineering professionals in the US economy has fueled interest in incorporating engineering into the K-12 curriculum (Gennari et al., 2017; Moore et al., 2015, Rose et al., 2015). This demand has led to new opportunities to design learning programs featuring Internet of Things (IoT) toolkits, coding, and creative making, expanding the umbrella known as STEAM education (Kafai et al., 2014; Author & Wohlwend, 2017). Given the steady increase of IoT toolkits in the market (e.g., Microbit, Sparkfun, Grove kit), researchers and educators advocate promoting IoT through STEAM integration to train future professionals who can have a greater understanding of IoT applications (Blikstein, 2015;). One of these toolkits, the Grove Arduino, accelerates the learning curve for IoT beginners through design features, such as scalability, flexibility, and extendability. In this study, we seek to find implications of designing IoT-making workshops for children to broaden their participation and support their understanding of IoT principles.

Prior research has explored how rooting complex STEM concepts in familiar modes of storytelling (Authors 2014), craft (Budd et al., 2007; Authors 2014), and play (Benford et al., 2000; Tekinbas & Zimmerman, 2003) has broadened participation and deepened learning in STEM. This framing centers children as a driver of their learning and reinforces their thinking through active engagement (Papert, 2020). These investigations share similar aims with the maker movement (Authors, 2013), which seeks to promote agency, creativity, and interest-driven engagement with new technologies, often through personally meaningful combinations of high- and low- (e.g., handicrafts, paintings, wood)-tech materials (Kucirkova, 2019). Maker-based approaches to K-12 STEM teaching have fostered open exploration and an innovative mindset. It stands to reason that a K-12-facing IoT pedagogy should leverage learnings from prior research of storytelling and crafting as tools to promote STEM education.

Through observation at a middle school's summer workshops in Southern California, USA, this study focuses on how students in 6th-8th grades learn IoT concepts through making and creative writing activities. The study aims to find meaningful insights from students' strategies of IoT making into creative writing and how students integrate their stories into the strategies and choices of their IoT making. The study showed students accomplished their IoT-making project and applied it to their writing. They improved their understanding of IoT components and computational thinking from the workshop.

Background

Constructionism

This project is grounded in a theory of *constructionism* (Papert, 2020) theory suggests that learning occurs when learners actively engage with the object, especially through the interaction with hands-on exploration of the externalized objects (Kafai, 2005). Recent studies in computing education have broadly explored incorporating hands-on activities in their curriculums compared to the traditional methods focused on software and textbook (Moore et al., 2015). Building on constructionism, physical computing acts as an "object to think with," and the externalized objects (IoT artifacts) and hands-on exploration enhance understanding of abstract, complex engineering concepts via visualization, simulation, prototyping, and making (Kusmin, 2019; Oh et al., 2017).

Storytelling in STEAM learning

The value of incorporating storytelling in learning has been broadly explored in STEM (Authors et al., 2014; Hadzigeorgiou, 2016) as an effective pedagogical tool that fosters a conceptual model of one's learning. Creating a story about learning content enforces interpretation and synthesis of the subject (Hadzigeorgiou, 2016; Weintrop et al., 2014). Open-ended creative story-making is central to advancing broader participation, increasing agency, engagement, and novelty. (Bobick et al., 1999; Garzotto et al., 2010; Phillips, 2000). Building on prior studies that investigate the efficacy of integrating narrative into STEAM activities in K-12 settings, our approach in the study is to situate children as active agents of story construction with the IoT-infused props and settings.

Internet of Things (IoT) toolkits

The Internet of Things (IoT) has become an essential part of the emergence of the new industrial revolution (Castillo & Thierer., 2015; Marco Iansiti and Karim R. Lakhani & Porter, 2020; Rose et al., 2015). Accordingly, the applicability of IoT to learning engineering concepts has been one of the prevalent topics in education studies (Chalmers, 2018; Author & Glosson, 2012; Kusmin, 2019; Moore et al., 2015. Learning programs with IoT toolkits promote a variety of subjects, including engineering, computer science, and data science, via sensors that collect, generate, and visualize information into a software platform and trigger actionable outcomes. For example, a temperature sensor detects temperature and displays the value online; a motor makes a movement when a motion sensor detects a movement. Most IoT in STEAM education is designed for science experiments (Cao et al., 2021; Fuhrmann et al., 2021; Hardy et al., 2019).

Curriculum design

The learning curriculum in which we incorporated IoT toolkits, coding, storytelling, and design-based making projects for children includes visual programming software with equitable IoT toolkits and design projects (see Figure 1). In the workshop, we provided lesson plans: 1) IoT toolkits with the Grove Arduino kits, 2) computational thinking (CT) through Blockly visual programming language, 3) paper crafting, and 4) writing activities based on their creation. With the IoT toolkits, we introduced concepts of input and output with sensors and actuators. For the CT project, students were taught various CT concepts, including a loop, variables, and conditional blocks for IoT kit manipulations. Students used low-cost crafting materials (i.e., papers, cardboards) for making with the IoT toolkits. Lastly, we provided a plot diagram for students for their narrative writing (i.e., exposition, conflict, rising action, climax, falling action, and resolution).

We introduced six distinct lesson plans (i.e., smart house, old Macdonald little farm, musical necklace, treasure chest, robot pet, and rocketship) (see Figure 2). The goal of the learning program was to promote the understanding of the connectivity of software (CT concept) and hardware (IoT components). To do so, students utilized a visual programming platform and physical computing toolkits, including various electrical modules (i.e., OLED, motors, sound, and light sensors). For the writing sessions after the crafting activity, we provided a composition template for story reference; We aim to reinforce their IoT concept understanding through writing activities and use their crafting artifacts to inspire their story.

Methods

We conducted a case study in a middle school in Southern California, USA, a two-week-long summer camp for the workshop. There were a total of 18 students of 6th to 8th graders with the main teacher and a sub-teacher. Three researchers observed the workshop at the location for the first week of the sessions, from Monday to Friday, for 150 minutes. For the qualitative data, we video-recorded the sessions to capture students' learning processes. During crafting sessions, we took semi-structured interviews with students and pictures of the artifacts students created. We also collected and reviewed students' creative writing.

The workshop started with introducing the CT concept for using the visual programming language; then, students introduced the IoT components with Grove Arduino kits; once they assembled the IoT toolkits, students created paper crafting by adding a design to IoT features. At the end of the workshop, students were allowed to write creative stories based on their IoT artifacts.

Data sources and analysis

In the study setting, we facilitated cameras on the desks to capture students' making processes. Researchers took field notes throughout the workshop, photos of students' artifacts, and videos of the semi-structured interviews. We drew observational data (i.e., video, audio, field notes, students' writings, and student artifacts) into our analysis. We transcribed the video data of students' dialogues and semi-structured interviews. Then we conducted a thematic analysis to find common themes with the semi-structured interview transcriptions. Additionally, we analyzed students' writing projects to investigate students' strategies to infuse IoT creating into their creative writing.

Findings

Our findings from the qualitative analysis of the students' semi-structured interviews and their writing projects showed three emergent strategies of students integrating IoT into their story: *1) personalization and agency, 2) settings and props, and 3) plots and composition.*

The theme of *personalization and agency* arises from creating unique artifacts to customize the attributes of IoT toolkits. Crafting materials are useful for promoting various ways to speak to their stories and settings. Torrey, one of the students in the class, created an interactive house with the idea of his own experiences playing Minecraft games. In the semi-structured interview during the making activity, he noted, "I remember the first time I played Minecraft and just made a dirt house, and I remember placing my torches outside. I added a little more design in my way. think it adds mostly creativity.". Making choices and decisions in students' crafting processes supports personalized learning and promotes agency.

Second, the theme of *settings and props* is about making interactive objects with IoT functionalities as part of their story. Such as dream houses, music boxes, and rockets with smart systems.

Students created IoT-enabled props as the setting of their stories. For example, Lucy used her IoT prop, a music box (i.e., a box that detects movement from a motion sensor and plays music with a buzzer), as a central component of the story. In her creative writing project, she wrote, “My grandma secretly gave me a music box before she passed away. When I opened the box, it always reminded me of my grandma. One day, when I opened the music box, it glowed, and someone said it’s a magical box.”. Lucy implemented sensors and actuators to create a magical music box and infused it into her story. The story centered around the IoT-infused prop with a motion sensor and LED lights.

Third, the theme of *plots and composition* came from incorporating IoT-infused props into the composition of their story. Incorporating the causality of the IoT modules (i.e., sensors and actuators sense and respond as the cause of an effect) are embedded in the stories. Torrey’s case highlights the theme as he created the house and stated, “You can hear a sound; this put the sensors into play. You could hear all this stuff from sound sensors, sounds like zombies, and if it's nighttime, the light sensor detects darkness. If monsters come near the house, the light will turn on.”. He used the cause and effect of the IoT functionality (detect and respond), detecting zombies’ attacks with a sound sensor and making an alarm with a light sensor.

Discussion

This paper presented a workshop experience regarding IoT-infused crafting, coding, and creative writing activities. The study aims to find meaningful insights from students’ strategies of IoT making into storytelling and how students integrate their choices of IoT crafting into the strategies of their unique stories. The learning workshops offer lessons on IoT crafting with coding and story composition. From the workshop, all of the students were able to complete the IoT-crafting with coding successfully and applied their crafting to their creative writing (see Figure 3). The study showed students’ improvement in understanding of IoT components and the functionalities and computational thinking, and how to utilize coding for IoT toolkits. From the qualitative research, we highlight the themes: *1. personalization and agency, 2. settings and props, 3. plots and composition.*

The findings of students' strategies of IoT crafting and storytelling led to design suggestions for improving workshops: first, to support a seamless interconnection between crafting and creative writing, we suggest encouraging students to design a narrative (e.g., a character, setting, or prop) before crafting activities and technical instruction. Second, for writing and crafting to become complementary educational opportunities, both activities should run simultaneously rather than as separate activities; adjusting the order of the workshop activities would be necessary. Lastly, for enhancing IoT-infused crafting activity, we suggest providing IoT modules to focus on the functionalities of each component instead of a full set of examples with pre-defined projects. For example, instead of providing pre-set projects like a pet robot, or a smart house, provide a list of the basic functionalities of the IoT modules (i.e., sensors and actuators), such as blinking LED with sensors, making music with buzzer, and making a certain movement with motor with a motion sensor. The plain functionalities of IoT modules allow students to create personalized artifacts freely.

References

Antle, A. (2003). Case study: the design of CBC4Kids’ StoryBuilder. *Proceeding of the 2003 Conference on Interaction Design and Children - IDC '03*. https://doi.org/10.1145/953536.953546

Benford, S., O'Malley, C., Simsarian, K. T., Stanton, D., Sundblad, Y., Taxén, G., Bederson, B. B., Åkesson, K.-P., Bayon, V., Druin, A., Hansson, P., Hourcade, J. P., Ingram, R., & Neale, H. (2000). Designing storytelling technologies to encouraging collaboration between young children. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '00*. https://doi.org/10.1145/332040.332502

Blikstein, P. (2015). Computationally enhanced toolkits for children: Historical review and a framework for future design. https://doi.org/10.1561/9781680830811

Bobick, A. F., Intille, S. S., Davis, J. W., Baird, F., Pinhanez, C. S., Campbell, L. W., Ivanov, Y. A., Schütte, A., & Wilson, A. (1999). The kidsroom: A perceptually-based interactive and immersive story environment. *Presence: Teleoperators and Virtual Environments*, *8*(4), 369–393. https://doi.org/10.1162/105474699566297

Budd, J., Madej, K., Stephens-Wells, J., de Jong, J., Katzur, E., & Mulligan, L. (2007). Pagecraft. *Proceedings of the 6th International Conference on Interaction Design and Children - IDC '07*. https://doi.org/10.1145/1297277.1297296

Cao, J., Chan, S. W., Garbett, D. L., Denny, P., Nassani, A., Scholl, P. M., & Nanayakkara, S. (2021). Sensor-based interactive worksheets to support Guided Scientific Inquiry. *Interaction Design and Children*. https://doi.org/10.1145/3459990.3460716

Castillo, A., & Thierer, A. D. (2015). Projecting the growth and economic impact of the internet of things. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2618794

Chalmers, C. (2018). Robotics and computational thinking in primary school. *International Journal of Child-Computer Interaction*, *17*, 93–100. https://doi.org/10.1016/j.ijcci.2018.06.005

Fuhrmann, T., Ahmed, D. I., Arikson, L., Wirth, M., Miller, M. L., Li, E., Lam, A., Blikstein, P., & Riedel-Kruse, I. (2021). Scientific inquiry in middle schools by combining computational thinking, wet lab experiments, and Liquid Handling Robots. *Interaction Design and Children*. https://doi.org/10.1145/3459990.3465180

Gennari, R., Melonio, A., Rizvi, M., & Bonani, A. (2017). Design of IoT Tangibles for Primary Schools: A Case Study. Proceedings of the 12th Biannual Conference on Italian SIGCHI Chapter.

Hadzigeorgiou Y. (2016) Narrative Thinking and Storytelling in Science Education. In: Imaginative Science Education. Springer, Cham. https://doi.org/10.1007/978-3-319-29526-8_4

Hardy, L., Dixon, C., & Hsi, S. (2019). From data collectors to data producers: Shifting students' relationship to data. Journal of the Learning Sciences, 1-23.

Kafai, Y. B. (2005). Constructionism. *The Cambridge Handbook of the Learning Sciences*, 35–46. https://doi.org/10.1017/cbo9780511816833.004

Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, *84*(4), 532–556. https://doi.org/10.17763/haer.84.4.46m7372370214783

Kucirkova, N. (2019). Children's agency by design: Design parameters for personalization in story-making apps. International Journal of Child-Computer Interaction, 21, 112–120. https://doi.org/10.1016/j.ijcci.2019.06.003

Kusmin, M. (2019). Co-designing the kits of IOT devices for inquiry-based learning in STEM. *Technologies*, *7*(1), 16. https://doi.org/10.3390/technologies7010016

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K‐12 state science standards. Journal of Research in Science Teaching, 52(3), 296-318.

Oh, H., Kim, J., Morales, C., Gross, M., Eisenberg, M., & Hsi, S. (2017). Foldmecha. *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction*. https://doi.org/10.1145/3024969.3024991

Papert, S. (2020). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Author & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, *95*(3), 22-27.

Author & Glosson, D. (2012). Stitching circuits: Learning about circuitry through E-textile materials. *Journal of Science Education and Technology*, *22*(5), 751–763. https://doi.org/10.1007/s10956-012-9428-2

Author, Gresalfi, M., Tekinbaş Katie Salen, & Santo, R. (2014). *Soft circuits: Crafting E-fashion with Diy Electronics*. The MIT Press.

Author, Santo, R., Gresalfi, M., & Tekinbaş Katie Salen. (2014). *Script changers: Digital storytelling with scratch*. The MIT Press.
Author, & Wohlwend, K. (2017). Theorizing the nexus of steam practice. *Arts Education Policy Review*, *119*(2), 88–99. https://doi.org/10.1080/10632913.2017.1316331
Phillips, L. (2000). Storytelling: The seeds of children's creativity. *Australasian Journal of Early Childhood*, *25*(3), 1–5. https://doi.org/10.1177/183693910002500302
Rose, K., Eldridge, S., & Chapin, L. (2015). The internet of things: An overview. The internet society (ISOC), 80, 1-50.
Tekinbas, K. S., Gresalfi, M., Author, K., & Santo, R. (2014). Gaming the system: designing with gamestar mechanic. MIT Press.
Tekinbas, K. S., & Zimmerman, E. (2003). Rules of play: Game design fundamentals. MIT press.
Weintrop, D., Beheshti, E., Horn, M. S., Orton, K., Trouille, L., Jona, K., & Wilensky, U. (2014). Interactive assessment tools for computational thinking in high school STEM classrooms. *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, 22–25. https://doi.org/10.1007/978-3-319-08189-2_3

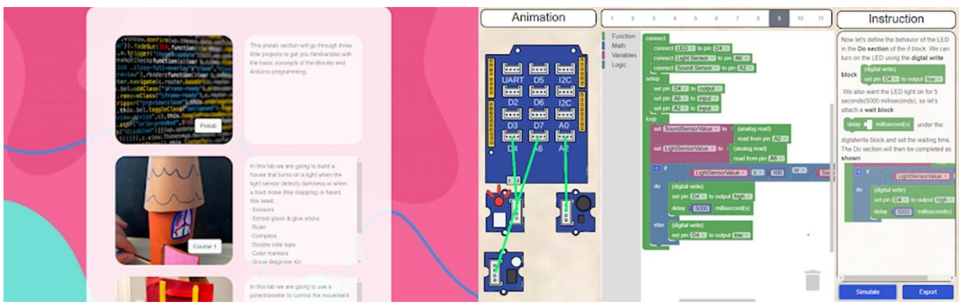

Figure 1. Blockly visual programming language website for the IoT making projects, intro page (left), workspace with simulation, coding, and instruction (right)

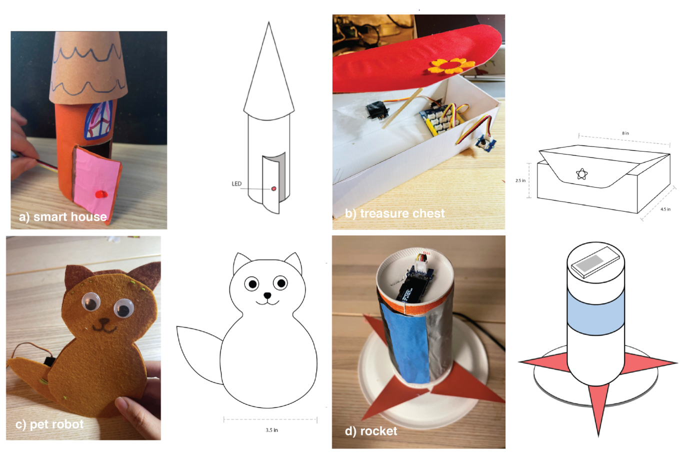

Figure 2. Example projects provided for the workshop: a) smart house, b) pet robot, c) treasure chest, d) rocket

Figure 3. Students' artifacts from the IoT crafting project.