

Let's test it!: Designing peer-to-peer engineering games with and for children

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Abstract

STEM digital games are an engaging way for children to explore engineering beyond the classroom, but many games do not incorporate children's perspectives or encourage collaborative learning through gaming experiences. Additionally, much of the research on joint media engagement (JME) focuses on parents and children rather than children engaging together. Beginning in fall 2023, KidsTeam UW – an intergenerational participatory design group at University of Washington – and GBH Kids – Boston's public media station and producer of children's media – collaborated on three digital engineering games focusing on peer-to-peer learning and JME. Over 18 months, the team worked with youth co-designers to develop several game concepts. We discuss our process and prototypes, as well as an ongoing technology probe study, focused on in-home family testing. Initial findings suggest that involving children throughout the design process can facilitate the development of games that are accessible, engaging, and encourage peer-to-peer creative problem solving.

CCS Concepts

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI; Human computer interaction (HCI); HCI design and evaluation methods; Field studies; • **Applied computing** → Education; Collaborative learning; • **Social and professional topics** → User characteristics; Age; Children.

Keywords

co-design, game design, STEM education, engineering education, Joint Media Engagement, participatory design, children's media

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1 Introduction

Engineering education is essential for living in a constantly evolving technological world, yet many children do not have access to quality engineering instruction from a young age [21, 28]. With the increase in the availability of internet connectivity and mobile devices to broader populations [8, 10, 39], there is growing potential to use digital games focusing on topics like engineering to support children's STEM learning in out-of-school contexts [17, 18, 34]. Games create playful engagement that is key to informal learning [7, 27] – and digital games hold a great deal of potential for learning early engineering principles, particularly when children learn collaboratively [2, 12, 36, 37].

However, digital educational games can sometimes fall short in either engagement or educational value [13]. These games are also often designed for children without involving children in the design process until the last phases of testing, resulting in games that do not meet the developmental needs or interests of children [13, 14]. In recent decades, researchers studying children's educational media have found that children's learning from educational media can be enhanced when they engage jointly with others – a concept known as Joint Media Engagement [35]. But few digital games, particularly for younger children, draw on the principles of JME [42]. Additionally, most studies of JME focus on parents and children [19], not on exploring the potential of peer-to-peer and sibling interactions in the learning process.

In this work-in-progress, we discuss the co-design and testing of three peer-to-peer engineering games that draw on the principles of JME, including how we plan to continue to test, iterate, and evaluate the games to understand their potential impacts. First, we briefly discuss the co-design process, followed by an overview of the games. Then, we discuss the ongoing user tests and technology probes, as well as our future work and potential directions. We will end with initial insights and recommendations on the co-design process as well as several approaches to peer-to-peer gameplay design.

2 Related Work

2.1 Designing games with and for children

In recent years, more interaction designers have incorporated children's perspectives directly into their design processes [1, 5, 9]. Scholars have varying perspectives on what role children should play in design, ranging from users to design partners [16, 30]. Druin [15] states that children provide expertise in being children that adults cannot, thereby providing unique contributions as design partners. In this work, we involve children and adults in the design process in multiple capacities [41], ranging from long-term design partners to one-time testers. We also conducted two co-design groups simultaneously, enabling us to use the same activity with two groups of children and identify differences in their approach.

Children also require scaffolding to engage equitably with design processes, and a number of techniques have been developed to support children's participation, ranging from breaking feedback down into simple categories to creating game-like constructs that invite children to present their ideas playfully [38]. Recent methods include having children play "Would you rather?" [32] and use tabletop robots for telepresence [25]. Throughout this project, we have used and adapted a wide range of co-design techniques to meet the unique needs of our work, furthering our understanding of design techniques and processes

2.2 Joint Media Engagement and peer-to-peer learning

Joint Media Engagement (JME) has emerged as a key concept that can enhance how children and parents learn from media together. JME focuses on how media consumption can be a beneficial learning experience if engaged with in a thoughtful manner [35]. There have been a number of studies focusing on JME with children and parents [42], but far less is known about JME between children. Given that so many children watch videos together, play video games together, and create media together, there is a crucial need to understand more about how they learn together through JME.

Prior research from the field of Computer-Supported Collaborative Learning (CSCL) supports the idea that children can learn together using technology, including digital games [3, 31, 34]. Families learn from playing games together, even games that some may not consider "educational," such as *Pokémon Go* [33]. Much of this CSCL research, however, focuses on formal educational spaces or structured interactions in spaces like museums [11, 12, 20] – fewer studies investigate casual peer or sibling gameplay [29]. We seek to identify the potential peer-to-peer opportunities in these casual sibling or peer JME moments and use them to encourage STEM learning together, particularly focusing on engineering concepts.

3 Co-Design process

Media producers from GBH and researchers from UW received a grant from the National Science Foundation to explore the potential of peer-to-peer JME for enhancing children's learning from digital engineering games. As part of this project, we are iteratively researching and co-creating three digital engineering games based on the PBS KIDS series *Team Hamster!*¹. The games are

¹<https://www.pbs.org/parents/shows/ruff/team-hamster>

intended for 5–7-year-olds and are designed to be played by two children together on the same device (sometimes called "couch co-op") in informal settings. Throughout the 2023-2024 school year, producers and researchers conducted 18 co-design sessions with KidsTeam UW – an intergenerational co-design group – approximately once per week. Six weekly sessions were also conducted with the KidsTeam Libraries group at the Seattle Public Library in spring 2024. After generating game ideas and developing early prototypes, we conducted 8 more sessions with KidsTeam UW and 4 sessions (once every two weeks) with an afterschool program run by the Seattle-area Associated Recreation Council in fall 2024. Overall, our team conducted 36 co-design sessions during this 18-month period, with 26 being KidsTeam UW sessions. This design process will be discussed in detail in a future publication.

Child participants in sessions ranged from 6 to 11 years old and were of diverse racial, ethnic, and socioeconomic backgrounds. Undergraduate research assistants facilitated the co-design activities with the authors. Design techniques were selected based on their appropriateness for the goal of the session, ranging from "Would you rather?" [32] to Bags of Stuff [40] to Comicboarding [23, 38]. The team met multiple times per week to discuss the session plan, finalize materials, and debrief after design sessions. Sessions early in the design process focused on ideation and surfacing what children thought was important for a game, while later sessions tended to focus on specific game aspects, evaluating early prototypes, and discussing Let's Play videos that could accompany the games when disseminated online.

As the GBH team was located in Boston, team members attended most of the KidsTeam UW sessions remotely, using video conferencing software. Children were also invited to participate remotely if needed, such as due to parental illness or scheduling issues. This allowed us to have the media producers collaborate directly with the children and discuss the prototypes with them over the course of the project. The children stated that this allowed them to have a better understanding of how their ideas were incorporated, while the designers said that this process provided extensive insight into how children think about and engage with games.

4 Game Prototypes

Three game designs emerged from our early co-design sessions and were developed into alpha versions (high-fidelity prototypes, see Figure 1) by the media producers at GBH. Each game uses a different approach to encourage peer-to-peer interaction based on feedback from the youth co-designers. The final games will eventually be disseminated publicly, with their design and educational goals explored in future work.

4.1 The Puzzle Game

An early concept that emerged was an escape-room inspired game that involved using everyday items to help the hamster character navigate the room and find objects by solving engineering puzzles. The current prototype has the players help the character build solutions to the puzzles using objects in the classroom, such as a lever to lift a heavy object and a sailboat to carry them across a fishtank. Children involved in the co-design process really wanted



Figure 1: Screenshots from a) the puzzle game, b) the tower game, and c) the obstacle course game

to experiment with as many objects as possible and found it amusing when their solutions failed in interesting ways. The current prototype has several multi-part puzzles that can be solved with various combinations of materials (for example, children can make a mast for their sailboat from an ice-pop stick or a pencil, but not a pipe cleaner – it’s too bendy!).

This game is intended for peer-to-peer play but the mechanic is more subtle than the other two games. Rather than assigning children to obvious Player 1/Player 2 distinctions, the game encourages players to discuss their ideas and work together more informally. This was one of the play patterns we saw amongst the children early in the design process.

4.2 The Tower Game

Another game that quickly became popular with codesign participants was a concept that involved tower building. This concept went through several iterations, and we used physical foam blocks for early prototyping to test out challenges such as whether a tower would withstand shaky ground (shaking tables or stomping) or wind (fans).

The current prototype allows for collaborative or competitive play; has several challenge options (withstanding a shaky desk, wind, rain, or building a tall tower on uneven ground); and incorporates multiple block types, each with its own material properties. The peer-to-peer element is clearly defined in this game, with defined turns and the option to play with or against the other player. Players may also asynchronously share a level they made with another player via a code.

4.3 The Obstacle Course Game

The third game concept that emerged as popular and engaging was a platformer-style obstacle course (platformer refers to games where characters move through, overcoming obstacles and/or defeating enemies). In this concept, hamsters navigate through levels together, collecting star pieces in order to form a whole star. Many of the children involved in the design process were fans of popular platformer franchises such as *Super Mario*.

During the co-design sessions on multi-player games, children often preferred to play on the same device synchronously. The current prototype of the game uses simple two-button controls for each player and escalates in difficulty as the levels are completed. The hamsters use simple machines such as levers and springs to navigate the levels. Players must collaborate simultaneously, as one hamster cannot collect all the star pieces on their own. Players

must open doors for each other, operate levers to unlock different areas, and move objects to help each other finish the level.

5 User Testing Methodology

To better assess the usability and educational aspects of the games, we are currently conducting a technology probe study [22, 24, 26] with Seattle-area families and running community user testing sessions at the Burke Museum in Seattle.

5.1 Participants

To assess the peer-to-peer aspect of the games, our technology probe study participants are families with at least two children, at least one of whom is in the target age range of 5 to 7 years old. Due to the prototype nature of the games, families must have some familiarity with tablet technology and be literate in English. Participants are being recruited from the Seattle area only, since the study requires delivery of materials and visiting the home.

For the community sessions, we are recruiting families visiting the museum and including both parent-child and child-child dyads. We are targeting families with children in the 5- to 7-year-old age range, but as the sampling in an open setting like a museum is somewhat opportunistic, we have thus far had children as young as 4 and as old as 9. In all, we plan to conduct the technology probe study with 15-20 families and the community user tests with approximately 20-30 dyads. Pilot work has suggested that these numbers are feasible.

5.2 Study Materials

For the technology probes, the research team has developed an activity book containing questions and drawing prompts to accompany the games, an interview protocol for after the activity phase of the study, and data collection sheets. These documents were developed by the first author and then edited with feedback from the rest of the team and the project advisory board to ensure their appropriateness for the study and for working with children. Feedback included suggestions for shortening the interview protocol and including more illustrations in the activity book. For the community sessions, the team created an observational protocol focusing on documenting evidence of peer-to-peer interaction and STEM learning. Both studies use tablet computers to present the games. As many children are familiar with touchscreen tablets, these devices are the most accessible method of presentation. All tablets are provided, families do not need to provide their own.

5.3 Procedure

The technology probes begin with an initial visit from a research team member to a participating family's home. The researcher goes over the consent process and the activity book with the family. The family is given a tablet computer with the game links loaded on it and instructions on how the children should play the games together, and how they should fill out their activity books. Families are given approximately a week – depending on availability – for the children to play the games and complete the activities. After the week is up, the researcher visits and conducts a semi-structured interview with each participating child, using the activity book and tablet as a guide and memory aid. The researcher also briefly interviews the parent/caregiver(s) about their observations. Afterwards, the researcher collects all notes and the activity books, leaving the tablet with the family as part of their compensation. A gift card is emailed upon completion of all study activities.

In the community user tests, families visiting the museum are greeted and invited to participate. The researcher reviews the consent process with the family and collects basic age information for the child participant(s). A dyad (parent-child or child-child) then plays the games, and the researcher takes notes on the observational protocol, allowing play to proceed naturally but assisting with any major issues and asking for clarifications on reactions and utterances as needed. The dyad is allowed to play whichever games they desire in any order and may leave at any time.

5.4 Data Collection and Analysis

Data for this study is collected via observational protocols and interview notes as well as artifacts such as the activity book. The note-taking process is structured by the observation and interview protocols, which emphasize usability, engagement, collaboration, and learning. This data is intended both for research analysis and to provide feedback to the design team for future iterations, so it is analyzed in two ways to provide insights for both applications.

For the initial analysis pass, the field notes are quickly collated and summarized into major themes in a short research memo to send to the larger team for use in the game iteration process. These memos are also discussed in project meetings and debriefs. Once data collection has finished, the data will be qualitatively analyzed using thematic coding processes to evaluate overall study findings [4, 6].

5.5 Initial Findings

This study is currently in progress, but the initial data from the community testing suggests that the games are successful in their goal of encouraging peer-to-peer play: we saw varied STEM communication, collaboration and competition, and playful problem solving. Children found the games to be engaging and enjoyed exploring the STEM concepts embedded in the games, such as properties of materials. Parents appreciated the ways in which the games encouraged players to work together, and adults who participated also stated that they had fun. Some usability issues surfaced, with a few children having difficulty with certain game aspects, such as placing blocks in the tower game, or navigating ladders in the platformer game. Researchers also found that children playing the puzzle game tended to use trial and error to solve challenging puzzles rather

than using the embedded hints. Improvements are currently underway. Overall, early feedback suggests that the games are providing meaningful peer-to-peer engineering experiences for children.

6 Future Work & Conclusion

Through this work, we developed three games that provide engaging ways for children to explore engineering concepts together, demonstrating the importance of peer-to-peer engagement for STEM learning in young children. This project builds on previous work in JME [19, 35, 42], by exploring how it can be applied to peer-to-peer media engagement. In this work-in-progress, we have shared the co-design process for creating the games as well as the process of developing studies and materials for conducting further testing. Our user studies and technology probes will provide insights to improve the next iteration of the games. Once the games and accompanying Let's Play videos are complete, a third-party evaluation study slated for the upcoming months will assess children's engagement and engineering learning. The full results of the studies and details of the design process will be presented in future publications. This snapshot of the current state of the project presents the complexity of co-design work and how it can impact the digital game development process.

7 Selection and Participation of Children

This research was reviewed and approved by the University of Washington's Institutional Review Board (IRB) and registered with the Office of Youth Protection Coordinator at UW. All researchers received training in ethical research with children. For the technology probes, we recruited families with at least two children, once of whom falls in the target age range of 5 to 7 years old. Children and families were selected based on their interest in the research and their ability to complete the research tasks, as well as their geographic proximity to facilitate data collection. Participants (children, parents, adults) were provided with consent and assent information given the opportunity to ask questions. Consent processes were developed in conjunction with the IRB office to ensure appropriateness for the ages of the youth and procedures. Research procedures and materials were developed with feedback from the project's advisory board and designed to be engaging and accessible to children.

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