Curious Construction Kit: A programmable building kit for early childhood

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ABSTRACT
Imaginative play is a rich source of learning and development for early childhood. Constructionist theory also highlights the benefits of play involving programmable elements and the process of construction and building. In this paper, we describe a new educational tool, the Curious Construction Kit (CCK), a building platform that allows children to become fully immersed in their creative, constructive play. We believe that young children will be able to engage deeply in design when using the CCK, both allowing for representations to emerge and planning for them. Design features of the CCK are explained, as well as hypothetical use cases. Future work and theoretical considerations are also discussed.

CCS Concepts
• **Social and professional topics → K-12 education**

Keywords
Constructionism; Early childhood education; Educational technology; Tangible user interface.

1. INTRODUCTION
Educators know good rich play when they see it, and generally do their best to encourage it in children. Educational researchers recognize the importance of developing tools to support this type of play and learning [7]. The goal of this project is to take the imaginative play that children naturally engage in with found objects and extend it by adding controllable electronic features.

Today, there are toolkits being developed to engage children in STEM starting at the age of four, but few of them take into account the high drama of fantasy worlds that children create on their own. While existing technology-infused construction kits for children allow them to control fantasy worlds, they usually require children to manipulate small objects on tabletops or screens [1, 3, 8]. This means that the imaginative play is enacted as a micro-world external to the child, constructed in front of them [6, 11]. In this paper we describe the development of a new building platform for early childhood, the Curious Construction Kit (CCK), which allows the child to construct their own immersive play environment. The CCK was developed for the course *Children and New Technologies (CD 114)* during the Spring semester 2016 at Tufts University, and inspired by programmable "playground" technological experiences designed at the DevTech Research Group [2, 13, 14]. The CCK has both static and interactive components. The static components are connectors and structural panels that can be assembled into play structures by children. The interactive components include functional panels and a "brain" to control the panel electronically. Each functional panel has a single electrical component (e.g. light, sound, motor) that is controlled by the child's interaction with the brain. A prototype was developed over the course of the semester. This paper describes the development of the prototypes, as well as several hypothetical play scenarios.

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2. THEORETICAL BACKGROUND
Play in the early childhood years is dominated by imaginative play. For young children, this is serious work; through play children develop new tools for thinking, being, and symbolizing [12]. Vygotsky [15] details the development of symbolizing in his work describing children's play. To symbolize, thought must be freed from perception, meaning that the thinker can separate the idea of a physical object from its meaning. This movement does not happen spontaneously. The process of understanding a symbol begins with a pivot, an object or action whose meaning is replaced by another. Vygotsky uses the example of a stick, whose meaning is replaced with a horse. The child needs a new object to "hold" the meaning of the horse. In this process he is symbolizing externally, an act that will become internal with time.

In imaginative play, internal and external processing is fused and the child has an opportunity to exercise the act of symbolizing. This serves as practice for later internal symbolic reasoning. The CCK presents the child with the opportunity to cast meaning onto the blank structural panels (perhaps they become the walls of a ship) as well as assign meaning to the actions produced by the functional panels (e.g., the spinning motor acts as a propeller). The child may also give new meaning to their interaction with the play structure, proclaiming "full speed ahead!" as they push the brain's slider forward to control the motor.

When children begin to engage in imaginative play they often recreate scenes from the real world—sailing, eating, war. By age four, even their wilder scenarios follow the physical and psychological laws of the real world [11, 12]. Pirate ships move because of the wind caught in their sails, and heroes fight villains because they are hurting people. These recreations and re-

representations show us that children are working hard to understand the world around them.

In play children have the ability to be their own teachers [15]. That is, they are able to learn from their imagined selves. Take, for example, the child that does not know how to count. In an imagined state of emergency, while playing as an astronaut on the intergalactic battle fields, he effortlessly counts down, "Three! Two! One! Blast off!" Through a close attention to these types of imaginative play we better understand it as the work of childhood.

2.1 Theory and Design Considerations

Constructionism asserts that knowledge is constructed by the individual, through interactions with the real world and with digital worlds [6]. More simply put, learning by making. Especially when the learner is engaged in building, or destroying, a public entity [7]. Papert [7] describes two styles of constructing. One allows for representations to emerge from the process of the building work, and does not follow a set plan. He borrows the term "bricolage" from the art world. The other style relies on mental representation to execute a building plan, without much deviation from the initial idea in a top-down approach [4]. Researchers in the field of educational technology urge designers of new technological tools to consider both of these construction styles when designing for children [9]. The CCK affords opportunities for both styles of constructors to engage in the process of building their own knowledge structures.

The "makerspace" world is full of toolkits and platforms that allow users to control electronic components (e.g. arduino, raspberryPi, little bits, etc.) with the promise of being able to "make anything." The rhetoric around these products is that anyone can pick one up and immediately build a complex robot. In reality novice prototypers have difficulty getting started due to the many ways they can fail. Sadler, Shluzas, & Blikstein [10] have shown that modularity reduces the chance of errors and improves the likelihood of novel creations. We have incorporated this into our design. The CCK is designed to be a modular system with each functional panel operating independently. All electrical connections are made with jacks that remove any chance of polarity error.

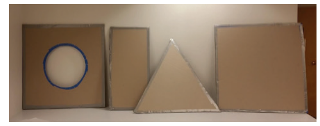
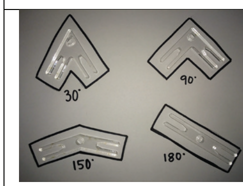
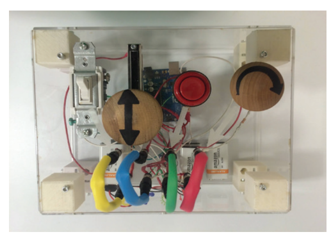
3. TARGET POPULATION

The CCK was designed for children ages 4 to 9, prime ages for imaginary play. The interactive and programmable elements of the CCK enable the child to enhance the high-drama already present in their imaginative play. The kit may be used as a tool in formal or informal learning settings. For example, in a kindergarten class investigating dinosaurs, children may be asked to collaboratively build a model. The various sizes and shapes of the *structural panels* require a child to think about the relationships between size and function of different aspects of different dinosaurs, while the sound emitting *functional panel* can be used to represent the roar of a T-Rex. Similarly, children in a home environment are free to construct their own castles, rockets, or music halls, and other interests using the CCK, exploring the same construction concepts individually or with family members.

4. CURRENT PROTOTYPE

The current prototype has four main components: structural panels, functional panels, connectors, and the brain. The structural panels are made of cardboard, come in a variety of shapes, and have at least one dimension that is 2'. The functional panels are the same size as the structural panels but incorporate one electrical component each (e.g. lights, sound, motor). Connectors are made of acrylic and are designed to connect both types of panels into three-dimensional structures. The brain is used to control the elements of the functional panels. Table 1 depicts the components of the current prototype.

Table 1. Description of Prototype Components

Component	Description
	*Structural Panels* are approx. 2 ft. tall cardboard shapes used to build large constructions. They are sturdy enough to withstand several rounds of rough play, but light enough to be easily manipulated by young children without fear of injury. They are joined with acrylic connectors.
	*Connectors* are laser cut from ¼ in. acrylic, with point-to-point connections in four angle options.
	*Functional Panels* are similar to Structural Panels, but they include the following controllable elements: LED, motors with cardboard attachments, and audio-devices that play sounds.
	The *Brain* controls the Functional Panels. It has four control input options: an on/off switch, a slider, an on/off push button, and a twisty knob. The child connects the controller to the icon that corresponds to the Functional Panel they wish to control. More than one Panel may be controlled by the same input. All connections are made with 3.5mm audio jacks.

5. USE CASES

In this section we describe two hypothetical scenarios, inspired by what we know about children and how they play. First we describe Dylan, who, while trying to figure out how to build a house with his friends discovers what it means to be a DJ. The second, Sara, has a clear idea of what she wants her house to look like and spends her time getting the kit to meet her needs.

5.1 DJ Dylan

Dylan and two of his first grade friends are introduced to the CCK. They all begin playing in their own way. One friend is holding up multiple pieces of cardboard with out any connectors and trying to arrange them in a cube. The other friend is trying to put as many connectors as they can onto a single piece of cardboard. Dylan begins playing with the brain and the sound panel. While his friends begin to team up and build a house-like structure Dylan is using the switch to turn the sound panel on and off. On the brain he changes the connection of the audio panel from the switch to the slider and the panel immediately changes pitch. He begins to move the slider back and forth; to his delight the sounds changed together with his movement. He exclaims, “I’m a DJ now! I’m making music! I’ve never done this before! I’ve always wanted to be a DJ!” With his newfound talent Dylan convinces his friends to use the sound panel as part of the roof of the house they are building so they can all sit inside and DJ.

5.2 Sara

When Sara, age 6, was told that the CCK would allow her to make anything, she decided to make a dinosaur. After a few moments of surveying the tool set she decided that she wasn’t sure if she could build a dinosaur but was sure she could build a house, and began to do so. She began by laying out the four panels that would make her walls then collecting the connectors she thought would be necessary to connect them. She had some difficulty holding the panels in place while trying to connect them, so she called out to her nanny for help. With some help Sara assembled a four-sided structure she called a house. Realizing there was no door, she swapped one of the panels for one with a hole cut out of it. Once inside she realized there was no roof. Intrigued by the square panel with a circle cut out of the middle lined with RGB LEDs she decided to make it her roof. She then brought the brain inside her house and connected the LED functional panel to the twisty knob. Changing the colors back and forth while watching them reflect on her skin, and suddenly exclaiming “it’s red, it’s like blood red.”

6. DISCUSSION

Dylan’s case presents the more “bricolage” style of making where knowledge emerges from tinkering with objects [7]. Once Dylan began to play at being a DJ, the tones being produced by the CCK as well as the action of sliding the knob became metaphors for the types of actions DJs do, as well as the content they produce. He constructed a new knowledge of what it means to be a DJ and how sound is made and controlled. Most importantly, his imagined self (DJ Dylan) is teaching himself (Dylan) that he is some one who can control his environment [15].

In Sara’s case we see a more top-down style of constructing. She considered several building options and did not select her initial idea, choosing instead to build something that she was sure she could make. Although the CCK is open-ended, it still afforded learning opportunities for Sara’s construction style. The ability to conceive of and execute a plan at this scale is unusual for children this age. In this case, Sara is exercising her ability to conceive and represent a house [7], while also finding playful relationships between the programmable panels and the things she is curious about (e.g. blood and the color red) [2].

7. FUTURE WORK

The research team looks forward to further developing and modifying this prototype. The core changes planned for the next prototype is to alter the structure of the CCK’s interaction with the brain. Instead of using wires to connect the brain to the functional panels, we plan to connect the brain to the functional panels wirelessly. Also instead of connecting the controls on the brain to icons of functional panels, tokens of functional panels will be produced to attach to the brain near the desired controller (see figure 1). We believe this will significantly streamline the process of controlling the functional panels, and leave room for more complex interactions for future versions.

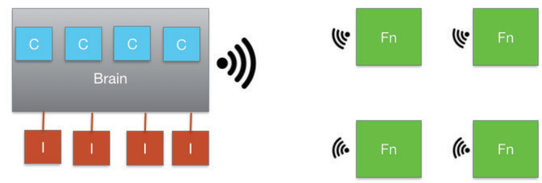


Figure 1: Wireless CCK

Additionally, experimenting with material changes, such as replacing the current plastic wrap and cardboard materials with lightweight plastic and wood, may add to the durability of the kit. We are also considering new panel shapes and sizes, and are particularly eager to make a trapdoor-style panel, as well as panels that could be decorated and personalized. In its current state the motor panel has a propeller mounted on it. We would like to develop a connector that allows a broader set of things to be attached to allow children to cast a diversity of symbols and actions onto it, instead of only propeller/fan related ones.

Most importantly, we are excited to begin empirical research on how this toolkit may enhance imaginative play and symbol development in young children. We also plan to investigate elements of collaboration to better understand how making can be a place for children to develop their social and emotional skills, and to better understand the optimal number of users for the CCK.

8. CONCLUSION

Through presenting the design of and rational for the CCK together with two use cases, we have shown how the CCK can be a powerful tool for promoting children’s development through play. The CCK presents opportunities for early symbolism (e.g. Dylan moving the slider to act as a DJ). It allows children to explore and make sense of ideas they are curious about (e.g. Sara exclaiming “it’s red, it’s like blood red”).

While the CCK is designed to provide children with the ability to physically control their environment, it simultaneously provides them with the control on an emotional level that they need.

We look forward to spending more time developing and investigating the CCK with young children. We hope that by blurring the lines of real and imaginary worlds this tool will contribute to young children’s developing sense of agency as makers of their own ideas and artifacts.

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