Block Talks: A Tangible and Augmented Reality Toolkit for Children to Learn Sentence Construction

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Abstract
The *Block Talks* toolkit combines the educational potential of tangible computing and augmented reality (AR) technologies to help children learn English sentence construction. Although examples of tangible AR reading systems for children currently exist, few focus specifically on learning sentence structure. *Block Talks* was developed using ordinary teaching supplies including letter tiles and blocks that can be manipulated to form words and sentences. A companion app allows children to scan these sentences to receive audio and AR feedback. *Block Talks* takes advantage of colour cues to draw children's attention to sentence structure patterns. This paper outlines existing tangible and AR systems for literacy learning, details the *Block Talks* design rationale, and concludes with a discussion of the advantages of using a combined tangible and AR approach for teaching sentence construction.

Author Keywords
Tangible user interfaces; augmented reality; children; sentence construction; blocks, colour cues.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: User Interfaces.K.3.1 [Computers and Education]: Computer Uses in *Education-Computer-assisted instruction*.

Figure 1: The *Block Talks* Toolkit: app running on a tablet and a set of magnetic colour-coded Lego blocks and letters.

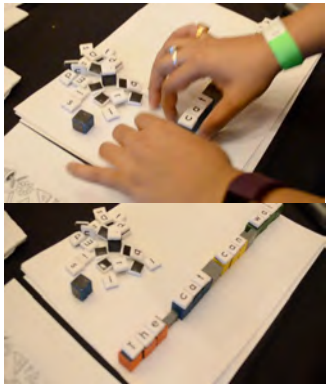

Figure 2: The child places letters onto the colour-coded blocks to make words (*The*, *cat*, *can*, *run*), and then connect the Lego-based blocks to the make sentence (*The cat can run.*).

Introduction

Literacy is a core competency that can greatly impact individuals' lifelong educational and economic outcomes. Learning to read and spell is a cognitive developmental process and is acquired in stages over time [2]. English-speaking children often learn these skills around age 7. This often starts with phonological awareness (manipulating sound units in oral language) and knowledge of the alphabetic principle (letter-sound correspondences) [7] and builds to include more complex syntactic (rules or grammar and punctuation) [9] and semantic (meanings [4]) acquisitions.

Syntactic and semantic knowledge are crucial to understanding meaning in text. Although most syntactic knowledge can be learnt from oral language [12], it remains challenging for many children to acquire. Research shows that at-risk children with phonological deficits often demonstrate less developed syntactic abilities when compared to their matched peers [13]. Many children who learn English as a second language also have poor syntactic knowledge, due to their phonological abilities and limited oral language skills [3].

Recent research suggests the potential of tangible user interfaces (TUIs) to support children's literacy learning [7,10,11,15]. These claims are based on the spatial nature and multi-modality of TUIs [6,15]. Words and sentences consist of linear sequences of letters which can be represented as objects that have visual-spatial properties. Tangible letters make it easy for children to manipulate and reposition letters to form words and sentences.

Augmented reality (AR) technology has the potential to make TUIs for learning affordable and easily accessible to teachers. Whereas many existing TUIs require complex hardware [1,5,7], the combined tangible and AR approach can be developed using an off-the-shelf technique that requires no customized electronic hardware. This new type of TUI can be realized with as little as a tablet device and a set of physical letters.

In this paper, we present *Block Talks*, a tangible and AR toolkit to help children ages 8-10 learn English sentence construction. *Block Talks* consists of a set of inexpensive wooden blocks, magnetic letter tiles, and a companion tablet app. Although examples of tangible AR reading systems for children currently exist, these systems focus primarily on basic spelling [1,7,16] or storytelling [16]. Few have focused specifically on assisting children to learn syntax of sentence structures (for exceptions, see [10,11,17]). The main contributions of our work are: 1) a design rationale for using AR-based TUIs for children's reading systems; and 2) the specific design and development process behind the *Block Talks* toolkit. This paper describes work-in-progress, and concludes with a discussion on the advantages of using a combined tangible and AR approach for teaching sentence construction to children with phonological deficits.

Tangible and AR Systems for Children's Literacy Learning

Combined tangible and AR systems

A number of tangible AR reading systems for children currently exist; however, most tangible and AR systems focus on either spelling or storytelling rather than sentence construction. For example, *Blackblocks* is a tangible tabletop that allows children to align three

Figure 3: The child scans the sentence (*The cat can run.*) under the tablet camera to check the augmented feedback.

Figure 4: The red arrow animation indicates the reversed order of the letters *i* and *r* in the word *bird*.

black uppercase letter blocks on a customized table to build a three-letter word [1]. The system responds by displaying the word and associated picture. However, educators often use lowercase letters to teach spelling [7].

ARBlocks is a block-based AR system that uses a table, camera, projector, and a set of marker-based blocks to help children improve their phonemic awareness and reading skills [14]. When children place a block on the table, the associated picture is projected onto its surface. Using such a design, children can do various phonemic activities such as matching two word-picture blocks starting with the same onset (e.g. *hit & hip*). A drawback of this AR approach is that it requires a large space to set up, and is difficult to move to other places.

Letter Alive is a commercial AR product to teach children phonics and syntax of English [17]. Children place picture cards under the web camera. The augmented content such as words or sentences display on the computer screen. This design is limited because children can only build a sentence with a maximum of four words. Also, using pictures rather than text to represent words may also lead to ambiguity since their interpretation may be biased.

Tangibles for learning sentence structures

We found only two other tangible systems targeting English sentence structures, although one was not specifically designed for this purpose. *Tiblo* is a tangible system that uses Lego-like blocks to represent concepts, including words, numbers, and potential phonemes [11]. Children draw the concept on a piece of paper, attach it to a block, and record a sound for the concept. The blocks have notches that can be connected to represent a sentence or another concept. Each block contains four notches and may be connected in a non-linear fashion. This is not ideal for learning linear sentence constructions. Moreover, no system feedback is provided for children's performance.

RoyoBlocks is a tangible reading system that uses a set of word blocks with RFID tags and a plush reading companion with an RFID reader [10]. Children can use the word blocks to construct sentences and listen to the audio. RoyoBlocks only provides audio, not visual feedback. Further, children can only use the provided words rather than creating their own.

Tangibles and colours

Two tangible reading systems, in particular, use colours to enhance children's learning. *Spelling Bee* is a tangible system that allows children to build words by connecting blocks embedded with LED lights [5]. The LED colours in the cubes indicate whether the spelling is correct (green) or not (red).

PhonoBlocks leverages the use of embedded dynamic colour cues within 3D tangible letters to help children learn various alphabetic rules [7]. Results showed that embedded dynamic colour cues attracted children's attention to the moment that letters changed their sounds, and that the 3D tangible letters enabled beneficial epistemic strategies for learning, such as pairing and ordering letters [7].

Block Talks **Toolkit**

Learning goal

The main learning goal was to teach children syntax of English word and sentence construction. We started with simple words and sentence structures such as

Sentence Structures	Colour Cues (Examples)
Article	Orange (A)
Subject	Blue (bird)
Modal verb	Yellow (can)
Verb	Green (fly)
Punctuation	Black (.)

Table 1: Colour cues for different sentence structures.

"The cat can run." and "A bird can fly." which children may learn in Grade 1-3.

Design goals

Based on previous research, we presented four main design goals: (1) using inexpensive, physical learning tools that are already available to students and teachers [10]; (2) using colours to draw children's attention to coded structures [7]; (3) using tangible letters and physical affordances to enforce children's learning of linear sentence structures [7]; and (4) using a multimodal feedback approach that includes 3D animations, letters, and audio recordings to help children learn to read [10,17].

Block Talks toolkit

Blocks Talks is a tangible and AR toolkit that helps children learn English sentence construction. This toolkit consists of an app running on a tablet and a set of magnetic colour-coded blocks and letters (Figure 1). *Block Talks* is intended to be used in a semi-supervised environment. A teacher first chooses colour-coded blocks for various sentence structures. The colour coding indicates parts of the sentence (e.g.: nouns, verbs, etc.). Children attach magnetic letters to the coloured blocks to form words. These blocks can be connected with physical notches to make sentences. Once the blocks are connected, children scan their sentence using the tablet to receive multimodal AR feedback (Figure 2 & 3). The toolkit was developed by Unity and Vuforia.

Colour cues

We used colours to help draw children's attention to various components of a sentence (Table 1). For example, blue represented nouns, and green represented verbs. We chose common colours that are often used in children's educational tools. Their high contrast and saturation would allow children to easily differentiate them. The colours appear not only on the tangible blocks, but also in the game application as AR 2D text.

Lego-based magnetic blocks

In each coloured group, we supplied 10 blocks so that the child could make both simple and complex words. We attached magnets and Lego-based notches. The magnets enabled letter tiles to be effortlessly attached to the coloured blocks. The Lego-based notches allowed the connection of blocks to form a sentence. We intentionally used different notches for different sentences structures so that the child could only connect the words (structure components) in a certain order (Figure 2). This design leverages the use of physical constraints to enforce correct sentence construction.

Magnetic letters

We created more than 52 square letter tiles, each with the dimensions of 1.5cm^2. Tiles were constructed using letters printed on cardstock glued to a magnetic base. The magnets allowed the letter tiles to be easily attached and detached from the coloured block surfaces. This design ensured that each letter tile could be reused for various words and sentence structures, thus reducing the total number of blocks required. The tile text was black, so as to not interfere with the augmented 2D text. We used a simple sans-serif font, Century Gothic, as recommended by teachers who work with at risk children [6].

Augmented feedback
Multimodal feedback is provided to children through the tablet device. Combining audio and visual feedback can reinforce learning [6]. After scanning the app, if the sentence is correct in both syntax and semantics, the app reads the sentence out loud, a 3D animation representing the sentence is presented, and the sentence (colour-coded in 2D) appears at the bottom of the screen. If the sentence is incorrect, a hint is overlayed on the screen. For example, the red AR arrow animation shows that the letter *i* and *r* are reversed in the word *bird* (Figure 4).

Discussion and Future Work

AR technology has the potential to greatly increase the accessibility of TUIs for learning. *Block Talks* is an example of an inexpensive toolkit that combines the educational benefits of TUIs and AR. Research demonstrates that tangibility matters in supporting children's literacy learning [7,10,11]. Children are tactile learners. By providing them with tangible letters, children can manipulate or organize letters in space, which may improve their attention through actions; reduce their cognitive load by separating spelling from writing; and encourage epistemic actions that can help them to easily solve the later tasks [7]. In addition, tangible objects contain rich information such as colours, shapes, textures, and weight. This information can provide cues to help children learn. For example, colours drawing attention to patterns, and physical constraints of connections offering implicit feedback. The benefits of TUIs could be particularly helpful for children with phonological deficits, for whom traditional instructional approaches may not have been successful.

We extended previous work which utilized colour cues to teach children the alphabetic principle [5,7], to sentence structures. Colours are often used in literacy instruction to help children notice grouped patterns, such as onset, rime and syllables. However, they are all focused on the phonological/word levels [5,7]. Our work is the first tangible and AR system that attempts to use colour cues to help children learn syntax of sentence structures. We take advantage of the existing colours of physical blocks and associate them with 2D digital letters, to increase children's attention to, and understanding of, various sentence components.

By combining tangibles with AR we reduce the complexity of the system. Compared to most TUIs that often require complex customized hardware (e.g. laser cutting or 3D printing tangible pieces embedded with electronics or tabletops), our approach uses off-the-shelf technology and only requires a tablet and a set of simple learning tools. All of the materials (coloured wooden blocks, Lego, and magnet paper) can be purchased from a dollar store. Although it requires some assembly, the making process is simple. Teachers could easily and affordably create this TUI themselves. The Vuforia plugin enables numerous word detection which makes it easy to extend current sentence patterns in the future although we still need to produce 3D animation for these sentences.

We demoed our toolkit to HCI and educational experts and received valuable feedback to include in our next iteration. We are continuing to develop the prototype and hope to soon conduct usability testing with children. Currently, our system has only one sentence pattern and one error feedback suggestion. However, we are interested in working with teachers to co-design

improved feedback and learning tasks to enhance and reinforce existing curricula. Although the current version requires assistance from a teacher, we are developing a Game mode to allow children to practice on their own. Once the toolkit is further along in development, we propose running a study to evaluate children's interactions and learning outcomes with *Block Talks* compared to traditional instructional approaches.

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