Designing for Computational Collaboration

Using a Storyboard Educational Design to Scaffold Collaborative Coding for Childhood Education

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Abstract
The current paper examines the multimodal and collaborative nature of young children's educational interactions. The paper draws from a design-based project on 3-5-year-old children's programming and hones in on the multimodal details of children's collaborative practices. We investigate video-recorded naturally occurring interactions during small group activities during which children learn programming while playing a storyboard-based game, using two analytical techniques to examine how coding sequences are solved. First, we examine how coding problems are solved within the whole dataset. Following this quantitative analysis of interactional conduct, we use multimodal conversation analysis to examine how collaborative coding unfolds in the intricate details of interaction, including gaze, gestures, and temporal aspects. Findings show how the storyboard fosters both individual scaffolds and collaborative solutions. The multimodal analysis unveils how collaborative coding by children consists of overlapping turns of interaction where children jointly solve sequencing problems using a range of embodied resources. The findings show how constructionism designs can foster collaborative, interactive solutions for young children's situated coding activities.

Keywords and Phrases: collaboration, coding, early childhood, multimodality

1. Introduction
Computers have become ubiquitous in almost all age brackets. Subjects such as coding are now commonplace, even in childhood educational settings (Tang et al., 2024). In early childhood education, coding has been introduced to ever-younger children using gadgets such as programmable robots, allowing children to tangibly engage with simple computing devices playfully without adding extraneous screen time (Samuelsson, 2024a).

Getting people to collaborate using computational devices is one key facet of modern life (Cukurova, 2024). A crucial distinction lies between cooperation and collaboration, where cooperation involves doing different parts of a problem separately. In contrast, collaboration entails solving problems jointly (Dillenbourg, 1999), often managed through joint face-to-face efforts where people negotiate meaning and problem-solving during embodied interaction (Goodwin, 2018).

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During early childhood, children's capacity for collaborative behavior develops. In many ways, early childhood ages 3-6 is prone to collaborative engagement, as children begin to develop intersubjectivity, often play together, and are less into the competitive games characteristic of school-aged children's play (Tomasello, 2019). In ethnomethodological studies and conversation analysis (CA), intricate methods for examining collaboration in increasingly multimodal detail have been developed (e.g. Church & Bateman, 2022). From this perspective, learning can emerge collaboratively from participants' joint engagement. Here lies the potential for understanding how collaborative designs can be constructed to foster joint engagement with computing educational matters.

This paper studies a design for young children's collaborative coding by examining collaboration using a storyboard and programmable robots. The paper combines a quantitative analysis of children's problem-solving of programming sequences and a fine-grained micro-level and multimodal examination of how children collaborate within the educational design.

2. Coding in Early Childhood Education

Programming is becoming a subject for childhood education, now engaging children of increasingly earlier ages across the globe (Macrides et al., 2022). Programming is well suited to the nature of children's playful learning modes active in early childhood (Samuelsson, 2023, 2024b). Still, the profession has significant uncertainty regarding how activities and programs for early childhood programming can be managed. Creating educational designs that are better adapted for young children remains a challenge (Su & Yang, 2023).

Furthermore, creating a broader computing education that can engage all learners from an early age remains an issue (Tissenbaum et al., 2021). Here, educators must create new forms of educational designs that can be playful and challenging. One way to meet this challenge has been to create play-based robotics (e.g., Bers et al., 2014) and work with child-centered project-work to engage children (Resnick, 2017), for example, using children's stories to make programming engaging (Yang et al., 2023). Coherent with the early visions of constructionism learning (e.g., Papert, 1980), creating efforts with young children, where making processes are key to engage children with computational thinking (Saxena et al., 2020), showing one way to involve children with coding. This paper investigates one design with the potential of both learner-centered construction of knowledge, together with peer collaborative interaction and teacher scaffolding, by using a common and popular children's tale engaging children to construct how children engage with a constructed material during an educational design in an early childhood design-based research project (cf. Bakker, 2018).

3. Methodology

The paper draws from a larger design-based project of computing pedagogies in early childhood education (see Samuelsson, 2024a, 2024b), using an educational floor robot, called the Blue Bot (see Figure 1a). The project involved iterative reflections and designs with teachers over a seven-month design process. The design processes involved several phases and educational materials. However, a key challenge during the project was creating more child-centered and engaging materials for the children (see Samuelsson, 2024b), highlighted in the educational design of this study (see Figure 1b).

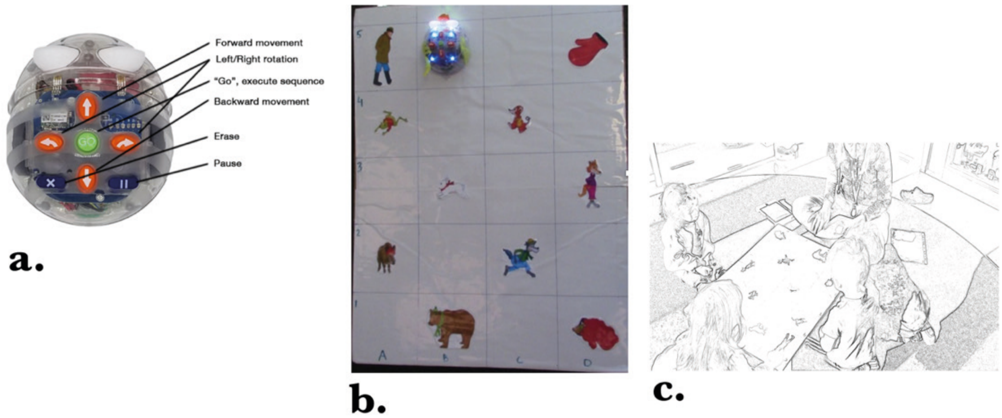

Figure 1: Outlining the materials and setup during the project.

The paper focuses on an educational storyboard design based on a Ukrainian folk tale, *The Mitten*, connecting programming with project work. The tale lends itself to the structured board designed during the project (Figure 1b). During the examined sessions, children work in small groups, taking turns programming the robot to the subsequent character in the tale, along with the teacher's reading (Figure 1c). In the collaborative computing literature, small group settings are identified as key for studying collaborative engagement (Stahl, 2006). Here, we combine a quantitative examination of problem-solving with methods from multimodal CA (MCA) to investigate how collaboration is accomplished among children.

3.1 Data collection and sampling

During the longer design-based study, preschool children's programming activities were followed using video-based techniques (Dicks et al., 2006), recording 10,3 hours of sessions using two cameras. This paper samples instances of children's *sequencing*, a central process in programming education, where commands are put to form a sequence to be executed by a computer device (see Shute et al., 2017). After synthesizing various approaches used to develop the construct in K-16 settings, we have created the following working definition of CT: The conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers), using 4,8 hours of group activities. Sequencing, in this context, is achieved when children put commands into the robot and execute them using the "go" button to solve a coding problem during the game.

3.2 Analysis of problem-solving during sequencing

For this paper, 61 sequencing instances have been analyzed and coded using techniques modified from Samuelsson, Jewitt, and Price (2022). Three ways of solving a programming sequence have been coded using MAXQDA: *Teacher-supported solutions*, *child-individual solutions,* or *child-collaborative solutions*, where each solution to a sequencing problem has been scored in one of the categories.

3.3 Multimodal conversation analysis

The paper uses a single-case analysis of children's collaboration. Single-case analysis can be used to investigate the unfolding of interactions within a single sequence (Waring, 2009; Sert, 2017). We apply MCA, examining in detail how collaboration is accomplished in the sessions, zooming into internationally salient phenomena using the MCA-techniques of Mondada (2016).

This approach sees interaction as intersubjectively established between actors utilizing embodied resources, such as gestures and bodily action, to accomplish joint goals (Streeck et al., 2011). Seen in this way, it is of less importance if one individual child can solve a programming sequence, but the lens is instead turned to how the participating children do this together (cf. Koschmann, Stahl, & Zemel, 2004). The paper provides a short part of the single-case analysis to display interactionally salient characteristics.

4. Results

4.1 Problem-solving during the design

During the phase with the designed board, children solve sequencing with the robot in several ways. As displayed in Figure 2, in the 61 coded sessions, children individually solved sequencing in 24 sessions, collaboratively in 23, and with teacher support in 14. The teacher's relative hand-off approach has been deliberate during this project design phase (see Samuelsson, 2024b) to allow for a collaborative environment.

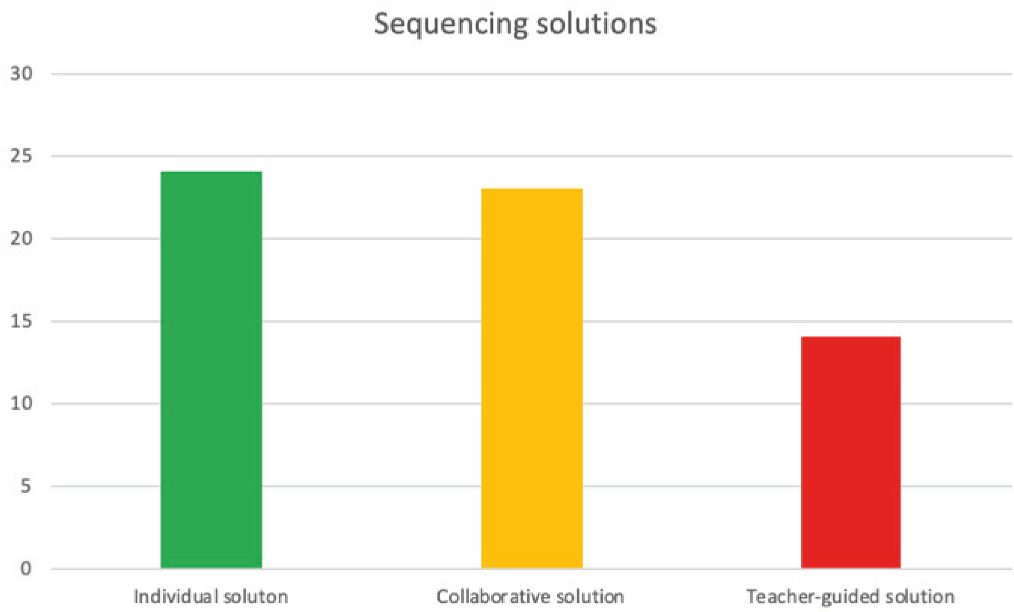

Figure 2: Results of children's sequencing solutions during the project.

An almost even number of solutions are done collaboratively among children, as opposed to individually by the child with the established turn. Thus, there is a collaborative environment among the children during most sessions, but there is also room for individual child construction of programming skills alongside teacher scaffolding.

4.2 Multimodal interaction during sequencing

The multimodal conversation analysis revealed how children collaborate, often using an interwoven set of embodied resources. In Figure 3, a part of an excerpt illustrates how such collaboration unfolds in interaction.

```
         CHI can you program it to the dog
63 CHI1  ja:.
         yes
64 CHI2  bara +EN: +fram:åt.
              +points at the dog picture
                   +CHI3 tries to push the button
         only one forward
65 CHI   de+n.
           + CHI presses the forward button
         that one
66 CHI3  +den go:.
         +touches the go button
         that one go
67       ((CH3 helps CHI move his finger to the GO button))
68 CHI   ↓go:.
69 CHI   ((presses the go button))
70       (1.5)
71 ROB   bip bip bip.
72 CHI   JA::
73 CHI3  JA::
```




Figure 3: Part of the excerpt showing the collaborative interactions of children.

In this short excerpt, lasting less than 5 seconds, the children scaffold each other using embodied means such as pointing, gesturing, and touch. Jointly, the programming sequence is solved within seconds. In the excerpt, several children simultaneously engage in problem-solving, showing the highly collaborative nature of these children's interactions. Before line 63, CHI1 receives a directive to programme the robot. Meanwhile, CHI2 gestures toward the right path, emphasizing that only one move is needed (64). CHI3 then hints at the correct action by tapping the go button lightly without pressing it (66). When CHI1 takes no immediate action, CHI3 carefully slides CHI1's finger to the go button (67), leading to the completion of the sequence (69-71).

Within these 5 seconds, the children jointly engaged in solving this, albeit simple, sequence. In these instances, where collaboration comes to fruition, the children are eager to help each other solve coding problems together. Supported by the teacher's relatively hands-off approach (see the first analysis and Samuelsson, 2024b), the storyboard provides affordances for joint engagement.

5. Discussion

The paper has delved into the nature of children's collaboration during a design project supporting children's coding. We show how a storyboard structure scaffolds children in individual and collaborative solutions. The early childhood age bracket of 3-5-year-olds explored here is identified in the developmental psychology literature as prone to collaborative engagement (see Tomasello, 2019). In the paper, we honed in on the multimodal details of such collaboration (cf. Mondada, 2016). Combined with the situated materials and small-group setting that undergird collaboration with computing devices (cf. Stahl, 2006), we show the intricate inner workings of collaboration in this setting. The MCA analysis shows how children use embodied resources to find solutions together, such as pointing, gesturing, and fine motor hand actions. The turn-taking structure involves simultaneous verbal and embodied actions, working toward joint sequencing. Our view of learning from an emic perspective adds a fine analytical level to the situatedness of collaboration during children's coding. From the vantage point of young children in interaction, results show the interrelatedness of children's actions and how multimodal and embodied components of learning interaction emerge as a joint enterprise where interactional resources are used collaboratively to find solutions.

Thus, the paper shows the micro-level potentials of project work building on children's interest and joy, a cornerstone in the constructionism literature (see Resnick, 2017) and, in particular, a working example of what this achieves in situated activity. The results indicate the potential of constructing materials that build on children's interests and projects to fuel collaborative engagement with programming (e.g. Resnick, 2017). Other studies have pointed to the role of using story structures for children's early coding (Yang et al., 2023). Here, we add how story structures can foster joint collaborative coding actions with children. Adding to the constructionism literature on learning (Papert, 1980), the results underscore the role of the storyboard structure as a way to provide an individual scaffold for children and engage in collaborative action.

Further research should explore the potential of collaborative work with young children. Likewise, the paper shows how face-to-face interaction with joint materials fosters collaboration in certain ways. Similar setups should also be explored for other age groups and with other designs in adult settings, using similar methods to compare how tangible, face-to-face interaction can support collaborative engagement.

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