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Crafting Computational Thinking with Rope Weaving

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Abstract: This study explores how integrating computational thinking (CT) with weaving can make CT more accessible and engaging. Nineteen undergraduates participated in a rope weaving activity to recreate patterns, test structures, and connect math to tangible materials. Analysis of reflections and video data revealed students applying CT practices like pattern recognition and algorithmic thinking. Findings highlight the value of tactile, craft-based activities in supporting CT learning and bridging abstract concepts with real-world, embodied experiences.

Introduction

Building on prior literature on computational thinking (CT) in collaborative learning environments (Huang & Parker, 2023), this study explores how weaving can serve as a tangible, accessible approach to computer science (CS) education. Weaving's historical connections to computational innovations like the Jacquard loom and core rope memory (Essinger, 2004; Schaffer, 1994) illustrate its deep-rooted relevance to computational thinking. Its structured, patterned nature offers a meaningful medium for exploring CT practices such as pattern recognition, algorithmic thinking, decomposition, and abstraction. While robotics and programming activities are widely used to teach CT (e.g., Bers, 2018; Resnick et al., 2009), they can feel abstract and inaccessible to some learners. Weaving, in contrast, provides a concrete and tactile entry point. Prior work with tangible tools like Arduino and tabletop games has demonstrated the potential of physical computing for improving CT skills (Kafai & Burke, 2015). Projects like Lee and Vicent's "Looming Code" show how weaving can bridge physical and digital realms by translating patterns into code (Lee & Vicent, 2019). While their focus was on digital translation, we center the embodied experience of physical manipulation to examine CT directly. Using a constructionist framework (Papert, 1980; Harel & Papert, 1991), we designed a rope weaving activity where 19 undergraduate students recreated patterns with colored ropes to simulate weaving. The rope weaving activity embodies this approach, allowing students to construct knowledge by physically creating woven patterns, making abstract concepts like matrix representations and cloth separability concrete and explorable. This hands-on approach encourages personal discovery and experimentation, aligning with the constructionist emphasis on self-directed learning. The collaborative nature of the activity also highlights the social constructionist dimension, where shared problem-solving fostered the application of CT practices. We analyzed reflections and video data to investigate how students demonstrated CT practices and transitioned from physical manipulation to algorithmic design. We ask: (1) What types of CT practices do students demonstrate during the rope weaving activity, and how do they apply these practices? (2) How do students transition from physical manipulation to algorithmic design when determining cloth separability?

Methods

This study was conducted in Spring 2023 in an undergraduate Informatics course in California focused on computing, robotics, matrix algebra, and textile arts. Nineteen students participated, working in small groups (3–4 students) based on diverse backgrounds in programming, engineering, mathematics, and the arts, as identified through pre-course surveys. The rope weaving activity, developed by the research team (Yankova et al., 2024), spanned two sessions and involved one hour of hands-on work. Students used ropes in two colors to simulate weaving patterns, exploring cloth separability and matrix-based representations. The activity introduced concepts from Grünbaum and Shephard's (1980) algorithm to determine if a woven structure separates into two layers. Students first created patterns using ropes, then physically lifted one set ("A") from the other ("B") to test separability (see Figures 1 and 2). They later discussed how to translate this process into a computational algorithm using binary representations, aligning with constructionist learning principles.

Data sources included pre- and post-tests, video recordings from 360-degree cameras (25 minutes per group), and written reflections. The assessments, scored on a 0–2 rubric (10 points total), measured students' understanding

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of cloth separability and their application of algorithmic thinking. A paired-sample t-test was conducted to examine learning gains between the pre- and post-test scores. Video and written data were used to support qualitative analysis of how students engaged with computational thinking during the activity.

Figure 1
Weaving Patterns

	B	A	A	B
A	0	0	1	0
B	0	1	1	1
B	1	1	1	0
A	0	1	0	0

Figure 2
Rope Representation

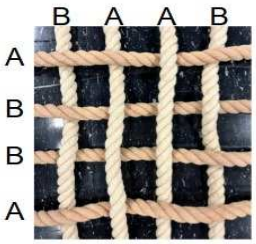

Figure 3
Collaborative Testing and Debugging of Rope Weaving Patterns

Results

A paired-sample t-test showed significant improvement from pre-test (M = 2.95, SD = 2.42) to post-test scores (M = 6.11, SD = 2.82), $t(18) = 5.66$, $p < 0.001$, Cohen's d = 1.22, indicating that the rope weaving activity supported students' understanding of cloth separability and strengthened computational thinking (CT) practices. Students demonstrated CT skills such as pattern recognition, algorithmic thinking, and debugging through iterative testing and rope manipulation. In Group 4, Priyank classified the rope strands into "A" and "B" sets based on the projected matrix, stating, *"The two middle ones are 'A,' and the first and fourth ones are 'B'"* (Figure 3). His classification prompted Kai and Hu to begin arranging the ropes on the floor to match the pattern. After their initial setup, Kai suggested, *"Let's just try it,"* leading the group to lift the ropes and test the structure's stability. When the weave separated, Hu pointed with his foot and noted, *"This one isn't matching what's on the screen,"* helping the group identify the error. They repeated this process, making small adjustments and re-testing—embodying a hands-on debugging loop that reinforced pattern recognition, algorithmic thinking, and visual-spatial reasoning.

Across groups, students translated virtual weaving patterns into physical arrangements and decomposed problems into smaller parts. These embodied experiences supported abstraction, as students connected physical patterns to matrix-based representations of woven structures. Kai reflected, "*Initially, I struggled to visualize what the 0s and 1s meant, but with help, I learned to figure it out just by looking at the matrix math.*" Jess echoed this shift in understanding, explaining, "*We identified threads held down at only one intersection, which allowed us to determine which threads were critical to the structure.*" Reflections also showed how students transitioned from trial-and-error to more formal reasoning, designing algorithms to determine cloth separability. Some students noted how their algorithms mirrored the group's physical strategies, while others proposed generalized solutions. One student emphasized, "*The benefit of using an algorithm is that the process can be automated, making it faster and more suitable for complex tasks*," while another acknowledged that "*physical manipulation doesn't work well for random patterns, which require more trial-and-error.*" These reflections illustrate how students navigated between physical exploration and abstract computational reasoning, using tactile engagement to inform and deepen their understanding of CT practices.

Significance

Findings show that students demonstrated CT practices through rope manipulation, highlighting the value of tactile approaches. The significant improvement from pre- to post-test in students' understanding of weaving concepts and cloth properties indicates how hands-on engagement with physical materials supports learning. This approach bridges the gap between abstract mathematical concepts and real-world applications, making complex ideas more accessible and tangible. By incorporating matrix math into the rope weaving activity, students connected mathematical representations with physical outcomes, applying CT practices such as pattern recognition, algorithmic thinking, decomposition, and abstraction. This study demonstrates how tangible materials enhance CT learning by making abstract ideas more concrete through physical manipulation and visual representation. Overall, this study has significant implications for the design of educational activities aimed at enhancing CT. The findings provide valuable insights for educators to create more engaging learning activities that integrate matrix algebra and CT practices.

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