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BOARD # 407: NSF ITEST: A Data-Driven Approach to Understanding Computational Thinking in Children: Embodied Learning with Augmented Reality and a Social Robot

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Dr. Jaejin Hwang, is an Associate Professor of Industrial and Systems Engineering at NIU. His expertise lies in physical ergonomics and occupational biomechanics and exposure assessment. His representative works include the design of VR/AR user interfaces to minimize the physical and cognitive demands of users. He specializes in the measurements of bodily movement as well as muscle activity and intensity to assess the responses to physical and environmental stimuli. In this project, he will lead multimodal behavioral data collection, processing, and analyses to assess children's learning and affective behaviors.

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NSF ITEST: A Data-Driven Approach to Understanding Computational Thinking in Children: Embodied Learning with Augmented Reality and a Social Robot

1. Introduction

Computational thinking plays a vital role in the development of young children, serving as a key building block for their academic and cognitive growth [1]. It is a structured way of problem-solving that involves breaking down tasks, recognizing patterns, developing logical sequences, and finding efficient solutions—skills that are not only essential in education but also in everyday life [2]. The study aimed to explore the effectiveness of an innovative educational environment grounded in embodied learning theory, which integrates emerging technologies—specifically augmented reality (AR) and a social robot. The primary focus was to assess how this combination of tools impacts the computational thinking skills of young learners, a critical foundation for problem-solving in STEM education. The study was funded by the **NSF ITEST** (Award Number: 2048989) from 2021 to 2025.

The research sought to answer the following key questions: 1) *Does the proposed embodied learning tool enhance students' computational thinking skills over time? 2) What is the relationship between a social robot's level of engagement and children's learning behavior? 3) Are there gender differences in the impact of embodied learning on computational thinking skills? 4) How do individual children interact with the embodied learning tool differently, and what effect does this have on their computational thinking development?*

2. Methods

This study investigated the computational thinking skills of young children (2^{nd}-year elementary students; 6 to 7 years old). Over a four-day period, 13 students (6 males and 7 females) engaged with the proposed educational environment that encouraged students to find the optimal path to acquire a gem by avoiding the obstacles (e.g., zombie). In real environments, the physical mat was provided, and each cell was equipped with the QR code for students to scan it with the tablet. Once students scan the QR code, they could recognize their location in the gaming environment displayed in the tablet as a 5 x 5 grid map (**Figure 1**). This encouraged students' spatial awareness, and they moved step by step for adjacent cells to reach the destination. When students struggled or achieved the mission, a social robot spoke to individual child to provide emotional support and needed instruction.

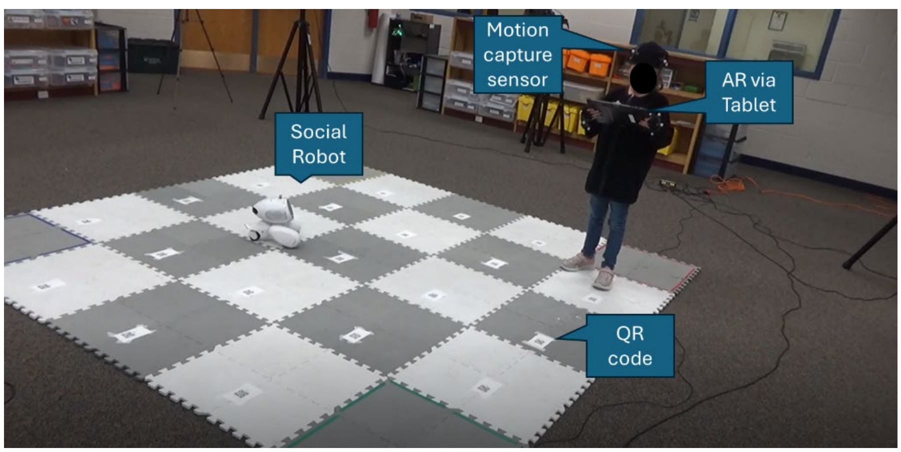

Figure 1. The experimental photo of the embodied learning environment robot.

Log data including students' location and time to complete the task were saved through the customized app built in the tablet. Simultaneously, the motion capture device was utilized to capture the student's head gestures by tracking the reflective markers attached to the hat. Children's sessions were also video-recorded, and their gestures and interactions were annotated by the researchers. A statistical analysis was conducted to determine the correlations between the social robot's feedback and children's learning behavior over three days. The first day (Tuesday) was excluded due to many students' incomplete activities associated with logistics and technical disturbances.

3. Results and Discussion

The total distance difference between the math-driven optimal path and student's actual path was changed over days (**Figure 2**). For males, the second day showed the best performance while the females showed the best performance at the last day. The difference of the task performance between the males and females was the lowest at the last day. For student's head movement (**Figure 2**), there was a decreasing trend for males, while females showed the U-shape trend. Like the task performance results, gender difference of the head movement was the lowest at the last day.

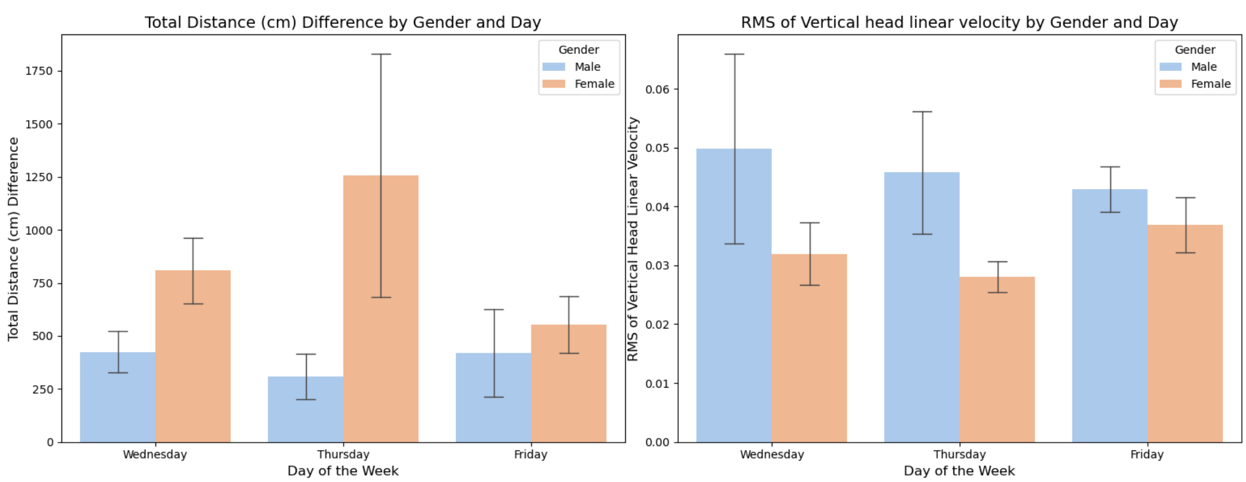

Figure 2. Mean and the standard error of the total distance (cm) difference (left figure) and root mean square (RMS) of the vertical head linear velocity (right figure) by gender and day.

The scatter plot with the linear regression line showed that the linear relationship between the frequency of the robot speaking and children's stepping movement increased over days (**Figure**

3). On the last day, the value of R^2 was 0.87, showing the strong positive linear relationship between the variables. The trends suggest that social interaction and cooperation between children and a social robot enhanced over days.

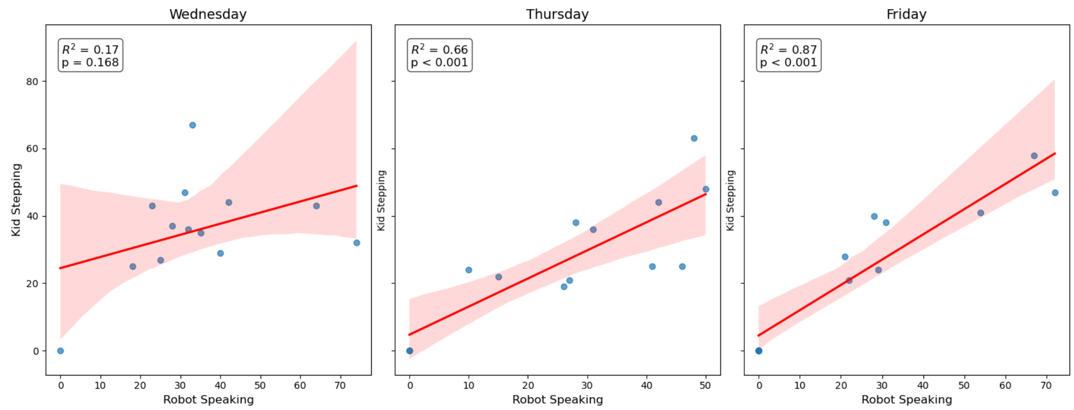

Figure 3. The scatter plot with the linear regression line and the confidence interval between the frequency of robot speaking to students and students stepping behavior during the session.

The bump chart displayed the ranking of the task performance (total distance difference between the optimal path and actual path) among participants between the second day and the last day of the implementation (**Figure 4**).

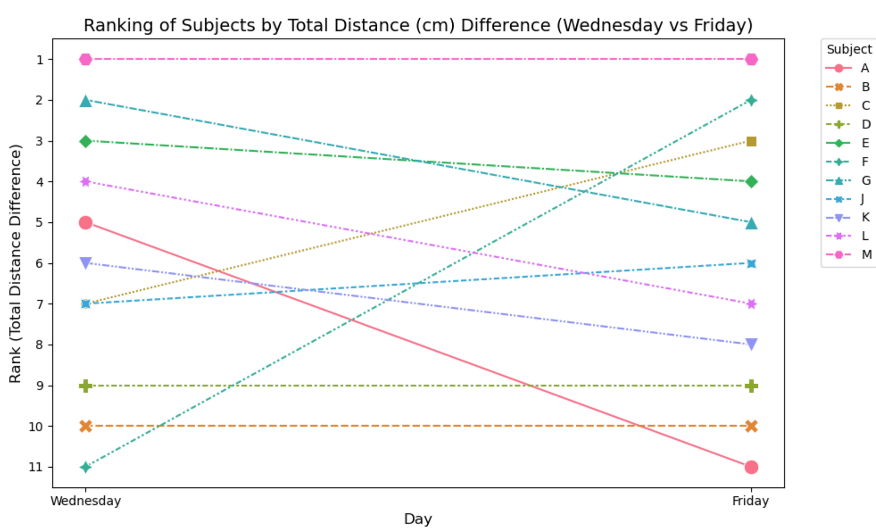

Figure 4. The bump chart shows the ranking of the task performance (total distance difference between the optimal and actual path) among students between the first day and the last day of engagement with the embodied learning environment.

There were several crosslines between the two days. For instance, the lowest ranking student (rank 11) improved to the rank 2 on the last day whereas the student with the rank 5 on the first day dropped to the rank 11 on the last day. These mixed trends show that adoption of new technology and embodied learning could depend on individual student's characteristics.

4. Conclusion

The study found that the embodied learning environment leveraging the AR, and a social root decreased the difference of the task performance and head movement between males and females over days. The relationship between the students' bodily movement and a social robot's conversation enhanced over time. Individual student's adoption of the proposed educational tool showed a wide range of variations. Future study could consider the scale-up project by investigating the long-term impact of the embodied learning educational tool to young learners with the increased sample size.

References

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