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# Development and Implementation of a Smart Toy Robot for Enhancing Interactive Coding Education in Beginners

Yong-Ho Seo[1]

## Abstract

This study explores the development and implementation of a smart toy robot, Bingle-S, designed to facilitate interactive coding education through intuitive and engaging learning experiences. This study investigates the use of a smart toy robot, Bingle-S, to simplify coding education for beginners through an interactive R-learning environment. By integrating service robots with graphical interfaces and unplugged coding via an IR remote controller, Bingle-S offers an intuitive and engaging educational experience that demystifies programming concepts. The implementation of this toy-like robot not only makes learning to code more accessible and enjoyable for young learners but also enhances their understanding of coding fundamentals. This paper presents the design and educational impact of Bingle-S, highlighting its potential to transform coding education by making it more relatable and effective.

**Keywords:** *Smart Toy Robots, Interactive Coding Education, Unplugged Coding, R-learning.*

## Introduction

In contemporary education, the teaching of coding and programming skills is increasingly recognized as crucial for developing problem-solving abilities and preparing students for a technology-driven world. However, traditional coding education often relies on text-based programming languages like C or Java, which can be daunting for young learners and beginners, particularly those without prior experience in electronic engineering or computer science. This creates a significant barrier to entry, making it imperative to explore more engaging and accessible methods of teaching programming concepts.

This research introduces a novel approach to coding education through the development of a smart toy robot, named Bingle-S, specifically designed for interactive coding exercises. This project is at the forefront of the shift towards R-learning, a pedagogical method that integrates service robots to create a dynamic and interactive educational experience. These robots facilitate an immersive learning environment where students can engage with programming concepts in an intuitive and engaging manner [1].

Interactive coding in this context emphasizes real-time feedback. Learners input commands and immediately observe the robot's reactions, which enhances understanding and retention of coding principles by transforming abstract concepts into concrete outcomes [2]. In addition, previous studies have explored the development of educational robots combined with Scratch-based programming to enhance coding education for young learners [3].

Our system seeks to address the challenges associated with conventional coding education by simplifying the learning process through the use of graphical programming interfaces and a toy-like robot that naturally attracts the interest of young learners. The design of the robot and its programming environment is intentionally playful and aligned with the developmental levels of the target audience, which includes preschool to elementary school-aged children.

Moreover, the research explores the benefits of unplugged coding activities that do not require additional electronic devices. Through the use of a simple IR remote controller, children can program the robot to perform tasks, which simplifies the introduction to coding and avoids the often complex setup associated with traditional programming education [4].

By lowering the barriers to entry and making coding education more relatable and enjoyable, this

[1] Department of Electrical and Electronics Engineering, Mokwon University, Daejeon, Republic of Korea, Email : yhseo@mokwon.ac.kr , ORCID: https://orcid.org/0000-0003-1426-7147

research contributes significantly to the field of coding education. It offers a practical and scalable model for integrating innovative technologies like service robots into educational settings, aiming to foster a more inclusive atmosphere where technology serves as a bridge to critical thinking and creative problem-solving skills in young learners.

**Design and Specifications of Smart Toy Robot, Bingle-S**

We have developed the Bingle-S, a smart toy robot designed as an interactive coding educational tool, suitable for young learners and shown in Fig. 1. The robot combines a sleek, child-friendly design with advanced technical features to facilitate an engaging learning experience.

Standing 153mm tall and 97mm wide, Bingle-S is perfectly sized for young users to handle easily. Its face features an OLED display that animates facial expressions and provides real-time feedback on coding activities, enhancing the interactivity and making the coding process intuitive and informative. Additionally, the robot is equipped with a microphone and a speaker, complemented by an RGB LED and a buzzer, which together deliver both auditory and visual feedback. This sensory feedback helps to enrich the learning experience, making educational interactions more appealing and effective.

The Bingle-S is also equipped with a variety of sensors that enhance its functionality. A light sensor allows the robot to adapt its behavior based on ambient lighting conditions, improving its interaction with the environment. Infrared sensors and an IR receiver enable the robot to detect obstacles and receive commands from a remote control, supporting its navigational and interactive capabilities.

Furthermore, the robot's mobility is powered by a servo motor and DC motors. The servo motor facilitates smooth head movements, which add to the robot's expressiveness and its ability to engage learners actively. The DC motors are crucial for allowing the robot to traverse different surfaces, enabling it to interact effectively with its surroundings and ensuring that it can participate in a variety of educational scenarios.

Through these features, the Bingle-S serves as an engaging educational tool that not only teaches coding principles but also fosters essential skills such as problem-solving and logical thinking. Its interactive capabilities and adaptability make it an invaluable asset in educational settings, engaging young learners in a comprehensive, enjoyable learning experience.

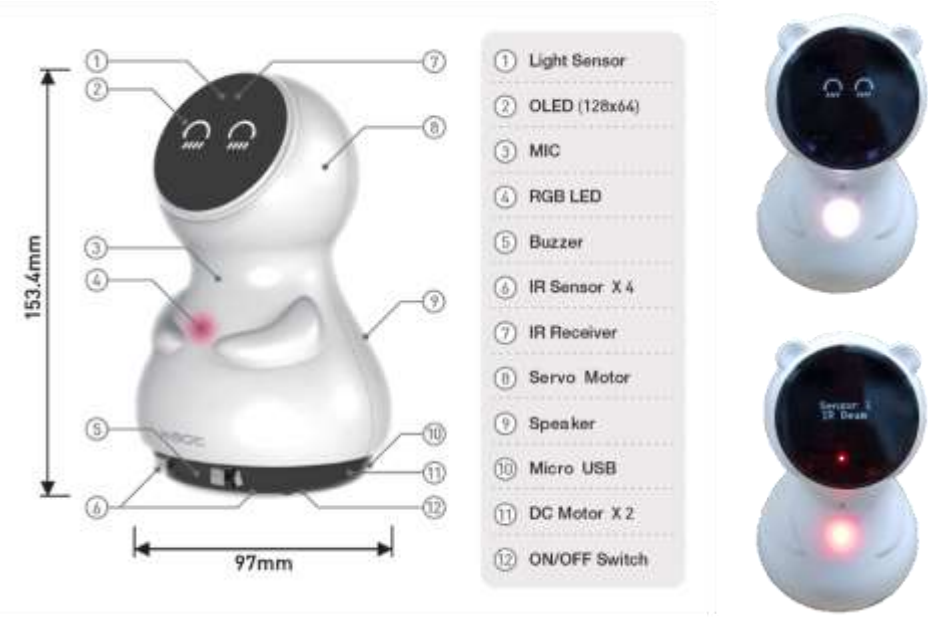


**Fig. 1. Appearance and specifications of the Bingle-S smart toy robot, showcasing its design, dimensions, and key components for interactive coding education**

**Requirements of Smart Toy Robot for Interactive Coding Education**

The Bingle-S smart toy robot is designed to meet the specific requirements of interactive coding education by combining educational functionality with engaging features. Its capabilities allow young learners to explore coding concepts through hands-on activities while enjoying an interactive learning experience.

Bingle-S is equipped with various sensors and reaction functions that enhance its interactivity. These sensors enable the robot to respond to user input and environmental conditions, making learning sessions more dynamic and engaging. The robot also features a Bluetooth microphone and speaker system, enabling advanced voice interactions supported by ChatGPT and Google Assistant. This functionality allows Bingle-S to understand and respond to voice commands, making it possible for users to ask questions, hear fun stories, or receive verbal guidance during coding activities [5].

One of the most significant features of Bingle-S is its support for unplugged coding. This allows children to engage with coding concepts using an IR remote controller or a dedicated mobile app without requiring a computer or tablet. By simplifying the learning environment, unplugged coding ensures that young learners can focus on understanding programming logic without the distraction of complex devices.

In addition to its educational functionality, Bingle-S can express various emotions and statuses through its facial expressions displayed on the OLED screen. These visual cues provide immediate feedback to users, helping them understand the success or failure of their coding commands. This expressive interaction not only makes the learning process more enjoyable but also reinforces the connection between coding input and robot behavior.

The Bluetooth microphone and speaker system of Bingle-S, as shown in Fig. 2, further enhance its interactive capabilities. This system supports both speech recognition and text-to-speech (TTS) functionality, allowing users to communicate with the robot in a natural, conversational way. Whether asking the robot to tell a story or answer a question, these features make coding education more dynamic and engaging for young learners.


**Fig. 2. Bluetooth Microphone and Speaker for Speech Recognition and TTS Functionality of the Bingle-S Robot, Enabling Advanced Voice Interaction for Educational and Entertainment Purposes**

### Unplugged Coding with IR Remote Controller and Visual Expressions

#### Unplugged Coding System

The Bingle-S smart toy robot supports unplugged coding, enabling children to engage with programming concepts without the need for computers or tablets. This system utilizes an IR remote controller as the primary interface for coding, allowing learners to execute commands such as movement, color changes, and sound effects in real-time. This hands-on approach enhances children's understanding of coding logic while developing problem-solving and critical thinking skills.

One of the most significant advantages of this system is its accessibility. The IR remote controller allows users to send step-by-step commands to the robot, making it easier for young learners to grasp the relationship between inputs and outcomes. Without the complexity of traditional computer-based programming environments, children can focus solely on understanding the logic behind coding sequences.

The IR remote controller, as shown in Fig. 3, features an intuitive button layout that simplifies the coding process. Each button corresponds to a specific function, such as movement, facial expressions, and sensory feedback. The remote also supports obstacle detection, light sensing, and sound detection, enabling learners to interact with the environment through coding [6, 7].

**Movement Commands**: The arrow buttons allow the robot to move forward, backward, turn left, and turn right, while the play/pause button starts or stops the robot's actions.

Facial Expression Commands: Users can select different facial icons to change the robot's expressions, making interactions more engaging and expressive.

**RGB Color Selection**: The RGB button allows users to change the robot's LED color, enhancing visual feedback during coding activities.

**Sound and Melody Control**: The remote includes buttons for playing pre-programmed melodies, adding an auditory layer to the learning experience.

**Sensory Feedback Activation**: The remote also supports obstacle detection, light sensing, and sound detection, enabling learners to interact with the environment through coding.

Bingle-S also provides a range of unplugged coding examples to guide learners through progressive tasks. Simple exercises include basic navigation, such as moving forward, turning, and stopping, while more advanced activities introduce conditional statements, loops, and multi-step sequences. These examples not only simplify the learning process but also create a foundation for understanding more complex programming concepts in the future.

The educational benefits of unplugged coding extend beyond technical skills. This approach fosters creativity, logical thinking, and resilience, as learners experiment with different command combinations and refine their coding strategies based on immediate feedback from the robot.

**Visual Feedback and App Integration**

To further enhance the learning experience, Bingle-S offers visual feedback through its OLED display, RGB LED, and buzzer system. The OLED display on the robot’s face shows various facial expressions, such as happiness when a task is successfully completed or confusion when an error occurs. This intuitive feedback mechanism helps learners identify mistakes and adjust their coding approaches accordingly.

The RGB LED system provides color-coded signals to indicate task progress. For example, a green light signifies successful command execution, while a red light indicates an issue requiring attention. This visual support simplifies troubleshooting and reinforces understanding through immediate, multi-sensory feedback. Additionally, the built-in buzzer complements the LED signals with sound alerts, making the coding experience more engaging and interactive.

Beyond remote-controlled coding, Bingle-S supports app-based programming through the BingleS App and Scratch XBOT App, available for Android devices. These apps provide a graphical user interface (GUI) where learners can create command sequences using drag-and-drop coding blocks. This approach introduces children to visual programming, simplifying the coding process while maintaining educational value.

Through the app, users can program the robot to perform complex tasks, such as navigating a maze, responding to voice commands, or executing multi-step routines. Real-time feedback within the app allows learners to identify errors and refine their code immediately. Moreover, the app expands the scope of learning by offering additional challenges and interactive missions, encouraging continuous engagement.

The integration of the IR remote controller and mobile apps ensures that users can engage with Bingle-S in multiple ways, offering a flexible and comprehensive coding environment.


**Fig. 3. IR Remote Controller and Mobile Apps for Bingle-S**

As shown in Fig. 3, The IR remote interface enables unplugged coding with movement, expression, and sensory commands, while the BingleS App and Scratch XBOT App provide additional programming environments for Android devices. Learners can seamlessly transition from unplugged remote-based commands to more advanced programming tasks using mobile platforms.

**Experimental Results**

This experiment demonstrates how unplugged coding with the Bingle-S smart toy robot can effectively teach programming concepts in an interactive and intuitive way. Using the IR remote controller, children executed commands and observed how the robot responded in real-time, reinforcing logical thinking and problem-solving skills.

To illustrate the coding process, an example scenario was designed, as shown in Fig. 4. The robot started at the beginning point and navigated toward the goal while overcoming obstacles along the way. The sequence is as follows:

**Start**: The robot begins at the designated starting point.

Forward Movement: It moves forward one grid space by executing the forward command.

**Obstacle Detection**: Upon encountering an obstacle, the robot detects it using its IR sensors and performs a predefined action, such as turning right to avoid the obstacle.

**Goal Achievement**: After bypassing the obstacle, the robot continues moving forward and reaches the goal.

This scenario demonstrated how children could learn essential programming concepts, such as sequential execution and conditional logic, while engaging in hands-on activities.

Throughout the experiment, the robot provided continuous feedback to enhance the learning experience. The OLED display showed facial expressions, such as a smiling face when reaching the goal or a puzzled face when encountering an error. The RGB LED changed colors based on task progression, while the buzzer emitted sound cues, reinforcing the connection between coding inputs and robot actions.

These interactive features helped children understand coding logic, develop problem-solving skills, and stay motivated through real-time feedback, making the learning process both effective and enjoyable.


**Fig. 4. Example Scenario of Unplugged Coding: The robot moves forward, detects an obstacle, turns right, and reaches the goal, demonstrating the application of coding commands and obstacle avoidance.**

## Conclusion

This study proposed a new smart toy robot, Bingle-S, designed to support unplugged coding and facilitate children's learning of programming concepts. Using an IR remote controller or dedicated apps via Bluetooth, children can engage in interactive coding activities by creating sequences of commands that the robot executes in real-time. This hands-on approach not only makes learning to code fun but also ensures accessibility for young learners without the need for computers or tablets.

The integration of unplugged coding with expressive visual feedback, such as facial expressions, RGB LED signals, and auditory alerts, enhances the learning experience. These interactive features provide immediate feedback, helping children understand the relationship between coding inputs and robot actions while promoting iterative problem-solving.

The combination of interactive features, unplugged coding, advanced voice recognition, and expressive feedback makes Bingle-S an ideal educational tool for teaching coding to young learners. Its child-friendly design fosters essential skills such as logical thinking, creativity, and resilience in a playful and engaging environment. Through this approach, Bingle-S empowers children to develop computational thinking while enjoying the process of learning, making coding education more effective, and enjoyable.

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