EcoSprout: A Smart Modular Toy for Engaging Children in AFNR Education

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***Abstract*—In an era of rapid industrialization, the link between agriculture and children has diminished significantly. EcoSprout is a smart modular toy that teaches children the concepts of agricultural cycles and resource management through activity-based games. It helps them gain important agricultural knowledge while simulating real-life farming activities and stimulates logical thinking. Our user study results show that this interactive learning methodology significantly increases the engagement and comprehension of key agricultural concepts in children, thus sparking their interest in nature and agriculture.**

Keywords—children, AFNR education, smart block toy, educational technology

I. INTRODUCTION

Agriculture has been the backbone of human civilization for years, yet modern industrialization has disconnected today's children from its significance. Despite our reliance on agriculture for essential resources, awareness and appreciation among younger generations are fading. AFNR (Agriculture, Food, and Natural Resources) education seeks to address this disconnect. Not only does it enhance agriculture literacy among students, but it also cultivates within the minds of children a profound appreciation of sustainability by nurturing their inborn curiosity and value system.

Research shows that activity-based and interdisciplinary approaches, such as STEAM education, serve to increase the engagement and learning outcomes of students. Smart Modular Toys enhance active learning even further by offering adaptive and interactive experiences that simplify complicated concepts in an easier way. EcoSprout was created to develop children's cognitive and logical thinking skills by teaching them about resource management and agricultural cycles in an engaging and feedback-rich way.

II. RELATED WORK

A. STEAM Education and AFNR Education

STEAM Education is a compound methodology of Science, Technology, Engineering, Art, and Mathematics, whose origin can be traced back to the 1gg0s, when the federal first came up with the concept of "SMET", which was composed of Science, Technology, Engineering, and Mathematics, and aimed to satisfy the growing scientific demand . The Art factor was emphasized since the 21st century, making the whole STEAM method more transdisciplinary, and can arouse more creativity among the students. As an integral concept, STEAM Education is always being used as an interdisciplinary approach to enhance students' problem-solving skills and creative abilities, especially in some specific contexts. STEAM Education method has been proven to have some positive impacts in practice. As for the children's education, it is a child-centered approach to enhance the feeling of joy and engagement; students' eagerness to learn will also be inspired . Various of studies had certified the importance of STEAM Education. The results of Ozkan et al.[1] showed that STEAM education is useful for understanding concepts, with Ahmad et al. [2]'s research proving that STEAM education significant improved the students' ability during the activation process.

Therefore, transdisciplinary integrations in many occupations, agriculture, food, and natural resources (AFNR) for example, is arising. Mabie and Baker in 1gg6's research [3] found that participation in agriculturally oriented experiential activities positively impacted the development of science process skills of elementary students. Elementary teachers generally believe that agriculture is a viable tool that can be integrated across disciplines, if the resources meet standards-based learning targets across disciplines. Additionally, studies show that students frequently have a deeper understanding of the STEM aspects of agriculture than they do of more general agricultural and environmental subjects [5]. These findings highlight agriculture's potential as an effective interdisciplinary educational tool.

B. Smart Modular Toys

Smart modular toys are vital instruments in creative education, providing flexible constructions that children may construct and rearrange to investigate many themes. For example, in the smart toy 'Amazing Land,' the integration of building blocks and storytelling activities allows developing creativity and collaborative work among participants [7]. Other projects, such as 'Family Tree,' include the use of IoT in supporting cognitive rehabilitation; Tommy Blocks are unusual geometric forms that stimulate creative construction [8, 9].

Smart modular toys often engage in touchscreen interactions or robotics to increase the interaction level. Products such as Osmo and Scabo have combined touchscreen devices with augmented reality facilitated in playful yet accessible means of learning science. Similarly,

LEGO Mindstorms and Kibo utilize robotics, allowing children to learn through programming for expanded skill development. Collectively, these provide hands-on engagement, thus creating comprehensive skill-building based on feedback and active participation. Building on these principles, EcoSprout offers a unique approach by using modular and interactive play to make agricultural cycles and resource management accessible to children.

III. User Research

In the preliminary research phase, we recruited 23 children aged 6-9 from a primary school and administered a questionnaire to assess their understanding of and interest in AFNR (Table 1). Additionally, two elementary science teachers and several parents participated in discussions focusing on effectively integrating agricultural knowledge and logical thinking skills into the toy's design.

TABLE I. Children's understanding of and interest in AFNR

Dimension	*Questions (1:Strongly disagree-5:Strongly agree)*	*If*	*More in-depth questions*
Interest and Cognition	I am interested in activities like planting and raising animals.	Yes	Which specific activities would you like to learn more about?
	I want to know something about farms, planting, and animal care?	Yes	What topics are you most curious about in agriculture?
	What type of games do you enjoy most, such as building, puzzles, or interactive games?	-	What elements make these games enjoyable for you?
Learning Preferences	Sensory Interaction: How do you prefer learning new things? (e.g., by looking at pictures, listening to sounds, or hands-on activities)	-	Which learning methods (visuals, sounds, hands-on) work best for you?
	Hands-On Skills: Do you enjoy games that involve manual building or assembly?	-	Which activities do you find most engaging when working hands-on?
	Feedback Mechanisms: What feedback do you prefer when you complete a task? (e.g., color changes, sound prompts)	-	How does feedback, like sounds or light changes, enhance your learning?
Areas of Curiosity	Are you curious about the tools or equipment used on farms?	Yes	What specific tools or equipment are you interested in?
	Do you want to understand how plants grow and how animals are raised?	Yes	What questions do you have about the growth of plants or animal care?

The interviews revealed that children are strongly interested in interactive, hands-on agricultural activities, with an average interest score of 4.83 out of 5. A significant 58% of the children showed a keen interest in farm tools and the stages of plant growth, highlighting the importance of integrating interactive, concrete agricultural examples. This not only engages children but also reinforces key concepts in agriculture and natural resources (AFNR).

While most children were unfamiliar with agricultural cycles at first, 35% responded positively to basic activities like planting, harvesting, and taking care of animals. Approximately half of the participants preferred independent exploration, while others preferred some level of guidance. This suggests that the toy's design should strike a balance between structured support and opportunities for autonomous exploration. Many parents also pointed out the toy's potential to help develop practical skills and foster a lasting interest in nature.

Based on these findings, we identified the following key design requirements:

- Modular Task Design: Break down farm-related tasks into smaller, manageable modules (e.g., planting, irrigation, harvesting) and provide incremental visual and auditory feedback to offer reinforcement as each step is completed.
- Balance of Guidance and Exploration: Present complex ideas in an approachable manner, encouraging both creativity and independent discovery.
- Multi-Sensory Interaction: Incorporate visual and auditory feedback to increase engagement and enhance the toy's appeal.

IV. Prototype

EcoSprout embeds a rich storyline that shall engage the children. In EcoSprout, each plant and animal has its particular role; children act as 'farm managers' with the task of maintaining ecological balance and creating harmonious interaction among all elements. Every designed element in the EcoSprout system is focused on showcasing knowledge with regards to agricultural cycles and resource management in an intuitive way.

A. Conception of the system

EcoSprout is an interactive farm that aims to develop the logical thinking of children aged 6-9 years old by teaching the basic concepts of agricultural cycles. Children take on the basic tasks grouped into identification, assembly, and combination of modules in sequencing a series of key agricultural practices like planting, animal husbandry, and resource management (Figure 1). Upon connecting the modules, immediate feedback in terms of lighting, on-screen displays, and sound effects makes it instinctive for kids to understand what happens at every stage of an agricultural cycle. The hands-on design is aimed at systematically creating a child's world of understanding of agricultural and ecological cycles for curiosity and creativity to grow.

B. System Structure

1) Hardware Composition: The EcoSprout system integrates an interactive base, scene modules, resource units, and a task display, with each component utilizing electronic elements for module recognition and feedback. Key hardware includes LED strips, resistors and buzzers (Figure 2). The central console houses interfaces for connecting scene modules and resource units, along with a power port.

Through color and sound feedback, LED lights and buzzers guide children in completing tasks.

Fig. 1. Details of EcoSprout

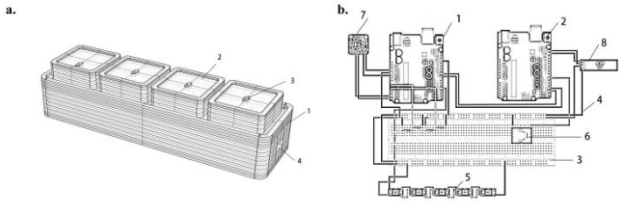

Fig. 2. a)The prototype base structure; b) Main electronic components includes: (1) Arduino UNO Master Board, (2) Arduino UNO Slave Board, (3) breadboard, (4) Dupont wire, (5) LED strip [WS2812B], (6) passive buzzer, (7) color sensor [KE4047S], and (8) dot matrix display [KE4061S].

2) Modules and Educational Intent: The system comprises scene modules, resource units, and a task display, all tailored to emphasize agricultural education (see Figure 3). Scene modules connect to the central console and represent distinct areas of the farm, such as fields, pastures, and production zones.

Resource units, including animals like cows and sheep, and crops such as plants, represent various farm elements. These units trigger feedback when connected to the scene modules, for instance, generating products that help complete specific tasks. Each resource unit is equipped with resistors for module identification, ensuring precise recognition of resource combinations and task-specific feedback. The task display provides clear, step-by-step instructions, allowing children to gradually build their agricultural knowledge.

EcoSprout utilizes an LED strip to demonstrate the agricultural cycle's different stages. For example, a green light intensifies to show plant growth from seed to sprout, then to maturity, providing children with a visual understanding of plant development. Furthermore, the system employs sound cues through a buzzer to enhance interactivity. After completing an 'irrigation' task, the system produces a water-flow sound, helping children connect irrigation with the necessary water for plant growth. The use of animal sounds and tool operation noises supports children's understanding of farm resource management by highlighting the role of each resource in agricultural production."

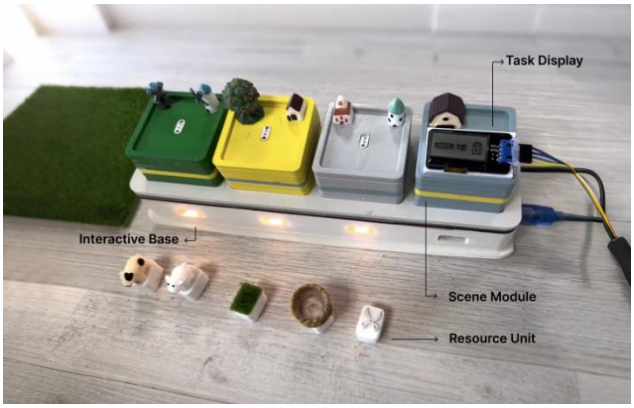

Fig. 3. All Modules of EcoSprout

C. Game Flow

The game opens with a welcome screen, then shows randomly the work to be done—for example, 'milk'—with the module lights accordingly lit. Stimulated by these cues, children choose and attach a main module which best fits the cues. If correct, it buzzes with a success tone; in the case of an error, a red light with an error tone shows up. Next, children use the color sensor to identify secondary modules, completing the configuration and advancing to the next task after receiving a success signal (figure 4).

As tasks progress, children gradually become familiar with each step of the agricultural cycle. EcoSprout's adjustable difficulty levels offer a graduated learning experience: at the introductory level, children explore relationships between individual units and scenes to understand basic production processes. Intermediate levels introduce additional modules to establish intricate agricultural cycles, including the use of a garden module for animal feed and the recycling of resources through a compost facility to establish a comprehensive ecological loop. At advanced levels, children can construct detailed farm systems, explore material and energy flows, and gain an understanding of waste management and resource reuse, reinforcing environmental sustainability principles.

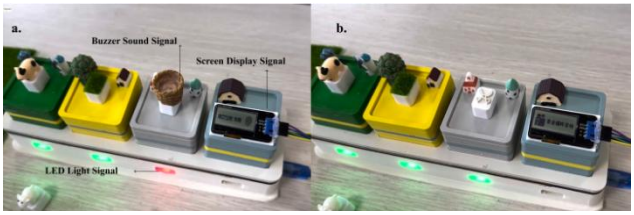

Fig. 4. a)Feedback signals when operating incorrectly, including lights, sounds and screen information; b)Feedback when operating correctly

V. User Experience

In our study, we invited 14 children to participate in a user experience evaluation. We gave a brief introduction to EcoSprout's gameplay and basic operations, then encouraged children to explore independently, allowing researchers to observe their natural reactions. The experiment included tasks of varying complexity (e.g., planting, animal care, and resource recycling), which children completed in small groups. Each child began by working alone and then collaborated with another child to complete tasks, while researchers observed and recorded their responses.

We designed a questionnaire(Table 2) evaluating three dimensions: educational value, enjoyment, and interactivity, rated on a Likert scale. Results showed that older children demonstrated a greater understanding of agricultural cycles, along with higher interest and engagement in the educational aspects. They also reported improvements in their problem-solving skills and logical reasoning. In contrast, younger children scored higher in interactivity and enjoyment. Their enthusiastic responses to the toy's lights, sound feedback, and flexible module combinations highlighted the effectiveness of its interactive nature.

Moreover, children rated EcoSprout highly for its enjoyment and interactivity, expressing a clear preference for this playful yet educational approach. Some children noted that they discovered the recyclability of resources and began thinking about how to better and more efficiently utilize farm products. This suggests that the toy enhances their cognitive and logical thinking abilities.

TABLE II. CHILDREN'S QUESTIONNAIRE AND INTERVIEW CONTENT

Dimension	***Questions (1:Strongly disagree-5:Strongly agree)***	***Average score***	***Over all score***
Educational value	I learned new things about farms, planting, and animal care from this toy.	4.29	60
	I found the information about farm activities interesting and engaging.	4.43	62
	Learning about planting and taking care of animals made me curious about nature.	4.71	66
Enjoyment	I enjoyed playing with this toy and completing the tasks it provided.	4.57	64
	The toy's colors, shapes, and overall design made it fun to play with.	4.71	66
	I liked the different activities and challenges presented in the game.	4.29	62
Interactivity	I liked that the toy gave feedback through lights or sounds after completing tasks.	4.43	62
	I enjoyed using the modules to build and take apart different parts of the farm.	4.57	64
	The toy's interactive features helped me stay engaged and focused during play.	4.50	63

Overall, EcoSprout successfully piqued children's interest in agricultural education. In the future, we will develop the toy's design to better meet the needs of learners of various ages by expanding its educational material and interactive features, allowing users to enjoy continual progress in their experiences.

VI. CONCLUSION

EcoSprout's modular architecture and interactive gameplay help children learn about agricultural cycles and resource management. All of this is done in a fun way to help them learn about farm management and logical reasoning. Building on the foundational aspects of agricultural education, we are considering exploring topics such as quantitative relationships in mathematics and ecological balance in science, transforming EcoSprout into a multidisciplinary educational tool that broadens children's knowledge across multiple disciplines.

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