

Research on Intelligent Plant Cultivation Product Design for Primary School Students Based on Multi-Sensory Experience

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Abstract: The rapid development of the education intelligence market in recent years has been driven by technological advancements, changing educational needs, and policy support. Its pedagogical and experiential aspects need to be improved. In this paper, the multi-sensory design concept is integrated into the development of intelligent planting machines for primary school students, and is applied to the after-school activities of primary school students, proposes the design principles of intelligent plant cultivation products, and carries out the practice of product design, which can meet the needs of personalised immersive sensory experience of primary school students with learning as the core and practice as the auxiliary. It has significant application effect on ecological enlightenment and interactive experience for primary school student groups.

Keywords: Intelligent Plant Cultivation Products; Multi-sensory Experience; Product Design; Ecological Enlightenment.

1. Introduction

The education smart hardware market is growing at a rapid pace driven by technological advancements and growing demand for personalised and engaging learning experiences. The global education technology market is expected to reach approximately USD 404 billion by 2025, growing at a CAGR of approximately 17.5% from 2020 to 2025 (Wang et al., 2021). The continued growth reflects the increasing reliance on technology to enhance learning outcomes and the widespread use of smart devices in educational environments. An important area of research has been the development of smart plant cultivation products for primary school students, which often combine technology with horticultural practices in order to engage primary school students in hands-on learning experiences that promote environmental awareness, healthy eating habits and cognitive development in primary schools. Research has shown that primary school students' participation in gardening activities, where they will go through the whole process from sowing seeds to harvesting and preparing produce, helps them to connect with the food they consume and understand the importance of sustainability (Davis et al., 2015). It also increases primary schools students' understanding of biodiversity and guides the development of eco-enlightenment for primary schools students.

2. Current Status of Research on Plant Cultivation Products for Primary School Students

2.1. Related Literature

The global definition of primary school students is usually between the ages of 6 and 12 years old and is also a critical stage for their cognitive, social and emotional development as they transition from early education to formal schooling (Kırkıç & Ulaş, 2022). Research has proposed that gardening programmes significantly increase vegetable intake and promote healthier eating habits among primary school children compared to traditional nutrition education programmes (Langellotto & Gupta, 2012). Additionally, the

effectiveness of tower garden systems in educational settings has been studied, and Sills 2024 enhances the learning experience for primary schools students by providing an interactive and engaging way to learn about plant growth and nutrition (Sills et al., 2024). This approach supports academic learning and also encourages primary schools students to develop a lifelong interest in horticulture and healthy eating. Afandi et al. used a microcontroller-based artificial lighting system as an educational platform for students to learn about the importance of light in photosynthesis and plant health, providing them with practical knowledge about plant biology and environmental science (Afandi et al., 2021). In summary, there is much room for research on plant cultivated products for primary school students to enhance their nutritional habits and academic learning and increase environmental awareness and responsibility.

2.2. Product Research

Current products on the market focus on automated management, with less hands-on practice, making it difficult for primary school students to directly perceive the changes in plant growth. In this study, we conducted a detailed research on related products sold in the market and found that: Fytó Smart Kid Friendly Composter focuses on eco-cycling and lacks a complete planting experience.

The Fytó Smart Kid Friendly Composter focuses on the ecological cycle and lacks a complete planting experience; the Click & Grow Smart Garden relies on smart soil and water management, which reduces the hands-on experience for primary school students and makes the experience more passive; and the Yimitian Smart Planting Companion, although it combines voice control and remote monitoring, lacks haptic and olfactory feedback, which makes the immersion experience less enjoyable. Yimitian Smart Planting Companion While the Olinze Nature Education Smart Planting Machine ignores multi-sensory interactivity (Table 1). To compensate for the shortcomings of the above products, this study proposes the Multi-sensory Intelligent Smart Planting (MIST) design concept in the hope of enhancing the experience of cultivation for primary school

students through multi-sensory interaction.

Table 1. Smart planting machine comparison

Product	Advantages	Core Technologies	Innovations	Shortcomings in Multi-Sensory Experience
Fytó Smart Kid Friendly Composter 	Educates children on food waste and composting. 360-degree transparent dome allows kids to observe the composting process. Highly interactive, children can deposit food scraps and observe worms.	Smart composting system, automatically decomposes food waste. Visualized design, enabling kids to observe the composting process. Biodegradable technology, promotes natural ecological cycles.	Interactive food cycle education, allowing children to engage in composting. Ecological cycle experience, demonstrating the transformation from waste to nutrients.	Lack of olfactory and gustatory experience, only focuses on visual and tactile education. Minimal auditory interaction, no sound effects related to the composting process. No direct plant cultivation, focuses only on soil nutrient cycling rather than plant growth.
Click & Grow Smart Garden 	Automated planting, ideal for users with no gardening experience. Supports a variety of plants (e.g., herbs, vegetables). Inspired by NASA technology, offers smart plant growth control.	Nano smart soil, stores oxygen and releases nutrients evenly. Smart water control system, requires minimal maintenance. LED lighting system, simulates natural light for plant growth.	Replaceable seed modules, reducing the complexity of planting. Automated plant care, requiring little user intervention.	Limited tactile interaction, no way to feel soil moisture. Lacks auditory feedback, no voice guidance or plant status alerts. Minimal olfactory and gustatory engagement, users can taste the final product but cannot experience the scents of growing plants.
Yimitian Smart Planting Companion 	Supports Mi Home APP, allowing remote plant monitoring. Voice control, integrates with Xiaomi's AI assistant. Encourages parent-child interaction, fostering shared learning experiences.	Smart irrigation system, detects soil moisture and adjusts watering. IoT integration, real-time monitoring via APP. AI voice assistant, provides plant care guidance.	AI-assisted voice guidance, enhancing interactive learning. Smart home integration, making it convenient for modern families.	No olfactory or gustatory elements, users can only observe and care for plants without experiencing their scents. Limited tactile interaction, no feedback on soil moisture through touch.
Olinze Nature Education Smart Planting Machine 	Designed for children aged 6-13, tailored for educational needs. STEAM education integration, fostering scientific literacy. Gamified planting experience, increasing learning engagement.	Full-spectrum LED lighting, simulates natural conditions for growth. Automated irrigation system, ensuring optimal water supply. Child-friendly interface, easy to use for young students.	Hands-on experimental learning, allowing children to engage physically. Task-driven gamification, incorporating plant care challenges.	Minimal auditory feedback, lacks ambient sounds or plant "growth sounds". Weak olfactory engagement, does not utilize scents to enhance learning.

3. Characteristics of Primary School Children

3.1. Cognitive Characteristics

Primary school children's thinking logic is gradually mature and able to understand cause and effect relationships, but still rely on concrete things to help understand abstract concepts. The attention span of primary school children at this stage is usually only 15-20 minutes, so when making products, they need to present information in an intuitive and concise way, avoiding complex and lengthy content. They are more willing to learn through such hands-on forms such as putting together, planting, and science experiments.

3.2. Emotional Characteristics

Primary school students in this age group express direct sensitivity to external feedback, have greater emotional and

affective fluctuations, have a strong emotional dependence on with their parents and teachers, want to get support and encouragement from their parents when they encounter difficulties or challenges, and are also eager to improve their self-confidence by completing tasks, getting praise or rewards, and are more likely to be driven by encouragement mechanisms in their learning or games.

3.3. Motivational Characteristics

Primary school students are directly influenced by teachers 'praise, parents' rewards or reward mechanisms in games. They like to ask 'why' and 'how', are highly interested in nature, science and technology, experiments, etc., like to set goals and challenge themselves, and get a sense of achievement by gradually completing tasks. This characteristic is very important in game-based learning and task-driven education design.

3.4. Behavioural Characteristics

They learn by observing the behaviours of adults or peers, have a strong social need for peers, like to interact with peers, have a high dependency on their peers when encountering problems, and tend to seek help from their parents or teachers instead of solving problems independently. Therefore, providing clear guidance and appropriate assistance in education or product design can better help them complete their learning or tasks.

4. Design Principles of Intelligent Plant Cultivation Products

4.1. Principle of Immersive Multi-Sensory Experience

Multi-sensory interaction can enhance primary school students' knowledge of plant growth more intuitive and vivid. Adding LEDs to the product design imitates the natural lighting environment to show the impact of different light sources on plant growth, and different materials, such as imitation soil structure and soft leaves, can also be provided to enhance the sense of reality. Combined with the plant growth cycle, the odour is released during the growth or maturity stage, so that primary school students can experience the growth and changes of plants. In addition, the audio effect is conducive to enhancing interaction and making learning more vivid. Adding the above multi-sensory design to the product can establish good interaction and prolong the interest of primary school students in the product.

4.2. Principle of Being Orientated to The User Needs of Primary School Students

Intelligent planting product design comprehensively considers the dual needs of intelligence and ecological enlightenment, forming a natural interaction between human and intelligent planting system. To make primary school students more sensitive to the colour of plants, leaves, and the growth changes of roots and stems, it is necessary to give full consideration to the integration of visual and tactile elements in the design, and to ensure the use experience of primary school students through the styling of the product. While optimising the experience of primary school students, it is also necessary to incorporate the needs of users, so that they can use the product more conveniently by improving the simpler operation.

4.3. Ecological Cycle Principle

Intelligent plant cultivation products incorporate the generalisation of sustainable development, reduce the waste of water resources through the recycling irrigation system, and use biodegradable materials to make planting boxes, so as to enhance the environmental awareness of primary school students. In the process of use, primary school students are guided to make natural fertilisers for plants from everyday fruit peelings, eggshells and other kitchen waste, to improve the knowledge of resource recycling. Cultivate primary school students' understanding of ecological balance and sustainable planting, and enhance their knowledge of plant growing.

4.4. Social Collaboration Principle

In the product design, encourage multiple members to participate in intelligent plant planting and integrate the

planting process into classroom teaching, so that students can improve their scientific inquiry ability by observing the effects of different variables. Allow students to enhance their scientific inquiry ability by observing the effects of different variables. In order to expand the impact of planting education, an online community is integrated to encourage primary school students to share their planting results and exchange experiences with friends, thus enhancing the fun of social interaction.

5. Innovative Design of Multi-sensory Intelligent Plant Cultivation Products

Multi-sensory Experience refers to the multi-sensory interaction with products to enhance consumers' cognitive processing, emotional resonance, and purchase intention through technologies such as augmented reality, virtual reality, and haptic interfaces during the shopping process. Compared with single-sensory experience, multi-sensory experience can provide richer perceptual information and reduce the uncertainty caused by product intangibility (Mishra et al., 2021).

Multi-sensory Experience has been widely used in the fields of education, culture and creativity, rehabilitation assistance, and industrial design. In recent years, research based on multi-sensory interaction has been introduced into the design of educational products for primary school students to enhance learning outcomes and user engagement. However, there are limitations in existing research on plant cultivation products. This paper analyses the innovation of plant cultivation products for primary school students, i.e. combining tactile, auditory, olfactory and other sensory interaction methods, so that primary school students can truly participate in the whole process of plant growth.

Visual Design. Introducing Augmented Reality technology to simulate the plant growth process, primary school students can see the photosynthesis simulation animation of the plant they are growing through their mobile phones, which is more intuitive than just static pictures or data, and helps them to clearly understand the growth process of the plant. The system is equipped with LED sensing and simulation functions. When the plant is dehydrated, the LED light will turn red, prompting the students to water the plant in time. When the plant is in good condition, the LED turns green to indicate that the plant is growing well. Pupils can design their own personalised planting process using the buttons. (Figure 1).

Tactile design. In the traditional smart grower, primary school students can't feel the soil, lack of direct interactive experience, and it is difficult to enhance primary school students' knowledge of the plant growing environment. The designer implanted an intelligent humidity sensor in the product so that primary school students can judge the moisture condition by directly touching the soil. When the soil is wet, students will feel the soft and suitable texture after touching, while when the soil becomes dry, the system will provide a slight vibration to prompt students to water. In addition, there is a tactile sensor in the root area of the plant to display real-time information about the moisture in the soil, which is conducive to cultivating the observation and hands-on skills of primary school students.

Auditory design. Auditory feedback system can make up for the shortcomings of existing products in auditory

interaction. In fact, in the natural environment, the growth process of plants has almost no sound, but primary school students rely on sound stimulation in the early cognitive development process. Therefore, the built-in AI voice assistant in this product simulates the growth of plants. When the seeds of the plant germinate, the system will emit the simulation sound of the seeds breaking the shell, and the sound feedback allows primary school students to understand the needs of the plant in a more direct way. When watering, the system will simulate the sound of irrigation. Primary school students can feel the growth process of plants under multi-sensory stimulation, which enhances their learning interest and makes it easier for them to engage in the process of plant care.

Olfactory design. Intelligent growing systems on the market mainly rely on visual and data feedback, ignoring the role of smell in plant cognition. However, plant growth is accompanied by different odours such as the scent of soil and the aroma of flowers, and as important information in the life cycle of a plant, these odours remind the user of which stage the plant is in. By mimicking the changes in odour during the growth stages of a plant, primary school children are able to use their sense of smell to perceive the state of the plant during the planting process. In order to mimic these smells, specific odour structures are placed inside the product that intelligently emit odours at different times of the plant's life. The combination of olfactory and learning interactions improves the depth of primary school children's knowledge of plants.



Figure 1. Smart plant growing machines

By optimising the visual, tactile, auditory and olfactory experiences combined with intelligent voice interaction, primary school students are able to experience the process of plant growth in a more immersive way and develop scientific thinking and a sense of ecological responsibility during the planting process, as well as gaining all-round development

during the critical period of natural science learning.

6. Conclusion

This study takes primary school students as the user group analysis of the research object, and after clarifying the characteristics of primary school students, it proposes the principles of user demand-oriented principle of primary school students, ecological cycle principle, social collaboration principle, and analyses the shortcomings in the existing products, and then combines the multi-sensory experience to innovate the intelligent plant cultivation products, comprehensively improves the planting experience of primary school students, and promotes the ecological enlightenment learning of primary school students. The future smart plant cultivator should further combine with artificial intelligence personalised learning system to provide a more intelligent and personalised planting experience, so that primary school students can obtain the most suitable plant cultivation education for them at different growth stages.

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