Story-Time Machine-Low-Tech Attachment Design for Pre-school Children

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Abstract. Parents' behavior has a great influence on pre-school children, and children's living habits are closely related to family lifestyle. This study combined design research and technology to develop a teaching aid for parent–child reading. The goal was to reduce the excessive use of computers, communication devices, and consumer electronics (3C), as such devices have been found to negatively affect the parent–child relationship and may result in the child feeling disinterested and anxious. The Double Diamond design process model was adopted for the design research. A literature review and product comparison were used to identify the weaknesses of existing products and five design and development principles were proposed accordingly. Next, a focus group of experts was organized to review and modify the viewpoints and insights proposed based on their observations. Then, the value propositions were drafted to meet customer needs and to ensure product value; the product perspectives were defined. Porter's five forces analysis was applied to improve competitiveness. Innovative business models that integrated profits for business, English learning, and parent–child learning were suggested to enhance the sustainability and increase the product value of teaching aids for children. As actual product design research, a prototype of the designed product was produced. Following repeated testing, the product was completed to the first stage. In the near future, an iterative approach will be adopted to raise some funding; therefore, the future remains promising.

Keywords: Parent–Child Learning · English Learning · Innovative Business Model · Non-technology-oriented · Teaching Aids for Children

1 Introduction

Parents have great influence on preschool children's behaviors through their own attitudes and behaviors, which, in turn, affects children's habits and lifestyles [1, 2]. In recent years, digital products have gained increasing popularity and have gradually dominated

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physical books, toys, and dolls. This trend has led to changes in children's learning environments and lifestyles and caused behavioral and emotional problems related to the excessive use of cellphones, impaired parent–child relationships, and increased boredom and anxiety [3, 4]. Therefore, it is a significant goal in product design to transform parent–child reading and learning into intimate and valued parent–child time in a society with an increasingly fast pace and limited time together. Children learn optimally between birth and three years old, when they start learning two languages and have high-quality interactions with other people [5]. In the company of their parents, children may learn English more easily than if they were separated from their parents. Methods such as bedtime reading and storytelling allow children to naturally integrate into an English-learning environment, while storytelling facilitated by projectors and sound-and-lighting performances is conducive to engaging children and helping them to relax, so that they are able to absorb knowledge in a stress-free environment. Such non-technology-oriented methods combine virtual and physical materials to minimize addiction to high-tech products, promote emotional communication between parents and children, and enhance intimate parent–child relationships. This study was conducted in cooperation with BigByte Education, an English education institution. Based on the teaching materials that BigByte Education is skilled at developing, and on the basis of advocating children's English learning and education, a Story Time Machine for bedtime reading was designed. The Story Time Machine is a technology-based application that is oriented toward human interaction, to support the distancing of parents and children from computers, communication devices, and consumer electronics (the 3Cs), and to increase engagement in parent–child interactions.

The purpose of this study was to combine design research and technology to develop a design for a teaching aid for parent–child reading. Through a corporate needs analysis, market analysis, and a literature review, the product was designed to provide parent–child learning and reading opportunities, reduce excessive use of personal technology products, minimize dependence on technology through a combination of virtual and physical approaches, promote parent–child relationships, and establish a daily learning environment for children. It was also expected that this study would help enterprises to establish innovative business models that integrate business profits, English learning, and parent–child learning to improve the sustainability and product value of teaching aids for children.

2 Literature Review

2.1 Importance of Parent–Child Interaction and Parent–Child Reading and the Impact of 3C Devices on Parent–Child Relationships

Parents have a great influence on pre-school children's behavior. Parents' attitudes and behaviors, including how they position themselves as a parent, are associated with children's habits and lifestyles [1, 2]. Studies have shown that parent–child interaction has a positive and healthy effect on children's thinking and psychological development, promotes perceived happiness and their ability to quickly adapt to and learn social interaction, and has a critical influence on children's growth [6–8]. Parent–child interaction may take many forms, such as nature-based activities, parent–child reading, leisure sports,

and board games [9, 10]. Parent–child reading usually starts with reading picture books together and serves as a direct family connection [11]. Family reading is also helpful for the development of children's language and vocabulary, as well as learning to read. Parent–child reading is thus an essential component of children's learning and serves as an opportunity for families to spend quality time together [12]. Therefore, establishing a strong parent–child relationship is of great significance to strengthening a family [13].

With the decrease in birth rates and increase in dual-career families in Taiwan, parents are spending more time at work and less time with their children [7]. Taiwan has also witnessed a decline in the average age of Internet users, as many parents use the 3Cs as a means to appease and reward their children. Although such an approach is effective over the short term, it reduces parent–child interaction, leads to children's addiction to 3C devices, and may even escalate to mental conditions and self-harm behaviors [14–16]. In addition, children learn from parents' behaviors. When parents use 3C devices frequently, children are likely to emulate them. Excessive use of 3C devices has been found to cause learning disabilities, apathy, and social alienation [17, 30]. Bedtime stories are a way to enhance parent–child interaction and reduce dependence on 3C devices.

2.2 Bedtime Stories and Smart Toys

Bedtime stories are an important activity in early childhood development, as they promote perceived well-being and improve sleep, language development, literacy, emotional control, and behavior. Studies have pointed out that reading with parents enhances parent–child relationships and has a positive effect on children's development [18, 19, 31]. In recent years, bedtime stories have evolved from simple reading to the use of smart toys [21, 23], leading to an increase in market demand for smart toys that facilitate learning. It has also been found that games are an important factor in developing social skills and intelligence [32]. In 2004 Kehoe et al. developed a virtual peer system that allowed children to interact with a virtual character to create interesting stories [33]. Language style has also been found to impact the effectiveness of smart toys. Hence, it has been suggested that both the narrator's voice and the way the stories are narrated should feel warm and familiar to children to enhance their learning [34, 35]. Cassell and Ryokai [36] designed a smart toy called StoryMat and found that cooperating with adults in playing games can effectively promote children's intellectual development. Similarly, Digital English learning can help make learning English more attractive to new learners, generating a positive attitude and willingness to engage with the learning process [24, 26]. Since many studies have pointed out that both bedtime stories and smart toys affect children's development, while learning English is a modern trend for parents, with many children exposed to American English from a very young age, the authors intended to design a smart toy that focused on combining bedtime reading and English learning.

2.3 Comparison of Teaching Aids for Children

This study selected competing teaching aids (such as pop-up books for games, audiobooks, and mobile-shaped audio books) sold on the market; compared their function, content, price, and advantages and disadvantages; and summarized the key competitive

features required for the product to be designed and developed in this study. The detailed comparison is presented in Table 1.

Table 1. Analysis of competing teaching aids for children.

No.	Name and Image	Function and Content	Differences
1	Pop-up book with game  Extracted on Jun 17, 2021, from https://reurl.cc/9r1d2a	(1) A pop-up book for playing house (2) Fun (3) Cultivates imagination (4) Encourages interaction with the toy (5) Comes with a stuffed doll (6) The 3D book can be extended (7) The stickers can stick to the cardboard Selling price: NT $750	(1) Limited content (2) Vulnerable to wear and tear (3) Difficult to store (4) No audio (5) Content cannot be expanded (6) Short product lifespan
2	Physical audio book  Extracted on Jun 17, 2021, from https://reurl.cc/O0E2lA	(1) Teaches daily conversation and corresponding vocabulary (2) Comes with a barcode scanner (3) Contains conversations in various scenarios, such as when shopping and at supermarkets, and about product categories. (4) Introduces payment tools Selling price: NT $880	(1) Content is limited and cannot be expanded (2) Content is fixed (3) Limited parent–child interaction (4) Large in size (5) Components need to be replaced as a whole when broken (6) Difficult to store
3	Mobile-shaped audio book  Extracted on Jun 17, 2021, from https://reurl.cc/lRZ3Dd	(1) Includes six English nursery rhymes (2) A mobile-shaped toy that sings and tells stories (3) Comes with storybooks (4) Illustrated buttons that facilitate selection (5) Has a simple flashing light Selling price: NT $680	(1) Allows reading and listen to nursery rhymes at the same time (2) Bilingual (English and Chinese) (3) Facilitates language development (4) Content cannot be expanded

(*continued*)

Table 1. (*continued*)

			(5) Heavy (6) Difficult to store
4	Story projection torch  Extracted on Jun 17, 2021, from https://reurl.cc/9r1dev	(1) Torch-shaped projector that projects story images (2) Comes with three slides of films (stories) (3) Comes with three story books (4) Can be used in the evening Selling price: NT $380	(1) Limited stories (2) Difficult to add other story films due to manufacturing specifications (3) Difficult to keep the projected image stable as it is handheld (4) May cause eye tiredness (5) Limited projection range (6) Low image quality (7) Cheap
5	Interactive puzzle game  Extracted on Jun 17, 2021, from https://reurl.cc/Yd211o	(1) Requires a tablet and other physical tools (2) Allows multiple accounts to correspond to different difficulty levels (3) Includes games for learning English, math, reasoning, physics, and music (4) Includes various modules to facilitate the learning of different subjects Selling price: NT $6,440	(1) May cause eye discomfort when used for long periods (2) Needs storage space for the various accessories (3) Limited parent–child interaction (4) Expensive (5) May cause addiction to high-tech devices (6) Limited parent–child interaction

(Data source: Compiled by the authors)

It can be seen from the comparison that the biggest weakness of traditional pop-up books lies in the lack of audio feedback and inability to expand the content. As a result, children may get bored easily, which allows for easy elimination from the market. Physical audio books are usually large in size, have limited content, and do not allow expansion nor facilitate parent–child interaction. Therefore, children tend to lose interest in them after a short period of time. The problem with story projection torches lies in the low quality of the projected image, which reduces children's and parents' interest in interacting with the device. In recent years, smart interactive puzzle games have

become more popular. However, such games require the support of high-end software and hardware; hence, they tend to be expensive and require frequent maintenance by the producers. Devices that lack sufficient maintenance tend to stop functioning, interrupting the learning process. In addition, long-term use of these products may cause fatigue and eye discomfort, reduce parent–child interaction, and affect children's development. The weaknesses of the teaching aids on the market are summarized in Table 2.

Table 2. Summary of weaknesses of existing products.

Type	Traditional pop-up books	Physical audio books	Story projection torches	Interactive puzzle games
Weaknesses	No audio Limited learning content Limited pages in the physical books Vulnerable to wear and tear Short product lifespan	Limited categories Large in size Content cannot be expanded Limited parent–child interaction	Limited projection lightness Limited projection range Low projection image quality Manufacturer specific specs	Requires the use of a tablet Fast elimination of software Insufficient maintenance of the system May cause eye discomfort when used for long periods Limited parent–child interaction

(Data source: Compiled by the authors)

The literature review and product comparison showed that, in order to provide a sound English environment in daily life and develop a habit of reading with parents, a game-based teaching aid should integrate technologies, contain structures and functions that meet learning needs, and incorporate the advantages of existing products while avoiding the disadvantages. Only products with flexible learning content, swift updates and supporting technology, and expandable and extensible learning content can satisfy consumers' changing demands and need for diversification, cope with changes in the market, secure long-term profits, and ensure sustainability. As such, this study proposed five design and development principles for the product to be designed, including (1) expandable learning content, (2) high audio and image quality, (3) reasonable weight, (4) suitable for parent–child interactions, and (5) long product life cycle.

3 Methodology

3.1 Design Research Plan

This study adopted the Double Diamond design model, which is a design process proposed by the British Design Council in 2005. The model includes four phases of design: discover, define, develop, and deliver. Every two phases involve a "divergence-convergence" process, which allows in-depth understanding of the problem, uncovers core issues, seeks various solutions outside of inertial thinking, and aims to develop a product that solves problems (Fig. 1). Studies have found that sliding tactile feedback wristbands developed using the Double Diamond model were able to assist the visually impaired in learning in virtual and real-world scenarios and effectively help them to engage with society [28, 29]. Therefore, this study applied the model to designing and developing a human-centered, non-technology-oriented interactive teaching aid. The four phases of the design process are illustrated in Fig. 1.

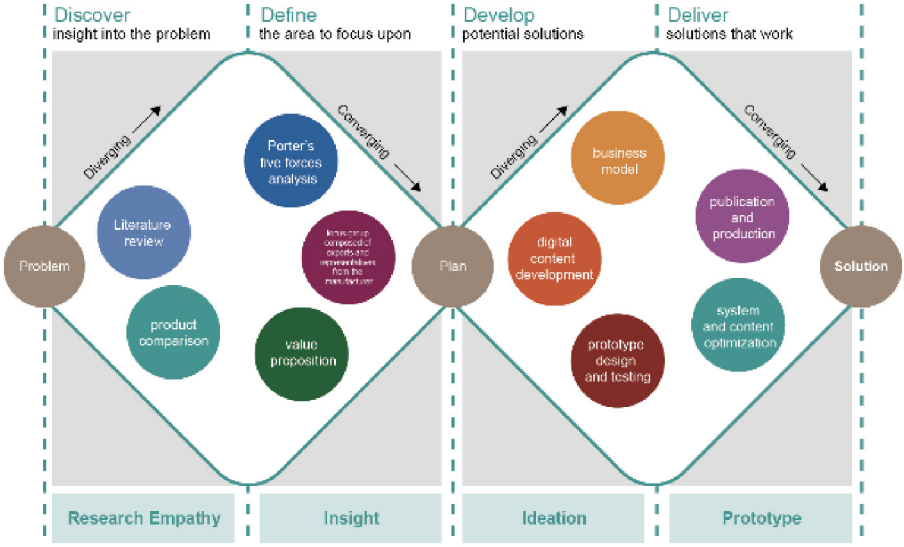

Fig. 1. Double Diamond design model (design process of this study).

3.2 Design Research

(1) Discover: In this phase, past studies on English teaching materials and parent–child reading were collected and reviewed, and competing English teaching aids for children in domestic and foreign markets were compared and their advantages and disadvantages analyzed.

(2) Define: In this phase, a focus group composed of experts and representatives from the partner company was organized to determine the design direction of the product. The focus group was composed of English lecturers and core textbook developers from

BigByte, and 12 to 15 experts in parenting education and child education, as well as cross-disciplinary experts in digital content design, mechanism design, and sensor module design. The goal was to review viewpoints proposed by the research team based on their observations and to propose new insights. A semi-structured questionnaire was used, and the duration of the focus group was three hours. The findings were compiled and used for the subsequent design planning and compliance guidelines. Next, the core value of the product was created using a value proposition map. A brainstorming session was organized to understand consumer needs, propose product benefits, resolve issues with existing products, and identify product characteristics, to gain customer recognition, satisfy customer needs, create core value, and define the product design principles. The initial value proposition is presented in Fig. 2.

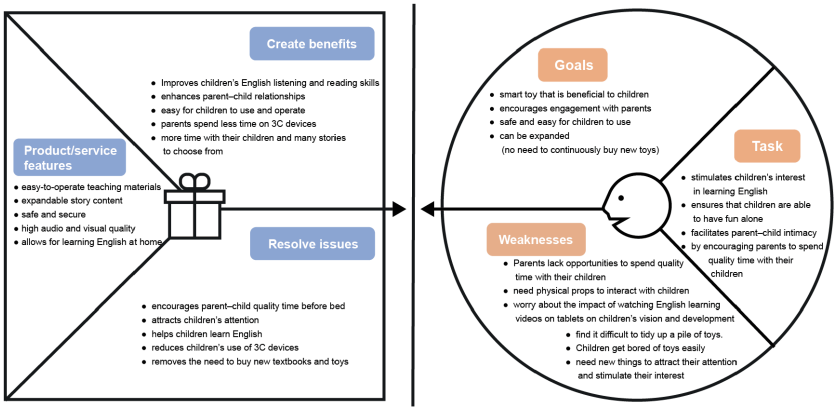

Fig. 2. Value proposition of the product.

Following the proposals developed within the value proposition, this study applied Porter's five forces framework to analyze the opportunities and challenges of the market, identify methods to resolve said problems, and improve the competitive advantage [27, 37]. According to Porter, there are five factors that affect competitive advantage: competitive rivalry (the number and strength of existing competitors), the threat of a new entry, the bargaining power of suppliers, the bargaining power of buyers, and the threat of substitutes (products/services). Porter's five forces analysis of the Story Time Machine (the product to be developed in this study) is exhibited in Fig. 3.

(3) Develop: The design principles, weaknesses of existing products, and new product value proposition identified in the previous phases were used as a reference for development. Porter's five forces provided a better understanding of the competitiveness of the product. Prior to developing a prototype, it is necessary to discuss the business model with the partner company in order to better understand its commercial value, help the company to create an innovative business model, identify target customers, and determine the market positioning of the product. Business models include nine interrelated elements, which can be categorized into four dimensions: supply, demand, value, and finance. The business model of the Story Time Machine is illustrated in Fig. 4. Once the business model was determined, the authors began to design the digital content of the

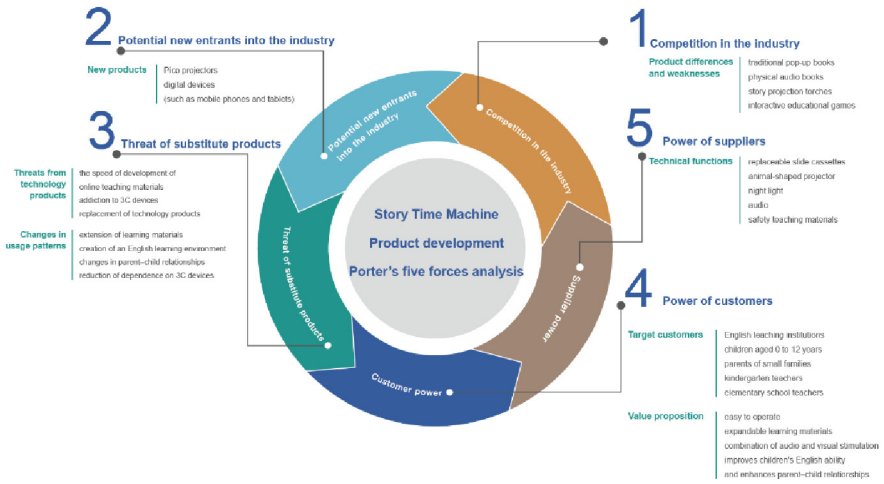

Fig. 3. Porter's five forces analysis of the Story Time Machine.

product and test the prototype. Specifically, English stories were converted into interactive digital content that facilitates parent–child reading. Next, the outlook of the product was designed, the color scheme was determined, and the user experience was planned. A prototype was then produced, and experts and representatives of the partner company were invited to test the projection technology and operating system and to identify their limitations. A revision of the design was conducted accordingly.

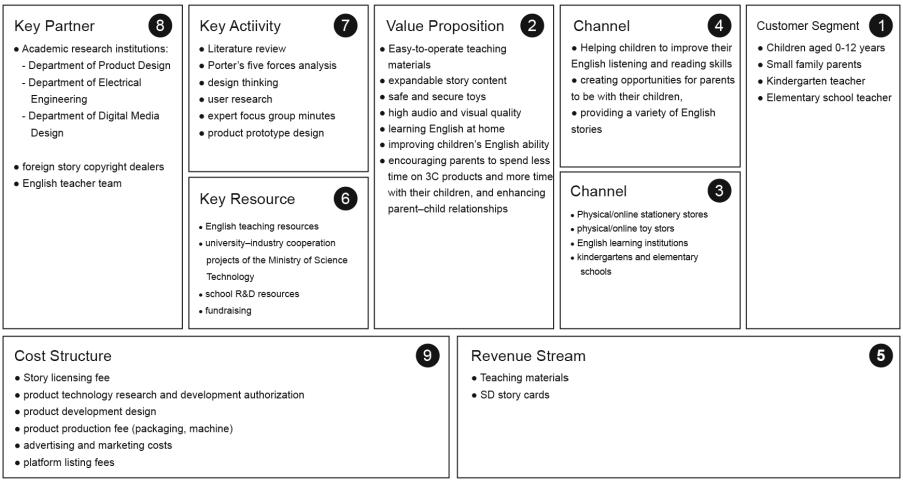

Fig. 4. Business model (preliminary concept diagram).

(4) Deliver: In this phase, the system and content of the product were optimized based on the test results of the prototype. The design was intended to be published and commercialized in preparation for market launch.

4 Results and Discussion

This study applied a cross-disciplinary design. The goal was to develop a children's English teaching aid that combines digital content and physical supports. The product design, computer machinery, and digital media design were conducted jointly by a professional design team and BigByte. Porter's five forces analysis showed that, although there were many types of product related to children's learning, the majority of them did not facilitate parent–child reading and the content was not expandable. Past studies have shown that children's learning effectiveness is correlated with parents' involvement. Therefore, this study aimed to develop a product surrounding the core concept of parent–child reading. With an emphasis on user experience, the design was expected to be customer centered. Moritz [38] asserted that service design should be holistic, multidisciplinary, and integrative, with comprehensive consideration of customer experience. The aspects designed and developed by the team are shown in Fig. 5.

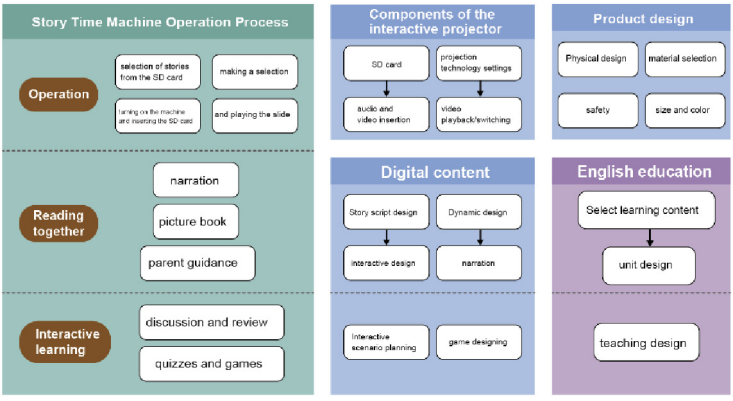

Fig. 5. Aspects designed and developed.

(1) Product Mechanism and Outlook

Based on the market research and analysis of existing products, the design team proposed the first conceptual mechanism and outlook of the product. The proposal was sent to the manufacturer for advice and the following suggestions were received: 1) The heat dissipation and sound emission holes were insufficient. They should be located on the same side as the projection to prevent hot air from blowing on to the user. 2) The heat dissipation holes, charging hole, and USB slot should also be moved to the front of the product to avoid disturbing users. 3) The USB access port is a feature of the main body; hence, different design options should be provided to the users. 4) The height of the

projector should be 20 cm. 5) The buttons should be larger. 6) The visual aspects of the product should be either cute, lively, or exotic to attract children's interest. 7) The shape could be changed to a bear or dinosaur. The first version (in the shape of a penguin) is presented in Fig. 6.

Fig. 6. The penguin-shaped projector.

Five more rounds of discussions with the manufacturer were conducted and the following suggestions were proposed: 1) Use a dinosaur as the shape of the product and ensure that the product is comfortable to hold. A milder color should be used to suit children's preferences. 2) There should be one or two more outlet holes for sound emission and heat dissipation, and the shape should be changed from long to round. 3) Push buttons with a beveled surface should be used so that they are comfortable to push. One button should be used for one function only. The buttons should be designed as spikes on the back of the device, the size for the "on," "off," pause," and "start" buttons should be made smaller, while that of the middle four buttons should be enlarged, so that they are easier to identify. 4) The material proposed in the original design was soft silicone. However, since the product contains a projector and sophisticated electronic devices, soft silicone may not provide sufficient protection and may lead to damage of the delicate components due to frequent holding and physical contact. It was suggested that hard silicone or plastic material should be used to protect the internal components, covered with an outer layer made of softer material. 5) Only one battery should be used, positioned upright with clear markings for positive and negative. A light should be installed as a battery indicator (no light when there is no battery). 6) The internal circuits and component settings were confirmed (Figs. 7, 8, 9, 10, 11 and 12).

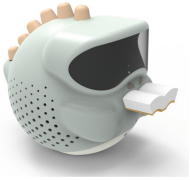

Fig. 7. Design of dinosaur-shaped projector

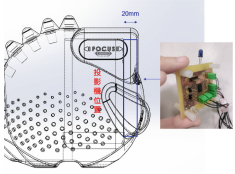

Fig. 8. Distance between projector and shell

Fig. 9. Prototype of dinosaur-shaped projector

(2) Interface Design and Usability

The design concept of the product focused on portability, ease of operation, replaceable

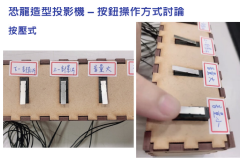

Fig. 10. Button style

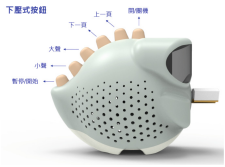

Fig. 11. Button function

Fig. 12. Hole function

slide cassettes, cuddling, and the shape of an animal character. ABS plastic, food-grade silicone (pacifier silicone), and other composite materials with high temperature resistance and high safety were used so that the internal components were well protected, the product was durable, and the appearance was appealing. The product specifications were determined based on the product comparison and literature review. Specifically, a micro SD card slot was used as the game cartridge, the size of the product was 15 × 25 cm (diameter × height), the weight was 800 to 1000 g, the material was ABS plastic and food-grade silicone, the battery used was 5 V–2 A, the music file format was mp3, and stereo speakers were used.

5 Contributions and Future Research

(1) This Study Developed a Game-Based Teaching Aid That Promotes Parent–Child Reading

The parent–child reading projector was a real product design that incorporated digital and physical materials to create a parent–child interactive experience. The projector was designed to be portable, easy to operate, cuddlable, and with a replaceable slide cassette. The outside was designed to look like an animal character, and the materials were made of a safe composite and were durable, strong, and collision resistant. This study applied the Double Diamond design process and used comparisons with existing products to identify potential weaknesses that needed improving in the product design. In addition, product value proposition, Porter's five forces analysis, and innovative business model development techniques were applied to identify market trends and to determine product value. After developing the prototype and conducting repeated testing, the first phase of product development was completed. The product was designed to combine commercial profits, English learning, and parent–child learning to expand the sustainability and product value of teaching aids for children.

(2) This Study Explored a New Approach to Parent–Child English Learning and Cultivated Cross-disciplinary Talent

When the prototype is completed, the intellectual property rights of the technology will be transferred to the manufacturer to improve the English learning ability of young children in Taiwan, help parents make good use of the product, enhance parent–child relationships, and facilitate children's learning and physical and mental development. The ability to communicate in English is a soft skill that parents value. Physical audiobooks provide parents with high-quality materials, which is in line with the orientation

of literacy education in the 2019 curriculum guidelines. With the product, children were expected to read/listen to at least 30 books suitable for their level in a year. The product provides children who are interested in English reading with more options and also stimulates the interest of children with no English foundation.

The Story Time Machine was the result of cross-disciplinary practical research. Its research scope covered parent–child reading and interaction, children's English teaching material design, sensory projection technology, product design, and English teaching toy design. The study also involved training the development team in the application of qualitative analysis, such as user engagement, service design, and design thinking skills. Participation in the design process was conducive to cultivating integral talent for cross-domain research and design practice needed in the future market.

(3) Future Versions and Market Evaluations

The Story Time Machine was the first generation of parent–child interactive teaching aids developed by the present research team. At present, prototype development has been completed, but the actual product testing has yet to be conducted. The subsequent focus will be on product concept reviews and product testing to resolve problems that arise during concept development, such as issues with the software and hardware and actual production of initial prototypes. A team of testers will be recruited to assist in testing the functions to ensure the quality of the product. Next, a front-end function test will be conducted to check for errors in the code to ensure sufficient stability for the product launch. A trial market will be planned, and marketing campaigns will be put in place and made ready for the launch prior to mass production. The final product concept will be determined following initial tests and released to the target customers. The product will be designed to suit future upgrades in response to the changing needs of consumers. The newest designs are expected to stimulate demand and lead the market.

The market for high-quality game-based teaching aids based on storytelling is stable. Since the stories are in English, it is not limited to markets that use traditional Chinese. Therefore, the research team is expecting to promote the product in the international market with the cooperation of BigByte. Based on the company's current customer needs and market planning, the demand for the product during the first stage is expected to reach 45,000 units. During the second stage, market demand is expected to reach 225,000 units. In addition to the projector, there will be additional stories and content available on the market, which will allow consumers to choose their learning materials in a way that corresponds to the language level and interests of their children. The product design will also be further refined. The initial selling price of the product is NT $1,850 per piece, and the price for each additional story will be NT $100 per piece, to maintain a moderate price on the market. The estimated turnover during the first stage is expected to be approximately NT $83.25 million and that of the second stage should be approximately $416.25 million. It is expected that the product will contribute to an increase in industry income and can be promoted in foreign markets.

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