

## **Building a smart library to improve literacy access for children: an innovative project of NLPI in Taiwan**

### **Ko-Chiu Wu**

Department of Interaction Design, National Taipei University of Technology, Taipei, Taiwan, China

E-mail address: kochiuwu@mail.ntut.edu.tw

### **Chung-Ching Liu**

National Library of Public Information, Taichung, Taiwan, China

E-mail address: ccliu@nlpi.edu.tw

### **Tzu-Heng Chiu**

Center for General Education, Taipei Medical University, Taipei, Taiwan, China

E-mail address: tzchiu@tmu.edu.tw

### **I-Jen Chiang**

Graduate Institute of Data Science, Taipei Medical University, Taipei, Taiwan, China

E-mail address: ijchiang@tmu.edu.tw

### **Saiu-Yue Tsau**

Department of Interaction Design, National Taipei University of Technology, Taipei, Taiwan, China

E-mail address: 062842g@gmail.com

### **Chun-Ching Chen**

Department of Interaction Design, National Taipei University of Technology, Taipei, Taiwan, China

E-mail address: cceugene@ntut.edu.tw

### **Li-Hsiang Lai**

National Library of Public Information, Taichung, Taiwan, China

E-mail address: lh lai@nlpi.edu.tw

### **Yu-Wei Tseng**

Graduate Institute of Library, Information and Archival Studies, National Cheng-Chi University, Taipei, Taiwan, China

E-mail address: wendy.tseng@gmail.com



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## Abstract:

*Digital natives are born into an information-dense resource-abundant world, which greatly influences their needs with regard to libraries. Furthermore, the information-seeking behaviors of children in the process of book selection, browsing, reading, and using a library differ significantly from adults. The high-quality information content and innovative service provided by smart libraries are capable of satisfying these needs. This inter-disciplinary study developed a mixed-reality children's library using a wearable smartwatch and RFID smart bookshelves for the Children's Learning Center at the National Library of Public Information (NLPI) in Taiwan. We conducted data mining on borrowing records to differentiate young users from the general population. A wearable smartwatch and beacon indoor positioning technologies were developed to help children navigate classified-code bookshelves and RFID Smart Bookshelves. These RFID bookshelves employ visualized interfaces to demonstrate popular books. We installed a touch-screen book wall to recommend books to different groups of young users. A virtual-world hallway built to immerse children in a game-oriented environment where they can learn about classification number. The information-seeking behavior of these young users has changed with the advent of digital technology, mandating attendant transformations in the functioning and lay-out of today's libraries.*

**Keywords:** information-seeking behavior, thematic classification, wearable smartwatch, RFID smart bookshelves, visualized interface

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## Introduction

Book storage and classification in libraries depend on book metadata. Most libraries integrate this metadata with the spatial arrangement of bookshelves in the physical space. When readers want to find a book, they need to make a conscious effort to combine these two cues and locate the desired book. For the new young generation of “digital natives,” this book-finding approach might not work. As children's conceptual abilities have not yet sufficiently developed, and their preferences and spatial experience differ vastly from those of adults, they have difficulty in finding the book they are looking for, and usually need to ask for librarians' help. Hence this study made a series of attempts in the following aspects: (1) to analyze children's information-seeking behavior under different contexts; (2) to design visualized interfaces based upon children's knowledge structure and how they perceive the thematic order of books; and (3) to evaluate how young users respond or react when using digital devices in a smart library. The aim of this study was to employ digital technologies to create a smart children's library so as to help young users of differing developmental phases make better use of a library.

## Literature Review

Bilal and Kirby (2002) pointed out the difficulties faced by young readers when they try to use their knowledge structure to interpret the metadata in the information-seeking process. The majority of adults are able to adopt a systematic or linear browsing style using search syntax, whereas children often use a looping style or trial-and-error strategy when browsing. Adults process information more efficiently, do not need a lot of hyperlinks and backtracks,

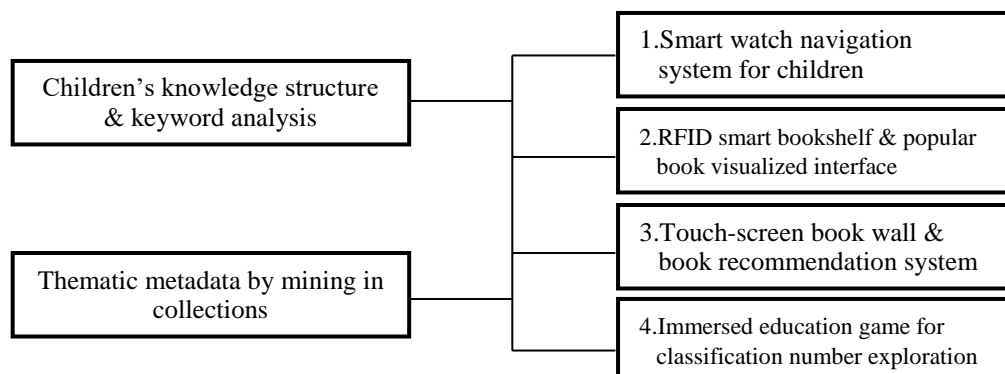
and can return to the right path immediately after an information breakdown in the process of keyword searching. Shenton and Dixon (2004) further explored how the information-seeking behavior of children and adults differ. Young users tend to make repeated attempts, and will often employ novel problem-solving methods at the start of each information-seeking process. Cooper (2002) probed into children’s processes in the pursuit of books and multi-media materials, and likened their behavior to a journey of self-discovery undertaken in a semi-structured manner in an unfamiliar environment. This is why children’s libraries should create a physical space that accommodates children’s cognitive abilities and successfully piques their curiosity, while making a game-like virtual-reality environment so as to keep children motivated and willing to start a joyful information-seeking process.

Information technology helps create new opportunities for the architectural space of a library. Various developments, such as Integrated Library System (ILS) combined with a biometric physical access control, smart living spaces, mobile technology, and the rapid advances in the Internet of Things (IoT), have contributed to a growing bulk of research dedicated to the integration of smart architecture into libraries (Hoy, 2016). Currently this body of research focuses on libraries in India and China (Wang, 2016; Singh & Singh, 2015). The Online Computer Library Center (OCLC, 2016) has launched a project called “Small Libraries Create Smart Spaces,” which is accepting applications from rural and small libraries across the US. Fifteen public libraries will be selected to participate in this transformative process. The aim of this project is to acquaint library staff with knowledge of human-centered spatial design, and to prepare them for community empowerment so as to create a pioneering library where readers can freely explore, have fun and acquire knowledge.

**Methodology**

This study suggests that developing a book-finding system requires a full understanding of how children classify book themes and find meaning in them. Secondly, it is vital to create a visualized interface for children because they prefer pictures and graphs over words and cannot be burdened with a heavy cognitive load. A sheet of fields was designed for future researchers to conduct data mining on user and spatial information. The experiment was conducted in the Children’s Learning Center at the NLPI. Four multi-media computing technologies were employed to monitor young users’ book-finding processes and browsing of popular or recommended titles. See Figure 1, the four devices are as follows: (1) A wearable smartwatch aids the children in navigating through the physical environment to find the desired book. (2) RFID smart bookshelves contain popular books and information visualized interfaces provide a service easily accessible by children. (3) A touch-screen book wall recommends different books to different reader groups. (4) Interactive games provide children with an immersion experience in which they are taught the meaning of classification numbers and learn how to use them to find the desired book.

**Figure 1. Information Seeking Analysis And Designed Devices**



## Result

### (1) Children's knowledge structure and keyword analysis

According to the results of a sampling experiment on e-book databases of public libraries conducted by Wu, Chiu, and Lin (2014), most children do not depend on the New Classification Scheme for Chinese Libraries to find desired books due to insufficient cognitive development and a poor command of the meaning of this classification method. In other words, they cannot rely on classification numbers to complete book-finding tasks. These researchers further presented the faceted classification of keyword tags to illustrate that the knowledge tree developed by young users differs vastly from an expert's knowledge tree, which is based on the classification of disciplines. Since experts (and the majority of adults) have developed a certain command of knowledge, they are inclined to understand a hierarchical system that depends on logic and order. Children, however, usually require cognitive load reduction and are inclined to grasp instinctive and easily comprehensible information. They have problems dealing with a rigid hierarchical knowledge structure, which burdens their working memory in the information-seeking process. Therefore it is vital that human-computer visualized interfaces are simple, clear, and classified by theme.

We started with an analysis of children's grasp of thematic classification, and then proceeded to their own descriptions of these classified themes. Obviously children tend to use concrete words learned from everyday life as keywords. Research results indicate that this thesaurus consists of six facets: topic, geography, style, genre, age-appropriateness, and context-appropriateness. By integrating this thesaurus into web resources classification, this user-oriented tag system can be appropriately extracted and hierarchized, and can thus be employed to help young users to browse library collections and web-based materials.

### (2) Thematic metadata generated by structure mining in library collections

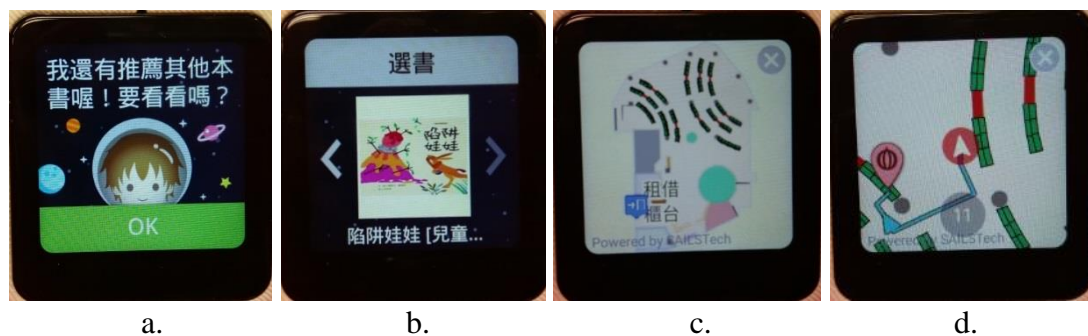
Children of different groups may exhibit different information-seeking behavior due to their specific cognitive abilities and preferences. Traditionally a library's ILS depends on large quantities of borrowing records, from which keywords are extracted so as to create keyword groups accordingly. We used the Children's Learning Center of NLPI as an example, exploring their borrowing records (400,000 records and 45,000 titles) from 1600 readers by performing an analysis of book titles (weighting) and abstracts. Then we employed K-mean text-mining to divide readers up into six groups. After redundant keywords were deleted, we then tried to match the keywords of each group with their favorite books, in order to make recommendations. A smart library can record the behavior and frequented locations of each and every reader. This, combined with the thematic classification of books on bookshelves (with the aid of classification numbers), helps to ascertain the length of time a reader spends in a certain area in the library. The reader's browsing and information seeking behavior can be predicted accordingly. Our research team built a database that chronicles the length of time users spend in an area and how they browse, read, and borrow books. This, coupled with the reader's past borrowing records, was used to analyze the preferences of readers of different groups.

### (3) A book-finding navigation system that corresponds to children's cognitive structure and spatial experience

As humans live in three-dimensional space, they naturally rely on their physical experience when they face the virtual world and learn to operate via digital technologies. This study focuses on cognitive behavior (an integral part of mobile learning) and how the interplay of the body and its surroundings contributes to learning and cognition. With the various needs of children in mind, our research team designed a navigation system using wearable devices.

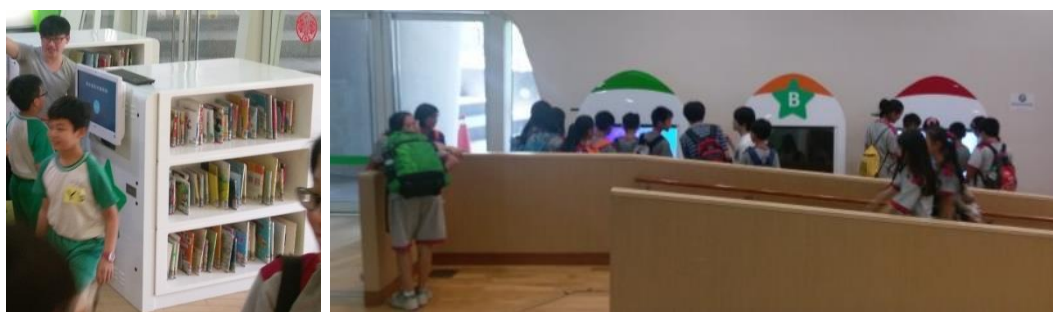
This system is well-integrated with search interfaces, icons, and a visualized knowledge map, on which icons and actual surroundings correspond accurately, so as to proffer young children a complete library experience on an instinctive level. Currently NLPI uses UHF RFID, which is compatible with the previous ILS. The library also provides location-based services with i-Beacon technologies and indoor positioning algorithm, which directs children to any location or bookshelf in any area. Figure 2 shows young users may select their desired book, and then find the location of that bookshelf by clicking the icon of that book. Children check directions shown on the wearable smartwatch interface as they navigate the coordinate space.

**Figure 2 Smart Watch Navigation Process**



(4) RFID Smart Bookshelves and a visualized interface for children’s popular books  
 The integration of the ILS, book tagging, and the RFID sensors allow any book on the bookshelves to be easily found. In Taiwan, National Tsing Hua University and Tamkang University provide a book reservation service with the aid of this smart system so that readers do not need to queue up in front of the information desk. As Pareto’s 80-20 principle states, most library books are borrowed by only a few readers, while a small share of the books is desired by the majority of readers. Therefore we built RFID smart bookshelves for popular books (Figure 3 left).

**Figure 3 RFID Smart Bookshelves (left) & Touch Screen Book Walls (right)**



These automatically sense if a certain widely read book is available, and most importantly, these bookshelves do not need to be arranged in accordance with classification numbers. Instead, popular books can be placed on the bookshelves in a non-linear fashion for readers to browse. When books are presented in a new way, there arises the opportunity to develop an information visualized interface that accommodates various types of young users. Readers can browse a wide array of titles in differing themes over a visualized interface in a short period of time, and make decisions as to which title to borrow. The current study created a visualized interface featuring an integration of smart bookshelves and a titles push system,

using thematic metadata and information visualization technologies. A total of 1,000 popular titles were categorized in accordance to children’s understanding of themes and keywords with regard to these books. The design of the visualized interface is as Figure 4.

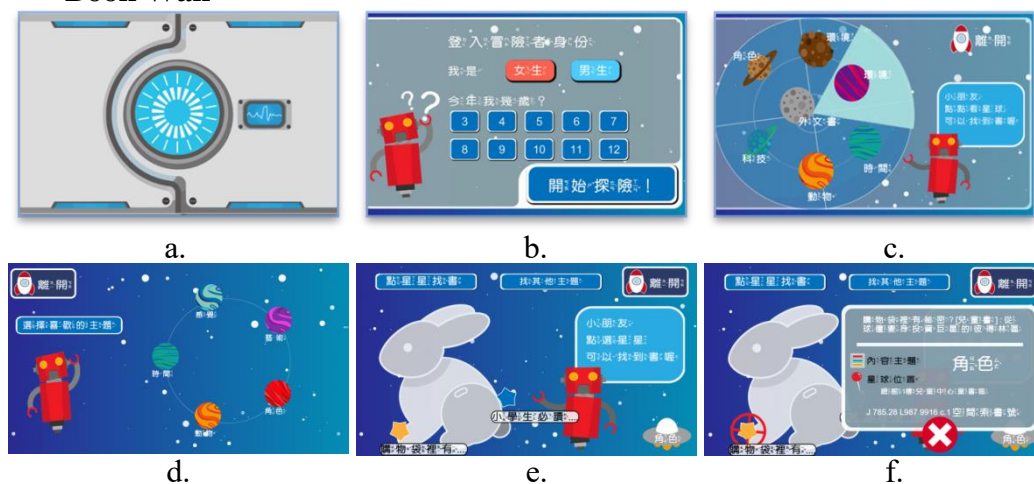
**Figure 4 The Visualized Interface for Children’s Popular Books in A Smart Bookshelf**



(5) Touch-screen book wall and book recommendation system

As a library is a significant educational resource, it should provide more than just information retrieval. In this endeavor, e-walls (see Figure 3 right) are an effective tool for book recommendation. The OPAC system provides a platform for users to retrieve desired information, while a touch-screen book wall attracts library patrons with an introductory animation of recommended books on the visualized interface. There are both clustering and categorization representations (see Figure 5). The former utilizes a geometric arrangement of icons/book titles, which is fun and appealing to young users, whereas the latter is a hierarchical coordinate system that enables children to make use of their existing knowledge structure to judge if the recommendation is worth considering.

**Figure 5 The Visualized Interface for Books Recommendation in the Touch Screen Book Wall**

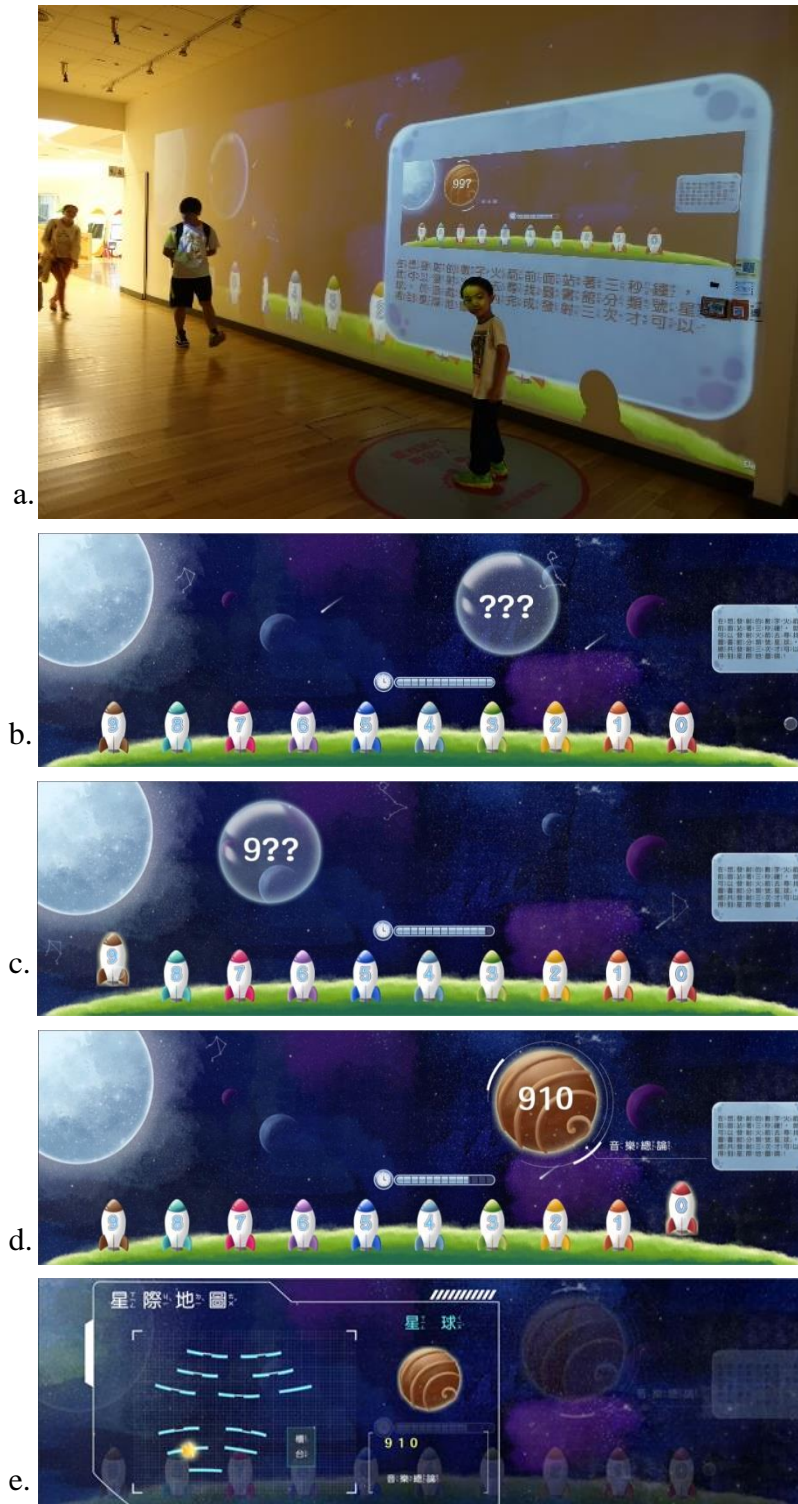


(6) Immersion in interactive games for classification number exploration

At the entrance to the Children’s Learning Center at NLPI, a ten-meter long LUCKY BOOK corridor leads children toward the inside of the library. Three projectors and sensory equipment are installed to monitor readers’ movement and create an immersion experience

for children by projecting shadows onto the right side of the wall. Our research team uses the existing devices to improve the interface over which the game is displayed. This immersive multi-projector display elicits children's interest and attention, so that they have a flow experience in the process of overcoming challenges. This immersive game not only prepares the children for a reading experience later on, but teaches them how to recognize classification number as clues to find books in a library (Figure 6).

**Figure 6 The Visualized Interface for Classification Number Education in the LUCKY BOOK Corridor**



## Discussion

### (1) A combination of metadata and a smart space

One of the core problems involving the relationship among readers, books, and the environment is means of developing collection and coding technologies to tackle an ever-increasing physical collection (coupled with digital archives) and addressing the mounting need of material application without affecting readers' rights to and discretion in the library. Mobile technologies provide some new solutions for this problem. Chinese-language libraries have for a long time depended on the New Classification Scheme for Chinese Libraries invented in 1929. This authoritative categorization is executed by librarians, who judge the content of the book before placing it on a certain bookshelf. Readers, however, might not necessarily agree with a book's categorization, leading to difficulty in finding desired information.

Mobile technologies allow a virtual/ augmented book-finding interface to exist in conjunction with the physical bookshelves. A layer of thematic knowledge is added to the existing system, which distinguishes among a wide diversity of thematic categorization that meets the needs and cognitive abilities of readers using data mining/ text mining. To break the limits of a physical book (a location and a classification number), we employed hyperlinks to connect multi-entities-relationships of books and their corresponding locations in the virtual structure. The ILS used by traditional libraries produces a ceiling effect. Even though the library is aware of the popularity of some books, the lengthy borrowing period of a book reduces the weighting of a theme. Book reservations do not help either, because readers tend to make reservations based on the likelihood of a book's availability; therefore it is nearly impossible to judge the level of popularity of a theme or a certain book. Moreover, the library does not have information on which groups of readers read which books when in the library space. The smartwatch navigation system enables the library to track and monitor the length of time and frequency a reader spends in an area. Then big data analysis can be used to determine which group of readers prefers which type of books. This is believed to supplement the current automated service, and helps the library develop customized services.

However, when users operate a natural user interface, they respond to the interface intermittently and randomly; therefore the data generated in this process would be unstructured big data, often fluctuating between threshold values (and hence subject to blurring effect). The present study performed an analysis of the relationship between readers and book themes, using the smartwatch's natural user interface to check browsing history. To further analyze the relationship between duration of usage and motivation for information seeking, we recommend employing precision measurement (physical signals) and conduct a detailed analysis.

### (2) Information-seeking behavior exhibited when operating a human-information interface

Children exhibit various types of information-seeking behavior in a library, such as conducting a search, browsing, receiving recommendations, and learning something new. This study employed different designs to explore the relationship between human-information interfaces (HIIs) and information channels that connect the physical and virtual spaces, such as a visualized interface for the titles push system by classification number. An information visualized tool featuring icons helps people browse in a more effective way. When popular books are placed together, RFID smart bookshelves provide children with an animated visualized interface: the icons can be clicked on and enlarged to increase children's attention and interest. Children can access the information they want via the interface, rather than seeking a single book by wandering in the aisles between bookshelves with only



classification numbers as clues. Our research team presents a human-information interactive interface using the IoT as a novel solution for book-finding.

This recommendation function triggers a need for information visualization. Pharo and Järvelin (2006) proposition that people start with what they are familiar when faced with large quantities of web-based materials. This information-seeking behavior not only illustrates humans' inclination toward labor-saving strategies, but demonstrates that "conviction" plays a role in information-seeking endeavors. With respect to touch-screen book walls, a large touchscreen allows two children to simultaneously operate the interface. Then the results of recommended books for a certain group of young users (as generated by big data analysis) are presented on the touchscreen video wall. It is advised that further explore sharing, and social recommendations on the touch-screen book wall.

### (3) Analysis of user preference and ability under various media channels

User gratification theory (UGT) tries to explain why and how humans choose different channels to seek information based on their various information needs. Pace (2004) employed grounded theory methodology to investigate the flow experience of web-searchers' in seeking information over the Internet and proposed that a variety of factors, such as time pressure, attention, and reward affect this experience. Whilst the movement around a three-dimensional space requires a lot of energy, the movement in a virtual world is closely associated with cognitive load. The HII user experience should thus be explored to learn more about this information-seeking process in which physical labor and cognitive ability are combined to produce results. Whether it is the smartwatch navigation that allows users to freely move around the space, or it is the touch-screen book wall on which readers can click an icon to see a book's introduction, these media channels help young users of various information needs to find the desired object in a more effective way. This is a golden opportunity to investigate if UGT and flow experience can be combined.

A mixed-reality corridor that helps children learn how to use classification numbers can be a measurement of other learning experiences. Since educational software is designed to elicit learners' interest, a sense of "flow" encourages gamers to thoroughly immerse themselves in the game. Motion sensing games demand a lot of physical endurance, which means gamers will likely lose their interest due to this time-consuming process. Hence it is suggested that future researchers investigate the relationship between flow experience and learning effect in a dynamic environment during a shorter period of time. Presumably the measurement results will be more reliable.

## **Conclusion**

Our research team built a smart library using mobile technologies in order to investigate multiple behaviors, including searching, browsing, reception of recommendations, and learning. Then we explored children's knowledge structure and how they perceive the thematic order of books, performed a keyword analysis, conducted structure mining of the thematic metadata of library collections, built the smartwatch navigation system to facilitate the book-finding process, developed RFID smart bookshelves for popular books and a visualized interface for browsing, created a large touch-screen book wall on which clustering and categorization representations are displayed for children to operate, and lastly, we presented an immersion game (in a mixed-reality corridor) designed to enable children to learn how to use classification numbers as clues in finding a book.

The above devices can be used to accumulate electronic records from various information systems and interfaces and thus allow children to better locate materials or books they are looking for in a smart library. Then our research team employed big data to determine the correlation between “children of different needs or preferences” and “their information-seeking behaviors,” which we believe denotes the future development of a smart library. It is advised to apply different functions of mobile devices to investigate how children’s logical judgment and physical and emotional responses interplay with their information-seeking behaviors. Icons representing children’s everyday life can be inserted into a visualized interface, so as to create a complete digital library database based on physical and virtual resources specifically designed for children.

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