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Children and parents' reading of an augmented reality picture book: Analyses of behavioral patterns and cognitive attainment

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ABSTRACT

Previous studies on augmented reality (AR) book learning have not provided an in-depth examination of the learning process, especially the interaction involved in child–parent shared book reading. Choosing an AR picture book to introduce its artistic work, this study aimed to explore how children and parents read the book through a series of analyses of behavioral patterns and cognitive attainment. A total of 33 child–parent pairs voluntarily participated in this study. Based on the indicators of the child–parent reading behaviors generated through content analysis, four behavioral patterns of AR picture book reading were identified: *parent as dominator, child as dominator, communicative child–parent pair,* and *low communicative child–parent pair.* The relationships between the child–parent reading behaviors and the children's cognitive attainment were further identified. Specifically, the child–parent behaviors of "*parent as dominator*" and "*low communicative child–parent pair*" were likely associated with simple description of the appearance of the artistic work by the children (low-level cognitive attainment). Conversely, the "*child as dominator*" and "*communicative child–parent pair*" behaviors resulted in the children explaining the artistic work they had seen or using their imagination to describe the content of the book (high-level cognitive attainment).

1. Introduction

Augmented reality (AR) technology, which allows users to see a physical space with virtual elements (or information) superimposed on it in real time, was developed for several applications in the 1990s, such as aircraft cable assembly guidance (Caudell & Mizell, 1992), surgical training (Bajura, Fuchs, & Ohbuchi, 1992), and laser printer maintenance demonstrations (Feiner, MacIntyre, & Seligmann, 1993). However, AR research did not gain popularity because of the restrictions of AR devices (i.e., head-mounted displays and backpack computers). Only recently has such research begun to come to fruition due to the maturity of AR technology. In 2012, a variety of enabling technologies for AR applications, such as smartphones and other handheld devices (Gervautz & Schmalstieg, 2012), advanced projector-camera systems (Mine, Van Baar, Grundhöfer, Rose, & Yang, 2012), and AR-extended professional devices (e.g., x-ray scanners) (Navab, Blum, Wang, Okur, & Wendler, 2012), were reported in a number of studies. Considering its likely advantages for education, the application of state-of-the-art AR technology has been suggested for its potential (Duh & Klopfer, 2013; Martin et al., 2011) and significance (Cheng & Tsai, 2013; Wu, Lee, Chang, & Liang, 2013).

Several AR studies in education have indicated the enhancement of students' motivation for learning with the AR technology (e.g., Di Serio, Ibáñez, & Kloos, 2013; Martín-Gutiérrez & Contero, 2011). Recently, the benefits of AR in learning effectiveness were also reported. For example, an AR learning system could help learners to acquire better understanding on physics (Enyedy, Danish, Delacruz, & Kumar, 2012; Lin, Duh, Li, Wang, & Tsai, 2013), electromagnetism (Ibáñez, Di Serio, Villarána, & Kloos, 2014), environmental reservation (Kamarainen et al., 2013), and construction engineering (Behzadan & Kamat, 2013). Through the mobile AR guidance, the students engaged more in gallery experience and performed better on painting appreciation (Chang et al., 2014). Researchers also considered the AR

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technology to be integrated in the physical classroom environment (Bujak et al., 2013) and proposed AR design principles for classroom (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013). That is, the affordances of AR environments have been emphasized in learning and teaching. Since AR has been applied in a variety of educational context, this study was focused on the combination of AR technology and traditional book reading. As the abstract concepts of a paper book probably misunderstood by readers, the authenticity supported by AR may lower the complexity of learning materials and visualize the unobservable objects or concepts (Wu et al., 2013). The further exploration of learning through book reading with AR is the attempts of this study.

1.1. AR book research

Along with the development of educational technology, researchers have continued to devote their efforts to exploring how technology such as interactive electronic storybooks (Smeets & Bus, 2012; Trushell, Maitland, & Burrell, 2003) assists students' learning through book reading. Nevertheless, traditional paper books are not likely to be replaced by electronic books due to their tangibility, which enables people to physically possess and touch them (Sellen & Harper, 2003). AR books, resembling printed books except that computer-generated graphics or information are superimposed on the pages, thus create an opportunity to enrich users' learning experiences beyond electronic book reading. This physical means of interaction may leverage users' knowledge from the real world, resulting in natural or intuitive uses of paper books with the aid of AR (Hornecker & Dünser, 2009). For learners with limited computer experience, the perceptions of seamlessness between the virtual and physical elements of the AR environment create unique educational benefits and new teaching/learning possibilities (McKenzie & Darnell, 2004). Through the interactions with synthetic audio-visual content, AR technology may enhance children's comprehension of book content (Dias, 2009). The examination of the effects of AR book reading on students' learning is thus likely to be an interesting issue to explore.

A variety of studies regarding the pedagogical applications of AR books have evaluated the usability of AR systems (Chang, Chen, Huang, & Huang, 2011; Sin & Zaman, 2010). The results of these studies mostly indicate students' agreement with their usefulness, ease of use, effectiveness, and satisfaction with AR book systems. Users have also exhibited positive attitudes toward the use of AR books (Billinghurst, Kato, & Poupyrev, 2001; Clark & Dünser, 2012). A few studies have further probed the effects of AR books on learning and, at least to a certain degree, have found improvements in students' cognitive attainment in areas such as spatial ability (Martín-Gutiérrez et al., 2010), conceptual change (Shelton & Stevens, 2004), and language skills (Liu, 2009). However, studies that involve the in-depth exploration of AR-related learning processes are limited (e.g., Lin et al., 2013). That is, although findings exist regarding what students obtain through AR-related learning, how students learn in the process of experiencing AR content is still not well understood.

1.2. Picture book reading for children and parents

In the context of preschool learning, it has been documented that picture book reading is beneficial for children's language development (Bus, van IJzendoorn, & Pellegrini, 1995), cognitive engagement (Elia, van Den Heuvel-Panhuizen, & Georgiou, 2010), and artistic thinking (Hsiao, 2010). How to support and facilitate children's picture book reading is thus worthy of further attention. During the picture book reading process, it is proposed that an adult, a child, and a book are the three main interactive components (Fletcher & Reese, 2005). Researchers have provided evidence that in picture book reading, parental reading behaviors such as pointing to pictures, labeling and commenting on pictures, or asking questions about the pictures or story are associated with children's language learning (Arnold, Lonigan, Whitehurst, & Epstein, 1994; Cronan, Cruz, Arriaga, & Sarkin, 1996).

Dialogic reading, another means of assisting children's learning, which is a shared picture book reading intervention for preschoolers, involves parents having a dialogue with children when reading a book together (Zevenbergen & Whitehurst, 2003). The PEER (*Prompt*, *Evaluate*, *Expand*, and *Repeat*) model is one of the dialogic reading strategies recommended for parents to implement with children aged 4–5. Specifically, the PEER model consists of four interaction-oriented behaviors: (1) *Prompt*: the adult prompts the child to pay attention to the content of the book (e.g., labeling objects in the book or talking about the story); (2) *Evaluate*: the adult evaluates the child's responses (e.g., praising the child's correct responses, offering alternative labels, or correcting incorrect responses); (3) *Expand*: the adult expands the child's responses (e.g., repeating what the child has said or adding information); (4) *Repeat*: the adult encourages the child to repeat the expanded utterances. Recently, the dialogic reading approach has been incorporated in tablet-based e-book reading and has been suggested as being beneficial for child–parent collaborative learning (Tseng, Liu, & Liu, 2012).

1.3. The purpose of this study

With regard to the role of parents in children's reading either with conventional media (e.g., paper books) or through information technology (e.g., AR books), how they behave or participate in the process of children's learning should be an essential research issue for investigation. However, few studies have endeavored to explore this issue in the field of AR book research. Previous studies have argued that children may benefit in peer-pair settings when reading AR books (Dünser & Hornecker, 2007; Hornecker & Dünser, 2009). This study assumed that incorporating parents into the process of children's AR book reading may yield different learning experiences and learning processes. In particular, through the lens of the dialogic reading model (Zevenbergen & Whitehurst, 2003), what interactive patterns may be exhibited when parents and children jointly read an AR book should be well understood. According to previous studies (e.g., Hornecker & Dünser, 2009), the behaviors of children and parents engaging in AR-related learning relate to the children's learning performance. For instance, those who are involved in more interaction sequences of AR book reading showed better ability of recalling story events. As a result, analysis of the child–parent learning process (i.e., behavioral patterns) and children's learning outcomes (i.e., cognitive attainment) within the context of reading an AR picture book constituted the basic research framework of the present study. The research questions are as follows:

1. How do children and parents behave and interact with each other during the AR book reading activity? Do they display different behavioral patterns across different child–parent pairs?
2. What is the cognitive attainment of children when engaging in the AR book reading activity?

3. What are the associations between child–parent behavioral patterns and children's cognitive attainment? Are there differences in cognitive attainment according to the different child–parent behavioral patterns?

2. Method

2.1. The AR picture book

To answer the research questions, an AR picture book, namely "*The Adventures of Yuyu: Yuyu Yang Artistic Journey*" published by National Chiao Tung University Press in Taiwan, was adopted in the present study for the investigation of AR picture book learning. The background of the book is based on a story about a boy, who is the grandson of the artist YuYu Yang, taking an adventure with a black cat in his grandfather's work studio. The black cat is the incarnation of YuYu Yang's work "home cat." Through the journey, the cat introduces the boy to get familiar with his grandfather's artistic work. The purpose of the AR picture book is to introduce the artistic work of Yuyu Yang through storytelling with pictures. Combining art appreciation with digital reading techniques, children can read the picture book with the aid of AR technology. To be more specific, by focusing on the book using a mobile device with a camera (i.e., an Android phone, Android pad, iPhone, or iPad), virtual information was overlaid on the page with the picture of a sculpture or an engraving and then shown on the mobile screen. The virtual information includes 3D models with audio and subtitle narration, videos, and interactive media that present the artistic work. It should be noted that the augmented information for showing the work is not the representation of the story on the book but the scaffolding information about the description of the work. For example, the book story states that "…the boy slipped in his grandfather's work studio slowly. He saw a sculpture in form of cat on the desk. Suddenly, a black cat jumped up from the sculpture and said hello to the boy…" By focusing on the book picture with the camera on a tablet PC, children can see the real sculpture "home cat" overlaid on the paper book in 3D form along with audio narration of the background and the idea for creating the work. Turning the mobile device or the picture book is helpful for viewing the different perspectives of the 3D object. Fig. 1 demonstrates the usage of the AR picture book.

2.2. Participants

In the process of reading the AR picture book, this study attempts to examine not only how children learn but also what role their parents play in the interaction. Accordingly, 33 child–parent pairs in Taiwan, including 12 girl/mother pairs, 19 boy/mother pairs, 1 girl/grandmother pair, and 1 boy/father pair, voluntarily participated in the AR picture book reading activity. Whereas the mean age of the parents was 37.91 years old (SD = 5.51), that of the children was 7.85 years old (SD = 1.58). Only 5 children were preschoolers, whereas the others were all elementary school students. The children ranged in age from 5 to 10 years old. Most of the parents had had experience of using smartphones or tablet PCs (82%); nevertheless, they had had relatively less experience of seeing AR (24%) and using AR (12%).

2.3. Procedure and data collection

Each child–parent pair was required to freely read the AR picture book using the tablet PC (iPads were used in this study). The average reading time was approximately 20 min. A researcher briefly described how to use the AR picture book before the activity. When the reading activity began, the researcher was not allowed to intervene in the participants' reading process, such as offering technical guidance. The participants all acknowledged that they were involved in a research project and formally agreed to be videotaped for the purpose of research analysis. All of the events including operation behaviors between participants during the reading process were videotaped for further data analysis. When the activity finished, each child was interviewed to reflect upon his/her learning experience while reading the AR picture book. The main purpose of the interview was to investigate the children's cognitive attainment after reading the book. Because children aged 5–10 may not be able to respond well to a paper-and-pencil test about art, the interview method was adopted to understand their learning outcomes regarding the comprehension of art. The following are the main interview questions:

1. What AR elements did you see in this book? Can you describe their appearance? Do they have any distinguishing features?
2. Do you have any other thoughts about the content presented by the AR picture book? For example, the story you have read, the details of the book you have seen, or any interesting things that you want to share with us.

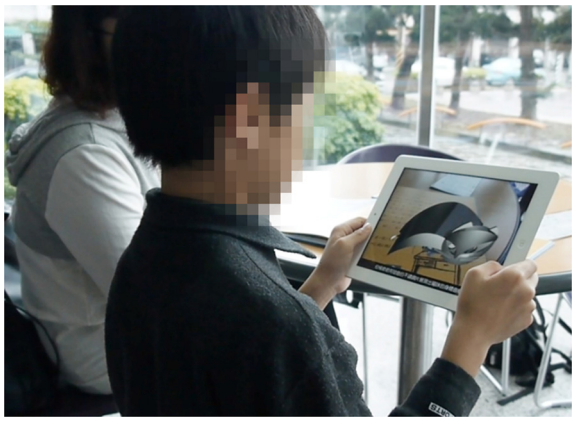

Fig. 1. Demonstration of the use of the AR picture book in this study.

2.4. Coding scheme and data analysis

2.4.1. Behavioral patterns

A preliminary review of the recorded video data revealed four major types of child–parent shared reading behaviors among the participants, as shown in Table 1, including (1) narrating (by the parents) or reading (by the children) behaviors, (2) interaction-oriented behaviors regarding the content of the book, (3) interaction-oriented behaviors regarding the AR elements, and (4) behaviors of operating the AR book. Examining the details of the interaction-oriented behaviors in greater depth, several specific reading actions such as pointing to pictures or commenting on pictures were exhibited by the children and their parents. The pairs also interacted while reading the AR picture book. For example, the parents provided hints or raised questions about the pictures to which the children responded. Accordingly, based on the parental reading behaviors addressed by previous studies (e.g., Arnold et al., 1994; Cronan et al., 1996) and the PEER model of dialogic reading (Zevenbergen & Whitehurst, 2003), this study developed a coding scheme to reveal the possible behaviors of AR picture book reading. The behaviors of the children and their parents were observed and categorized by the codes listed in Table 1. The coding scheme mainly consists of eight major behaviors of the participants (i.e., PN, PIC, PIAR, POAR, CR, CIC, CIAR, COAR) which include several specific behaviors. For instance, the parents' interaction-oriented behaviors regarding the content of the book (PIC) consists of six specific behaviors which are pointing (p2), commenting (p3), prompting (p4), evaluating (p5), expanding (p6), and repeating (p7), presented in Table 1. Due to the fact that the behaviors of parents' disciplining (p10), children's intervening in operation (ca10) and distraction from the activity (c11) are not directly linked to the AR picture book reading behaviors, they are categorized as other behaviors.

Through the content analysis of the recorded video data, the researcher first reviewed how the children and their parents behaved. For each time span of 5 s, the behaviors of the participants were chronologically coded according to the specific behaviors defined in Table 1. A sample of the coding is presented in Appendix 1. It was considered that some significant actions of the participants may be neglected by coding the behaviors over a longer time span, such as 10 s. However, in a short time span of 1 s, the actions of the participants are difficult to observe. After some pilot trials, 5 s for the coding time span was determined as being sufficient for properly representing the child–parent reading behaviors. Another research assistant was involved in the coding, and the inter-rater reliability of the codes was verified as being

Table 1
The coding scheme of the AR book reading behaviors of children and parents.

Major behavior	Code	Specific behavior	Description
Parent			
Parent's narrating behaviors (PN)	p1	Narrating	The parent narrates the book for the child.
Parent's interaction-oriented behaviors regarding the content of the book (PIC)	p2	Pointing	The parent points at the details of the pictures.
	p3	Commenting	The parent makes comments on the pictures or the content of the book.
	p4	Prompting	The parent provides hints or questions the child on the pictures or the content of the book.
	p5	Evaluating	The parent evaluates the child's responses or comments on the book.
	p6	Expanding	The parent expands on the child's responses and provides additional information regarding the pictures or the content of the book.
	p7	Repeating	The parent encourages the child to repeat the additional information to make sure that the child has understood it.
Parent's interaction-oriented behaviors regarding the AR elements (PIAR)	pa2	Pointing (AR)	The parent points at the details of the AR elements.
	pa3	Commenting (AR)	The parent makes comments on the AR elements.
	pa4	Prompting (AR)	The parent provides hints or questions the child on the AR elements.
	pa5	Evaluating (AR)	The parent evaluates the child's responses or comments on the AR elements.
	pa6	Expanding (AR)	The parent expands on the child's responses and provides additional information regarding the AR elements.
	pa7	Repeating (AR)	The parent encourages the child to repeat the additional information to make sure they have understood it.
Parent's behaviors of operating the AR book (POAR)	pa8	Controlling	The parent controls the operation of the AR book.
	pa9	Turning	The parent turns the mobile device or the book to view the different dimensions of the AR elements.
Other	p10	Disciplining	The parent corrects the child's behavior to draw him/her back to the activity.
Children			
Child's reading behaviors (CR)	c1	Reading	The child reads the book him/herself.
Child's interaction-oriented behaviors regarding the content of the book (CIC)	c2	Pointing	The child points at the details of the pictures.
	c3	Commenting	The child makes comments on the pictures or the content of the book.
	c4	Questioning	The child asks questions about the pictures or the content of the book.
	c5	Responding	The child responds to the parent's questions or comments on the book.
	c6	Repeating	The child repeats the parent's additional information regarding the pictures or the content of the book.
Child's interaction-oriented behaviors regarding the AR elements (CIAR)	ca2	Pointing (AR)	The child points at the details of the AR elements.
	ca3	Commenting (AR)	The child makes comments on the AR elements.
	ca4	Questioning (AR)	The child asks questions about the AR elements.
	ca5	Responding (AR)	The child responds to the parent's questions or comments on the AR elements.
	ca6	Repeating (AR)	The child repeats the parent's additional information regarding the AR elements.
Child's behaviors of operating the AR book (COAR)	ca7	Controlling	The child controls the operation of the AR book.
	ca8	Turning	The child turns the mobile device or the book to view the different dimensions of the AR elements.
	ca9	Inspecting	The child inspects the AR elements and tries to touch it.
Other	ca10	Intervening	The child intervenes in the parent's operation of the AR book.
	c11	Distraction	The child is distracted during the process of reading.

satisfactory (Cohen's kappa value = 0.82, $p < 0.000$). Based on the coded data, the reports of the quantitative content analysis may depict how the participants behaved during the learning activity.

To further understand their possible behavioral patterns, cluster analysis was employed. The eight major behaviors of the participants (i.e., PN, PIC, PIAR, POAR, CR, CIC, CIAR, COAR, as listed in Table 1), but excluding the "other" behaviors, are the indicators for the cluster analysis. A two-phase cluster analysis was then adopted to ensure the accuracy of the clusters. Therefore, a Hierarchical Cluster Analysis with the Ward Method was first conducted to determine the appropriate number of clusters according to its dendrogram. K-Mean Cluster Analysis was then conducted according to the cluster number. K-Mean Cluster Analysis successfully identified features of the certain groups of children and parents' reading behaviors when engaged in AR-related learning.

2.4.2. Cognitive attainment

The interviews for understanding the children's cognitive attainment after the AR picture book reading were conducted in Chinese and audio recorded. The researcher fully transcribed all of the interview data to verbatim text in Chinese. These verbatim transcripts were then examined and analyzed according to the representation of increasing cognitive complexity, including two types of codes: *appearance description* and *extensive description*. In general, when the children responded to the interview questions, some could merely describe the AR artistic work they had seen (*appearance description,* considered as low-level cognitive attainment), while others could provide extensive thoughts on the AR artistic work or the content of the book (*extensive description,* regarded as high-level cognitive attainment), whereas others expressed a mixture of these two descriptions with varying proportions of the two. That is, these two codes were generated from the children's responses to the interview questions. The children's interview responses were therefore coded according to these two types of cognitive attainment. For example, a child's statement of "I saw a cat with a blended body; it was also made of iron" was coded as the *appearance description* category with two frequency counts. Specifically, the utterance of "a cat with a blended body" was coded as one count, and the utterance of "it was also made of iron" was coded as the other count. Another example of a child's statement, "I know that the artistic meaning of the engraving is about Taiwanese folk opera," was coded as the *extensive description* category with one frequency count. Finally, the frequencies were calculated for further analysis. The codes rated by the researcher and a research assistant were analyzed through a statistical measure of inter-rater agreement, with the results indicating high reliability of the codes (Cohen's kappa value = 0.91, $p < 0.000$). The details of the coding scheme of the children's cognitive attainment are presented in Table 2.

3. Results

3.1. Child–parent reading behaviors

To understand the participants' AR book reading behaviors, the video recordings were chronologically analyzed in 5-s time slots according to the specific behavior codes listed in Table 1. Through the quantitative content analysis, a total of 7468 coded behaviors were generated. The count and distribution of the coded behaviors are presented in Table 3. Examination of the coded behaviors of the parents revealed that narrating the book for the children (p1, count = 1015, 13.59%) and controlling the AR book (pa8, count = 658, 8.81%) was the most frequent behavior. As for the coded behaviors of the children, similarly, the children frequently read the book themselves (c1, count = 2084, 27.91%) and controlled the AR book (ca7, count = 1353, 18.12%). The above results also indicate that the children were more involved than their parents in reading and controlling the AR book.

When focusing on the specific behaviors of AR book operation, a few actions such as turning the book or the mobile device by the parent (pa9, count = 126, 1.69%) and by the child (ca8, count = 218, 2.92%) were found. The children were also likely to inspect the AR elements and try to touch them (ca9, count = 107, 1.43%). With regard to the behaviors that may be negatively related to the learning activity, it was found that the children rarely attempted to interrupt their parents' operation of the AR picture book (ca10, count = 28, 0.37%). However, to a certain degree, some children were distracted during the AR picture book reading (c11, count = 157, 2.10%). That is, compared with the children's interrupting behavior, the children's distraction is more noticeable.

Although the count of interaction-oriented behaviors is relatively low compared with the behaviors of reading and controlling the AR book, commenting on the pictures (p3, count = 175, 2.34%) or the AR elements (pa3, count = 133, 1.78%) by the parents was frequent, as was prompting about the pictures (p4, count = 276, 2.70%) or the AR elements (pa4, count = 220, 2.95%). Table 3 also shows that to some extent, the children could respond to their parents' prompts about the pictures (c5, count = 212, 2.84%) and the AR elements (ca5, count = 108, 1.45%). It should be noted that throughout the entire activity, the parents did not encourage their children to repeat the extensive information about the book (p7) or the AR elements (pa7) they offered. As a result, the children did not have opportunities to repeat their parents' additional information about the book (c6) or the AR elements (ca6). In other words, the *Repeat* strategy in the PEER model of dialogic reading was not represented by the child–parent pairs in this study. The approach of dialogic reading was originally designed to help adults to read picture books with children aged 4–5. Because the children in this study had an average age of 7, their parents may not be used to or may not find it necessary to encourage their children to repeat the additional information.

Table 2
The coding scheme of the children's cognitive attainment.

Code	Description	Example
Appearance description	The child simply describes the appearance of the AR elements he/she saw.	*"I saw a phoenix with five metal slices sticking together."* *"I saw an art work with two split stones of green."* *"I saw a cat with a blended body."*
Extensive description	The child can explain the AR elements he/she saw or use his/her imagination when describing them.	*"I think the engraving is awesome because nothing is left blank; it is all filled in with black and yellow."* *"The grain of TAROCO canyon looks like the surface of the earth."* *"I can image that the phoenix will flutter its wings and the cat will blink its eyes."*

Table 3
Count of codes for reading behaviors.

Code	Specific behavior	Count	Percentage
Parent			
p1	**Parent narrates the book for the child**	**1015**	**13.59%**
p2	Pointing at the details of the picture	27	0.36%
p3	Commenting on the pictures	175	2.34%
p4	Prompting about the pictures	276	3.70%
p5	Evaluating the child's responses	75	1.06%
p6	Expanding the child's responses	21	0.28%
p7	Encouraging the child to repeat	0	0%
pa2	Pointing at the details of the AR elements	62	0.83%
pa3	Commenting on the AR elements	133	1.78%
pa4	Prompting about the AR elements	220	2.95%
pa5	Evaluating the child's responses (AR)	66	0.88%
pa6	Expanding the child's responses (AR)	3	0.04%
pa7	Encouraging the child to repeat (AR)	0	0%
pa8	**Controlling the AR book**	**658**	**8.81%**
pa9	Turning the device	126	1.69%
p10	Disciplining	75	1.00%
Children			
c1	**Children read themselves**	**2084**	**27.91%**
c2	Pointing at the details of the pictures	11	0.15%
c3	Commenting on the pictures	46	0.62%
c4	Questioning about the pictures	28	0.37%
c5	Responding to the parent's prompts	212	2.84%
c6	Repeating parent's additional information	0	0%
ca2	Pointing at the details of the AR elements	16	0.21%
ca3	Commenting on the AR elements	117	1.57%
ca4	Questioning about the AR elements	47	0.63%
ca5	Responding to the parent's prompts (AR)	108	1.45%
ca6	Repeating the parent's additional information (AR)	0	0%
ca7	**Children control the AR book**	**1353**	**18.12%**
ca8	Turning the device	218	2.92%
ca9	Inspecting the AR elements	107	1.43%
ca10	Intervening in the parent's operation	28	0.37%
c11	Distraction	157	2.10%
Total		**7468**	**100%**

Note: The highest and second highest counts of the reading behaviors for the children and the parents are marked in bold respectively.

3.2. Children's cognitive attainment

According to the coding scheme in Table 2, the utterances of the children's interview responses were coded to represent their cognitive attainment after reading the AR picture book. The results in Table 4 show that a total of 160 codes are categorized as *appearance description*. The children on average displayed 4.85 segments of description about the appearance of the AR elements. By contrast, there are only 47 codes in the category of *extensive description*, as the children seldom provided descriptions when explaining the AR elements they saw or used their imagination to describe them (mean = 1.42). That is, the children generally showed a low level of cognitive attainment after the reading activity in light of their interview responses.

3.3. The relationships between reading behaviors and cognitive attainment

In this step of the data analysis, the aim is to gain an initial understanding of the relationships between the major reading behaviors and the children's cognitive attainment through Pearson correlation analysis. As a result, based on the categories listed in Table 1, the frequencies of similar specific behaviors were summed. For instance, the count of the parents' interaction-oriented behaviors related to reading the content of the book such as pointing at the details of the pictures (p2), commenting on the pictures (p3), prompting about the pictures (p4), evaluating the child's responses (p5), expanding the child's responses (p6), and encouraging the child to repeat their parent's expansion (p7), were summed to produce a measure of the count of the major behaviors, named Parents' interaction-oriented behaviors related to the content of the book (PIC). In addition, it should be noted that the behaviors with the codes p10 (Disciplining), ca10 (Intervening in parents' operation), and c11 (Distraction) are not major behaviors of the AR picture book reading. Therefore, these three types of behaviors were not included in the correlation analysis.

The results of the associations between the major reading behaviors and cognitive attainment are revealed in Table 5. It is shown that the children's cognitive attainment regarding appearance description ability has relationships with their behaviors of reading the book ($r = 0.52$, $p < 0.01$), operating the AR picture book ($r = 0.38$, $p < 0.05$), interacting with their parents about the content of the book ($r = 0.53$, $p < 0.01$), and interacting with their parents about the AR elements ($r = 0.49$, $p < 0.01$). As far as the children's high level of cognitive attainment was concerned, only the behaviors of their interaction with their parents about the content of the book ($r = 0.45$, $p < 0.01$) and about the AR elements ($r = 0.35$, $p < 0.05$) were related to their production of extensive description. That is, when the children were more actively involved in the interactive process of the AR picture book reading with their parents, they displayed more cognitive attainment (both in terms of appearance description and extensive description). However, when the children actively read and operated the AR book themselves, they may have attained cognition regarding the appearance of the AR elements (*appearance description*) rather than being stimulated to think deeply or even use their imagination (*extensive description*).

Table 4
Count of codes for children's cognitive attainment.

	Total count	Mean (SD)	Max	Min
Appearance Description	160	4.85 (3.09)	11	0
Extensive Description	47	1.42 (1.77)	6	0

With regard to the role of the parents, it was found that the parents' interaction-oriented behaviors regarding the content of the book ($r = 0.45$, $p < 0.01$) and the AR elements ($r = 0.35$, $p < 0.05$) were related to the children's expression of appearance description. Similarly, it was found that the parents' interaction with their children regarding the content of the book ($r = 0.50$, $p < 0.01$) and the AR elements ($r = 0.39$, $p < 0.05$) were related with the children's production of extensive description. These results imply the importance of the interaction-oriented behaviors of parents. Moreover, it is interesting to note that the frequencies of parents' narrating for the children or operating the AR picture book were not significantly correlated with the children's cognitive attainment.

3.4. The child–parent reading behavioral patterns

The children's and parents' reading behavioral patterns when engaged in the process of reading the AR picture book were explored using cluster analysis. The cluster analysis was conducted based on the eight major reading behaviors of the children and parents listed in Table 1. Through the two-phase cluster analysis described previously, four groups/clusters of child–parent reading behaviors were identified, as presented in Table 6. Group 1 ($n = 7$) presents the highest count of the parents' behaviors of narrating (PN) and operating (POAR) the AR picture book. The parents in group 1 showed a significantly greater tendency to narrate for their children ($F = 24.19$, $p < 0.001$) than the pairs in groups 3 and 4, and, compared with the reading behaviors of the pairs in group 4, the group 1 parents' operation of the AR picture book for their children was much more frequent ($F = 3.10$, $p < 0.05$). The results reflect that the parents in group 1 behaved as dominators in managing the reading process, particularly in narrating and controlling the AR picture book for their children. The behaviors of the parents in group 1 might constrain their children's involvement in reading and operating the AR picture book. It is thus proposed to characterize the reading behavioral patterns of group 1 as "*parent as dominator*." On the contrary, the highest frequencies of the children's behaviors of reading (CR) and operating (COAR) the AR book are shown in group 4 ($n = 9$). The ANOVA post hoc tests also indicate that the count of the children's behavior of reading ($F = 28.34$, $p < 0.001$) is statistically higher than that of the pairs in the other three groups. In addition, the children's count of operating the AR book ($F = 3.12$, $p < 0.05$) in group 4 is significantly higher than that of their counterparts in group 1. In contrast to the behaviors of the children in group 1, the children in group 4 dominated the reading and operation of the AR picture book. The parents in group 4 showed relatively less involvement in narrating and controlling the AR picture book. The reading behavioral pattern of group 4 is accordingly featured as "*child as dominator*."

In addition, the participants in group 2 ($n = 3$), though including only a small number of child–parent pairs, expressed a significantly higher count of parents' interaction-oriented behaviors regarding the content of the book (PIC, $F = 16.10$, $p < 0.001$) and the AR elements (PIAR, $F = 5.75$, $p < 0.05$) than the pairs in groups 3 and 4. In addition, the group 2 pairs displayed higher count of children's interaction-oriented behaviors regarding the content of the book (CIC, $F = 6.96$, $p < 0.01$) and the AR elements (CIAR, $F = 4.00$, $p < 0.05$) than those in group 3. That is, the children and their parents in group 2 expressed a significantly greater tendency to reciprocally interact with each other (e.g., the parents prompted about the AR elements and then the children responded to the prompts) when reading the AR picture book than the other groups. Due to the greater degree of child–parent interactive reading behaviors found for group 2, this group is characterized as demonstrating "*communicative child–parent pair*" behavior in this study.

Both the parents and children in group 3 ($n = 14$) exhibited moderate levels of reading (or parental narrating) and operating the AR picture book. However, they showed the lowest count of interaction-oriented behaviors, such as the parents' interaction-oriented behaviors regarding the content of the book (PIC) and the AR elements (PIAR) and the children's interaction-oriented behaviors regarding the content of the book (CIC) and the AR elements (CIAR). These results imply that the participants in group 3 may have shared time reading and operating the AR picture book, but they rarely interacted with each other, the children rarely asked questions about the AR elements, and their parents correspondingly offered few responses to their questions. Therefore, group 3 is identified in this study as exhibiting "*low communicative child–parent pair*" behavior.

Table 5
The correlations between reading behaviors and cognitive attainment ($n = 33$).

	Appearance description	Extensive description
PN	−0.20	−0.11
PIC	0.45**	0.50**
PIAR	0.35*	0.39*
POAR	−0.21	−0.16
CR	0.52**	0.20
CIC	0.53**	0.45**
CIAR	0.49**	0.35*
COAR	0.38*	0.21

**$p < 0.01$, *$p < 0.05$.
PN: Parent's narrating behaviors, PIC: Parent's interaction-oriented behaviors regarding the content of the book, PIAR: Parent's interaction-oriented behaviors regarding the AR elements, POAR: Parent's behaviors of operating the AR book, CR: Child's reading behaviors, CIC: Child's interaction-oriented behaviors regarding the content of the book, CIAR: Child's interaction-oriented behaviors regarding the AR elements, COAR: Child's behaviors of operating the AR book.

Table 6
The cluster analysis of the child–parent reading behaviors.

	Reading behaviors					
	Group 1 ($n = 7$): *parent as dominator* (mean/SD)	Group 2 ($n = 3$): *communicative child–parent pair* (mean/SD)	Group 3 ($n = 14$): *low communicative child–parent pair* (mean/SD)	Group 4 ($n = 9$): *child as dominator* (mean/SD)	F value (ANOVA)	*Post hoc* tests (Scheffé tests)
PN	**82.43/33.98**	68.33/10.41	13.86/19.31	4.33/13.00	24.19***	1 > 3, 1 > 4 2 > 3, 2 > 4
PIC	19.29/9.16	**65.33/35.81**	*3.93/5.27*	21.33/17.07	16.10***	2 > 1, 2 > 3, 2 > 4
PIAR	16.00/8.98	**33.00/12.49**	*10.36/8.67*	14.67/10.37	5.75*	2 > 3, 2 > 4
POAR	**39.86/31.86**	15.00/15.52	26.86/30.05	9.33/14.69	3.10*	1 > 4
CR	1.14/2.03	39.33/27.97	50.57/30.39	**138.89/42.61**	28.34***	4 > 1, 4 > 2, 4 > 3 3 > 1
CIC	10.00/5.86	**26.00/19.00**	*2.79/4.62*	12.22/10.53	6.96**	2 > 3
CIAR	9.57/8.58	**19.67/15.94**	*4.64/4.50*	10.78/6.36	4.00*	2 > 3
COAR	29.57/32.88	51.00/10.15	44.79/35.73	**76.78/29.40**	3.12*	4 > 1

***$p < 0.001$.
PN: Parent's narrating behaviors, PIC: Parent's interaction-oriented behaviors regarding the content of the book, PIAR: Parent's interaction-oriented behaviors regarding the AR elements, POAR: Parent's behaviors of operating the AR book, CR: Child's reading behaviors, CIC: Child's interaction-oriented behaviors regarding the content of the book, CIAR: Child's interaction-oriented behaviors regarding the AR elements, COAR: Child's behaviors of operating the AR book.
Note: The data marked in bold and italics is the significant indicators for identifying the distinct cluster patterns.

3.5. The differences in cognitive attainment for the different child–parent behavioral patterns

Because the associations between the child–parent reading behaviors and the children's cognitive attainment were identified in Table 5, it may be interesting to understand the differences in the four cluster patterns of the child–parent reading behaviors regarding the children's cognitive attainment. Therefore, an analysis of variance (ANOVA) examining the inter-cluster differences of reading behaviors across the two indicators of cognitive attainment (i.e., *appearance description* and *extensive description*) was implemented. Table 7 presents the mean values and standard deviations of the indicators of cognitive attainment for each cluster as well as comparisons of the post hoc tests (Scheffé tests). It was found that there were significant differences among the clusters for the *appearance description* and *extensive description* of the children's cognitive attainment. To be more specific, group 2 (*communicative child–parent pair*) exhibited a significantly higher count of *appearance description* for the AR content than group 1 (*parent as dominator*) and group 3 (*low communicative child–parent pair*); moreover, group 4 (*children as dominator*) also outperformed group 1 and group 3. Regarding the children's *extensive description* of the AR content, group 2 (*communicative child–parent pair*) showed significantly higher count than the other three groups. The results reflect that in general, the children in group 2 (*communicative child–parent pair*) and group 4 (*children as dominator*) displayed better cognitive attainment regarding *appearance description* after the learning activity. In terms of *extensive description,* the children in group 2 (*communicative child–parent pair*) exhibited better learning outcomes than the others. In other words, the results may highlight the benefits of the behavioral patterns of group 2 (*communicative child–parent pair*) in achieving extensive or higher-level cognition.

4. Discussion

In the AR book shared reading activity in this study, it was found that, for the most part, the children could describe the appearance of the artistic work (*appearance description*). However, they exhibited few examples of descriptions explaining the artistic work or using their imagination to explain the content of the book (*extensive description*). Because the associations between children's behaviors when operating an AR book and learning performance have been suggested by earlier studies (e.g., Hornecker & Dünser, 2009), researchers may speculate on which reading behaviors of the child–parent pairs might foster the children's cognitive attainment, particularly at a high level.

According to the correlation analysis, when a parent and child engage in AR picture book reading, behaving in an interactive way may be beneficial for the child's learning outcomes (i.e., *appearance description* and *extensive description*). The pairs' behaviors of reading (by the children) or narrating (by the parents) and operating the AR picture book may not play an important role in the child's high-level cognitive attainment (i.e., extensive description). The child's reading behaviors and operation of the AR picture book have relationships with their having a low level of cognitive attainment (i.e., appearance description). This finding may imply that when children read or control the AR picture book themselves rather than have their parents narrate or operate it for them, they may engage in more cognitive operations regarding the descriptive appearance of the artistic work. The benefits of the narration and operation of the parents, however, may not be helpful for obtaining a higher level of cognitive attainment during the process of the AR picture book reading by the child–parent pairs.

The results of the behavioral pattern analysis correspond to the above argument. Cluster analysis revealed four patterns of AR picture book reading behaviors demonstrated by the participants: "*parent as dominator*", "*child as dominator*", "*communicative child–parent pair*", and "*low communicative child–parent pair*". The children in the "*communicative child–parent pair*" and "*children as dominator*" groups

Table 7
The comparisons of different reading behaviors by cognitive attainment.

	Appearance description	Extensive description
Group 1: *parent as dominator* ($n = 7$), Mean (SD)	2.71 (1.25)	0.00 (0.00)
Group 2: *communicative child–parent pair* ($n = 3$), Mean (SD)	8.33 (1.53)	5.00 (1.00)
Group 3: *low communicative child–parent pair* ($n = 14$), Mean (SD)	3.57 (2.71)	1.21 (1.42)
Group 4: *child as dominator* ($n = 9$), Mean (SD)	7.33 (2.50)	1.67 (1.50)
F value (ANOVA)	8.89***	11.20***
Post hoc tests (Scheffé tests)	2 > 1, 2 > 3, 4 > 1, 4 > 3	2 > 1, 2 > 3, 2 > 4

***$p < 0.001$.

presented better learning outcomes, particularly in terms of high-level cognitive attainment shown by those in the "*communicative child–parent pair*" group. In other words, the behavioral patterns of the groups "*child as dominator*" and "*communicative child–parent pair*" may be an appropriate model for child–parent pairs when sharing AR picture book reading in the future. It is thus argued that by adopting these two types of behavioral patterns, learners' comprehension of book content may be enhanced (Dias, 2009).

Accordingly, it is proposed that children should be empowered with the autonomy to master the entire process of AR book reading (i.e., reading the content of an AR picture book and operating a mobile device to explore virtual elements blended with it). In terms of children's domination, it is suggested that their exploration of AR picture books emphasizes the actions of turning the mobile device or the book to view the different dimensions of the AR elements as well as inspecting the AR elements and trying to touch them. As for the appropriate role of parents in shared reading, it is suggested that they promote communication with their children but do not intervene in operating the book (e.g., controlling or turning a mobile device to see the AR elements) too much. In this case, this study proffers an alternative approach for parents to adopt, which is to demonstrate and guide their children in the proper use of a mobile device to explore AR elements overlapped on the paper book, particularly in the initial stage of the learning activity.

In addition, the merits of parental reading behaviors (e.g., pointing to pictures, labeling and commenting on pictures, or asking questions about pictures or stories) for children's language development have been well documented (Arnold et al., 1994; Cronan et al., 1996). Research has also reported that the dialogic reading approach incorporated in e-book reading is advantageous for child–parent collaborative learning (Tseng et al., 2012) and that more interaction while reading an AR book leads to the children's improved ability to recall story events (Hornecker & Dünser, 2009). Corresponding to these previous findings, in the present study, it is suggested that parents show their interaction-oriented actions such as pointing, commenting, and prompting when reading an AR picture book together with their children. It is also proposed that parents should pay attention to their children's follow-up responses and make efforts to evaluate those responses and further provide additional information. If the target subject children are of a lower age (e.g., 4–5 years old), the final stage of the PEER model of dialogic reading (Zevenbergen & Whitehurst, 2003), which encourages children to repeat their parents' additional information, could also be included in the child–parent communication.

For future pedagogical applications of AR picture books, this study considers that an AR book system should include guidance, which is the suggested child–parent reading approaches mentioned above, for parents to read with their children. The design of the guidance could be considered to integrate prompts into the AR book system for reminding children and parents to interact with each other, for example, offering a question "What does the sculpture look like?" or "Why does YuYu Yang want to make this work?" for users to think and discuss thoroughly. The findings of this study indicated that, commonly, the cognitive attainment of the children was not satisfied with high level. By the scaffolding of child–parent interaction, the children might be assisted to achieve higher level of cognitive attainment regarding the learning materials. The prompts can also consist of the messages of the appropriate AR book operation, for example, providing a prompt of turning the mobile device or the book to acquire more dimensions of the AR elements and transferring dominance of AR book operation to children. Through the guidance integrated in the AR book system, it may help those parents without knowledge of shared reading strategies or with intention to dominate the shared reading process to involve in child–parent shared AR book reading appropriately and further foster the learning outcomes of their children.

Someone may suspect whether the identified child–parent behavioral patterns found in this study could be also applicable to the child–parent learning process performed with ordinary paper books. In general, it might be the case. However, similar behavioral patterns may result in different degrees of cognitive attainment between traditional book reading and AR book reading. That is, the virtual information provided in the AR picture book was designed to scaffold children and parents to read the book. Compared with paper book reading, there are more learning elements to observe and discuss in more depth in AR book reading context. Therefore, it is supposed that the child–parent interaction in the AR book reading context would be more sophisticated than that in the traditional book reading context. This study also contends that more thorough communication between children and parents may contribute to higher learning performance of children. Nevertheless, the findings of this study showed that, compared to reading or narrating behaviors, the interaction-oriented behaviors for engaging in the AR learning activity were relatively rare. Apparently, the suggestions for integrating prompting guidance into an AR book system may be beneficial for the enhancement of child–parent interaction. For the AR picture book with the topics of art, those parents without background knowledge of art probably are capable of introducing their children to explore the ideas of artistry and motivating the art appreciation of their children with the aid of the guidance design. Moreover, for those children only having surface understanding about the main idea of the book, the guidance design may improve their comprehension of the book. This is what the implications of the findings for future applications of AR books in education are.

In addition, someone may argue that some confounding factors, such as the duration of reading process or the age of the children, possibly affect the findings of the relationships between cognitive attainment and behavioral patterns. However, through further statistical analyses, it was found that how long the child–parent pairs read was not related to the performance of the children. Also, there was no difference of the children age in the cognitive attainment regarding artistry. In other words, the results in this study are reliable and could be a model of child–parent shared AR book reading.

5. Conclusion

The significant influences of AR technology on education are likely to gradually become more considerable; however, studies that present a thorough exploration of AR-related learning, especially the involvement of children and their parents in learning activities, remain limited. This study endeavors to discover the behavioral patterns of children and their parents when child–parent pairs collaboratively learn within the context of reading an AR picture book and subsequently explores the children's learning performance by examining their cognitive attainment regarding artistry. The relationships between the four identical child–parent reading behavioral patterns and the cognitive attainment of the children were established. The behaviors of dominating the reading process by the children and acting in a communicative way by the parents were found as beneficial for children's learning performance. According to the findings, this study provided the implications for future pedagogical applications. For example, an AR book system can be integrated a prompting guidance for promoting children and parents to interact and transferring the dominance of the AR book reading to children.

Despite the suggestion of the interaction models for child–parent pairs to share reading with an AR picture book, investigation into the factors that may attribute to these child–parent reading behaviors is limited. For example, the children's or parents' conceptions or beliefs of AR learning are expected to link to how they behave when engaging in AR learning. Because several studies have identified the relationships between learners' conceptions of learning and their approaches to learning (e.g., Cheng & Tsai, 2012; Ellis, Steed, & Applebee, 2006), learners' conceptions of AR learning may consequently influence how they behave in AR-related learning environments. Moreover, the general cognitive levels of children and the nature of the relationship with their parents were not investigated in this study. Future work could consider those factors and further examine their role in child–parent shared AR book reading. In addition, parental variables such as parent reading literacy or parent reading beliefs have been documented as playing an important role in children's picture book reading. It is reasonable to assume that these parental variables may have an impact on children's reading behaviors with paper books. Following the aforementioned suggestions for future work, the features of child–parent shared AR picture book reading may be unveiled, further contributing to their practical application for educational purposes.

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Appendix 1. A sample of the coding work.

Timecode (min:sec)	Context	Code
01:00	The boy sits beside his mother and listens to her narration of the AR picture book.	p1 (narrating)
01:05	The boy continues to listen to his mother's narration of the AR picture book.	p1 (narrating)
01:10	The mother points to the graphics of the black cats in the book while she continues to narrate.	p2 (pointing)
01:15	During the narration, the mother raises a question about the content of the book: "Why is it named a street of cats?"	p4 (prompting)
01:20	The boy answers his mother's question: "There are many cats on the street."	c5 (responding)
01:25	The mother continues to narrate the book.	p1 (narrating)
01:30	The boy listens to his mother's narration of the book.	p1 (narrating)
01:35	The mother picks up the iPad and focuses on the AR picture book with the camera on the iPad.	pa8 (controlling)
01:40	When the AR element pops up on the screen of the iPad, the mother says: "Wow! It is so cool."	pa3 (commenting)
01:45	The mother continues to control the AR picture book and the boy looks at the screen with the iPad.	pa8 (controlling)
01:50	With the mother controlling the AR book, they continue to look at the AR element on the iPad.	pa8 (controlling)
01:55	The mother provides a hint to remind her child: "What does the AR element look like?"	pa4 (prompting)
02:00	The boy responds to his mother: "It looks like a white cat."	ca5 (responding)
02:05	The mother starts to turn the iPad to see the different aspects of the AR artistic work.	pa9 (turning)
02:10	The mother continues to turn the iPad.	pa9 (turning)
02:15	The mother tries to turn the paper picture book.	pa9 (turning)
02:20	When the mother continues to turn the AR book, the boy says: "I see the big eyes on the cat."	ca3 (commenting)
02:25	The mother continues to control the AR picture book.	pa8 (controlling)
02:30	The mother puts the iPad down and narrates the content of the picture book for her child.	p1 (narrating)

Note: When two or more actions occurred simultaneously, a higher level of reading behavior was coded. For example, compared with the narrating behavior, the interaction-oriented behaviors were deemed to represent a higher level of reading behavior.

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