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Analyzing Children's Viewing Behaviors in Science Demonstrations with and Without Interactive E-Book Support

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Abstract

This study explored the impact of interactive e-books on the viewing behaviors of children in science demonstrations at museums. To conduct this study, an interactive e-book on a pendulum experiment was developed and integrated into a physical science demonstration at a museum. Two scientific demonstrations were conducted in this study. The first demonstration was conducted using the conventional science demonstration method, without integrating the interactive e-book into the demonstration. The second was a science demonstration with an integrated interactive e-book. The study analyzed and compared the children's learning motivation, viewing behaviors, and knowledge gained in both demonstrations. The results showed that the different science demonstrations did not significantly affect the children's current knowledge gain or learning motivation. However, the sequence analysis revealed that in the conventional science demonstration without the interactive e-book, children were more engaged in observing the science demonstration, experiment, and instrument operation and interacting with neighboring viewers. In contrast, in the science demonstration with the integration of the interactive e-book, children had more physical involvement, including pointing at the answers in the e-book, swinging their arms with the pendulum animation, and nodding when confused about the expected results. In addition, the children who joined the demonstration with the interactive e-book made more attempts to learn about procedural knowledge. These results demonstrated that both learning modes have similar learning effects on children, indicating the feasibility of the two learning modes. Furthermore, the results revealed that children's needs might differ when engaged in different modes of science demonstrations; for example, conventional modes need more support from companions, whereas e-book modes need more children's physical participation.

Keywords Science demonstration · Behavioral analysis · Physical involvement · Interactive e-books

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Introduction

Science education in museums offers the public opportunities for emotional and cognitive engagement beyond formal education (Dawson, 2014; Falk & Dierking, 2012). Museums commonly use science demonstrations to convey scientific knowledge to visitors. These demonstrations are typically led by instructors who provide narratives, stories, and hands-on equipment (Kumar & Dunn, 2018; Maricic et al., 2019). They provide an enjoyable experience that is either entertaining or artistic (Burns et al., 2003), and have been recognized as an effective model for the next generation of science learning (Price et al., 2015a, b; Rainey et al., 2018). This model allows the public to observe, investigate, explain, or predict scientific phenomena from a scientist's perspective and is a successful phenomenon-based learning tool (Kaldaras et al., 2021; Like et al., 2019; Wang &

Liu, 2022). Therefore, it meets individuals' needs and curiosity for scientific knowledge while helping them develop knowledge and literacy in science (Stocklmayer et al., 2010). Because of the connection between science demonstrations and the public's life context, it has aroused the public's interest in science and motivation to learn (Howell et al., 2023; Potvin & Hasni, 2014).

However, researchers have found that some of the scientific content and phenomena are abstract, and even through demonstrations, changes in chemical structures or physical movement patterns may not be easily observed or understood by the public (Cheung, 2014; Sumers et al., 2023). This research indicates that despite the use of science demonstrations, the public's understanding of scientific knowledge is still limited, hindering the achievement of educational goals (Kerby et al., 2018; Rose, 2018). Moreover, scholars have argued that the mode of science demonstrations often lacks interactivity and creates an imbalance of power between the instructor and the public (McCrory, 2013; Milne & Otieno, 2007); researchers have argued that interaction between the public, the instructor, and the scientific knowledge needs to be taken into account in order to satisfy a highly interactive science demonstration (Howell et al., 2023; Reiser et al., 2021). To address this gap, museums should focus on developing technology-assisted science demonstrations that meet the public's expectations and learning experiences (Gronemann, 2017).

In recent years, technology-enhanced learning has emerged as a popular teaching approach for scientific studies, providing learners with more opportunities to observe and understand science in museums (Despotakis et al., 2007; Kennedy et al., 2021; Kumar & Dunn, 2018). In a literature review conducted by Xu et al. (2021), the use of technology in museum education for knowledge transfer, learning support, and interaction was found to be effective. Studies have often used technology to provide personalized and adapted services to increase public autonomy in museum learning, enriching the available scientific content (Chen et al., 2017; Nelson et al., 2020). However, in the highly interactive learning context of science demonstrations, there is relatively little discussion about whether technology intervention is changing public learning.

Therefore, this study utilized interactive e-books to develop teaching content for technology-assisted science demonstrations and introduced them into science demonstration activities. Interactive e-books are regarded as a highly flexible teaching tool that can provide teachers and students with diverse multimedia content, including videos, animations, quizzes, and even personalized feedback based on quiz results (Burvill et al., 2022; Zhao et al., 2021). They help assist the teacher in conveying the concepts of the learning content and the students to make predictions and observations of phenomena (Li et al., 2013; Liaw & Huang, 2016). As a result, they are widely used in many teaching settings, including science demonstration events (Yorganci, 2022). However, little has been done to explore the interactive behavior among the public, the learning knowledge, and the role of lecturers when e-books are used for science demonstrations. Therefore, this study adopted an experimental research method to explore the effectiveness of using interactive e-books to assist in science demonstrations on the public's performance and viewing behaviors.

The following research questions were posed:

1. Were the children's learning motivations when participating in the interactive e-book-supported science demonstration different from those of the children who participated in the conventional science demonstration?
2. Were there differences in the number of viewing behaviors among children who learned with the different science demonstration modes?
3. What were the viewing behavior patterns of children who viewed in the conventional science demonstration mode?
4. What were the viewing behavior patterns of children who viewed in the interactive e-book-supported science demonstration mode?
5. Did the children's viewing behaviors during the interactive e-book-supported science demonstration differ from the behaviors of those who participated in the conventional science demonstration?
6. Did children who used different demonstration modes have different perceptions of knowledge gain and different types of knowledge they expected to learn?

Literature Review

Technology-Enhanced Museum Education

The introduction of technology fulfilled the vision of integrating constructivism into museum education (Tsai et al., 2012). It satisfied the three dimensions of constructivism (Peng et al., 2009), including knowledge construction, active learning, and knowledge elaboration. Learners can reflect on their learning experiences through investigation, comparison, and reflection (Chu et al., 2010). Therefore, the intervention of technology has realized the opportunity for learners to engage in inquiry learning in museums (Wellington, 1990); the function of technology has shifted from merely extending information about exhibits to becoming a learning partner for the public, providing museums with self-directed, adaptive, and interactive learning services (Chiou et al., 2010; Hwang et al., 2012; Tuckey, 1992).

According to the classification of Xu et al. (2021), the application of technology in museums can be divided into three major categories: (1) resource constructive technologies, (2) assistive technologies, and (3) interactive technologies. Resource constructive technologies are usually used to actively or passively provide knowledge content and extended information (Price et al., 2015a, b; Serrell, 2015). For example, Dong et al. (2011) developed an online exhibition museum and used questionnaires to understand public perceptions of the museum. They found that technology helped to promote science education and literacy, while Castro et al. (2022) used virtual 3D models to assist learners in understanding zoology; they found that learning in this way created good motivation for students to learn. Assistive technology provides visitors with intelligent navigation tools to expand exhibition resources. For example, Chen et al. (2017) used iBeacon technology to develop a system that allows users to learn independently in a science museum. They found that the system was effective in guiding visitors to interact with exhibits, engage in deliberate learning, and extend the length of their visit from a variety of student learning performances. Finally, interactive technology is the technology that facilitates human interaction with exhibits, providing visitors with a convenient, enjoyable, and immersive viewing experience. For example, Khan et al. (2021) used augmented reality technology to provide a variety of interactive opportunities. They found that augmented reality combined with gaming activities successfully helped participants to connect learning with emotional performance. In addition, Nelson et al. (2020) used gamified quizzes to assist participants in their science learning. They found that the game helped learners to participate more actively in the learning activities.

On the other hand, science demonstrations are activities in museum education that allow the public to directly experience science and engage in a higher level of interaction (Cheung, 2014; Kerby et al., 2018). Instructors use stories, scientific instruments, and experiments to create impressive experiences during demonstrations. It is also a mode that stimulates the public's multiple senses, including visual participation, auditory understanding, and hands-on practice (Potvin & Hasni, 2014). It simultaneously motivates the public's interest in science learning through multiple channels (Austin & Sullivan, 2019; Howell et al., 2023). However, as DeKorver et al. (2017) noted, researchers have yet to examine the impact of science demonstrations on public learning outcomes. In particular, as technology has changed the teaching ecology of museums, the way science demonstrations are presented has changed as well. These changes alter the effectiveness of scientific demonstrations; it is more likely to alter the level of interaction between the public, the concept of knowledge, and the lecturer. The discussion of interactive behavior has been an essential topic in educational research, providing valid evidence to explain the effectiveness of learning and unveiling the learner's actual behavioral performance to the researcher (Hou & Keng, 2021; Liu & Lai, 2023; Zheng et al., 2019). Sequence analysis is a method that allows researchers to explore the interaction between learners, teachers, and technology through the visualization of qualitative data (Bakeman & Quera, 1992). However, there needs to be more discussion of the interaction between these three elements in highly interactive science demonstrations. Increased discussion in this area would give science demonstration designers more suggestions for planning the future activity process.

The Application of Interactive E-Books in Education

E-books combine the features of traditional printed books with interactive computer technology (Tlili et al., in press). Compared to printed books, e-books offer greater flexibility and accessibility (Abdullah, 2022; Yorganci, 2022). In addition, e-books are interactive and have multimodal features such as sound, animation, video, and narration that affect how students learn (Tsuei et al., 2020). The recent development of interactive e-books provides learners with the aforementioned interactive content and content that is responsive to the learner's choices (Sung et al., 2022). As a result, many studies have incorporated e-books into personalized learning, to help learners answer questions, read feedback, make decisions about problems, and understand consequences (Hwang et al., 2018; Sung et al., 2015). Because they offer a flexible and interactive platform, interactive e-books can increase student engagement and improve learning outcomes (Herianto et al., 2022; Maynard, 2010; Yang et al., 2013).

Studies have explored the potential of e-books in different educational contexts, examining their effectiveness in teaching complex concepts, motivating students, and enhancing the learning experience. A study by Hsiao et al. (2016) focused on the use of interactive multimedia e-books (IME) to teach cell morphology of blood and bone marrow. The researchers found that interns in the multimedia e-book group achieved significantly better scores in the posttest than those in the PowerPoint group. In a study by Zhao et al. (2021), they also found that the students who adopted a gamified interactive e-book (the GIEBFL group) significantly outperformed those in a traditional classroom and those in a technology-integrated classroom. Additionally, the questionnaire on students' learning motivation showed that the GIEBFL students had better motivation than the other groups. These studies demonstrate the potential of e-books to enhance the learning experience and improve student outcomes in different educational contexts.

Some studies have started to explore the impact of interactive e-books on student learning behaviors from different perspectives. For instance, Li et al. (2020) developed a situation-based interactive e-book system and found that high-achieving students tried multiple strategies to solve tasks. However, low-achieving students exhibited more distracting behaviors. On the other hand, Mifsud et al. (2021) explored the e-book affordances of children's individual engagement and parent–child joint engagement. The study found that e-books offer a range of affordances that can support personalized, affective, and interactive engagement, as well as didactic, dialogical, self-directed, and experiential engagement between parents and children. Through behavioral analysis, the researcher understood the differences that e-books bring to individualized learning and the patterns of interaction between the instructor and the learner.

Recently, museum education has begun to incorporate technology-assisted education. This phenomenon not only changes the way museums present scientific knowledge but also changes the mode of information reception. Especially in the scientific demonstration activities in museums, it is important to present scientific information through interactive e-books, but it may be more important to understand how the introduction of interactive e-books affects the viewing behavior of children. Through analysis, this study hoped to determine the changes in children's viewing behavior with or without interactive e-books and to provide suggestions for future related research and teaching practices.

Research Method

Participants

This study employed an experimental design method and invited the public to participate in scientific demonstration activities. After consulting with the science demonstration team, the simple pendulum was selected as the theme. Two demonstrations were conducted, one using a conventional science demonstration (CSD group) method and the other utilizing an interactive e-book to support the science demonstration (ESD group).

Before the science demonstrations began, the public was allowed to enter the demonstration hall. Participants were typically K-12 children accompanied by their parents. In both demonstrations, the research team performed the science demonstration first and then distributed e-questionnaires to the children to fill out. The study ensured that data collection was conducted in a respectful manner, with anonymous questionnaires provided to the K-12 children. Participants who completed the questionnaires received a science gift from the museum as an expression of gratitude. We collected data from 10 children in the first demonstration and seven in the second demonstration. The age distribution was 6 – 12 years old; three boys and seven girls filled out the questionnaire in the first demonstration, and four boys and three girls in the second.

The Development of Interactive E-Books

In this study, an interactive e-book was used as a tool for science presentations; such e-books have been widely used to support teaching and learning and have been shown to be effective in previous studies (Hsiao et al., 2016; Zhao et al., 2021). The interactive e-book was used in a science demonstration where instructors or children on stage could use the tool with an interactive screen. The e-book allowed instructors to guide children to observe scientific phenomena or stories on the screen. Children could also operate the e-book and receive feedback from it. The scenario of using the interactive e-book is illustrated in Fig. 1, where the scientific equipment was originally placed on the stage for the demonstration, and a large touch screen TV at the side displayed the content of the interactive e-book. Instructors or children could approach the screen to operate the e-book.

For this study, an e-book was created using the SimMAGIC eBook software, which includes sound and animation features. This tool enables instructors to incorporate additional visual and auditory content when narrating the story. An example of the e-book is provided in Fig. 2, demonstrating how the e-book enhances the reading experience.

In addition to sound and animation features, the interactive e-book also provides a range of interactive tools. For instance, the masking function allows instructors to hide important scientific concepts and reveal them later during Q&A or experiment sessions. Another feature is the ability to link the e-book to other open resources for simulations, such as demonstrating the oscillation of a single pendulum with varying lengths or weights to cater to the children's needs. An example of these interactive features is shown in Fig. 3.

Furthermore, the interactive e-book included a quiz function that helps instructors introduce a topic and prompt children to think about it. The children are then invited to participate and reveal the answers, as shown in Fig. 4. This interactive feature encourages children to engage more actively with the e-book and scientific demonstrations, promoting a more practical and engaging learning experience.

Instrument

In this study, children's learning motivation, perceptions of knowledge gained, and knowledge they expected to learn were collected through an e-questionnaire after the activity. In addition, a coding scheme was developed to analyze the children's viewing behavior.

The learning motivation measure this study adopted was developed by Tuan et al. (2005). It has 24 questions and

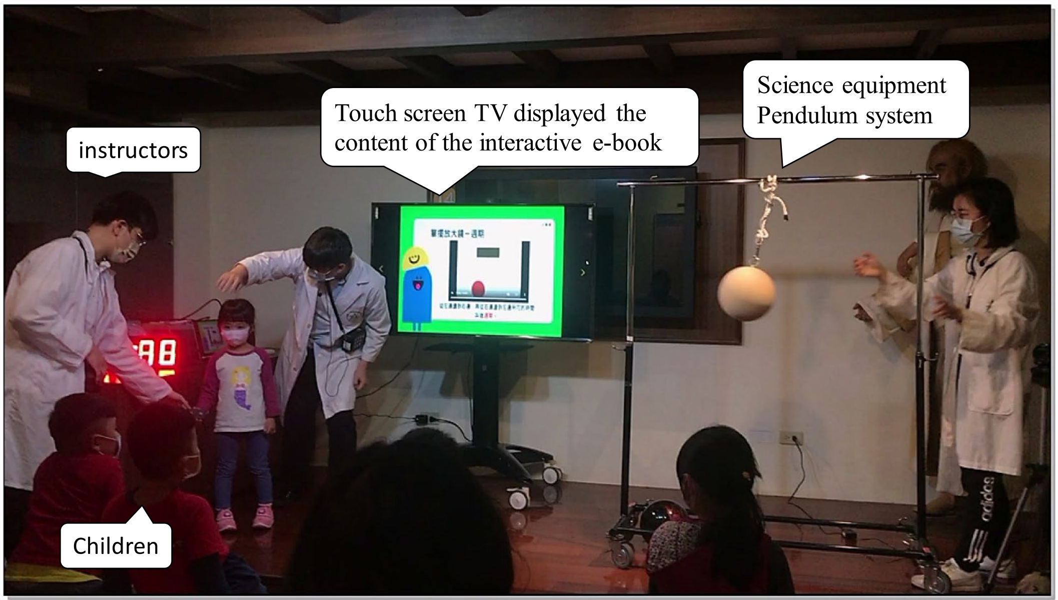

Fig. 1 The scenario of an interactive e-book support science demonstration

uses a 5-point Likert scale, which ranges from 1 (*totally disagree*) to 5 (*totally agree*). It consists of six aspects, that is, self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The number of items in each aspect is 4, 4, 4, 2, 5, and 5, respectively. The overall Cronbach's alpha value of the questionnaire was 0.89; for each scale, the Cronbach's alpha value ranged from 0.70 to 0.89.

To explore the children's viewing behaviors, this study analyzed the video recordings of two science demonstrations. The video recordings are a regular event at the museum and are used to evaluate the effectiveness of each science demonstration. Participants were informed in advance that a camera would be placed behind them and that their actions would be recorded throughout the study. Due to the study period coinciding with the COVID-19 pandemic, participants wore masks and faced the demonstration stage, preventing their frontal images from being captured as the cameras were positioned at the rear of the venue. After recording the videos, two learning behavior analysis experts were invited to categorize the children's viewing behaviors. They reached a consensus and generated a coding scheme consisting of 13 codes, which are shown in Table 1. The experts also provided descriptions and examples of each code. For instance, if a child listened to the instructors and raised their hand, their behavior would be categorized as code VH. To ensure consistency, two researchers with 2 years of teaching experience were then invited to independently code the videos using the coding scheme. Prior to coding, a consensus meeting was held, and both researchers were provided with 5 min of the two videos for coding training to confirm their familiarity with the coding content and to reach a consensus. The researchers then independently coded the videos, achieving a high level of consistency with a Kappa consistency test result of 0.92.

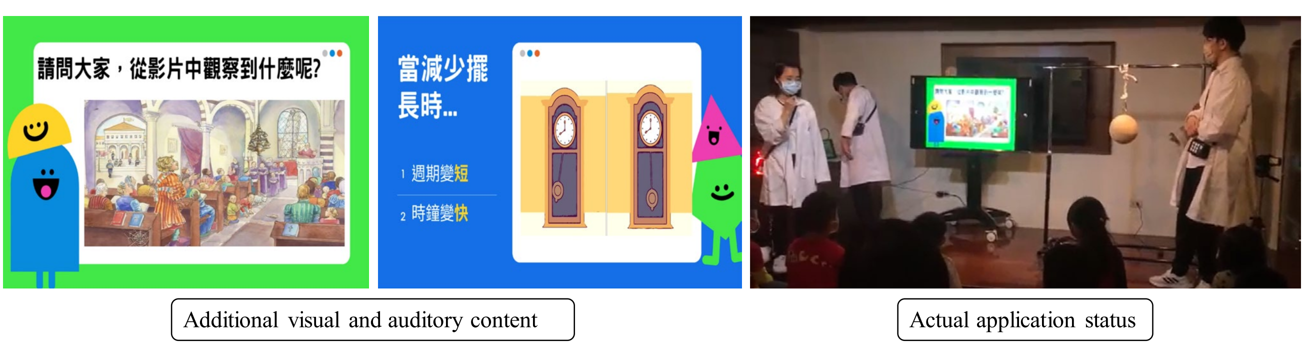

Fig. 2 The scenario of providing additional content with an interactive e-book in the science demonstration

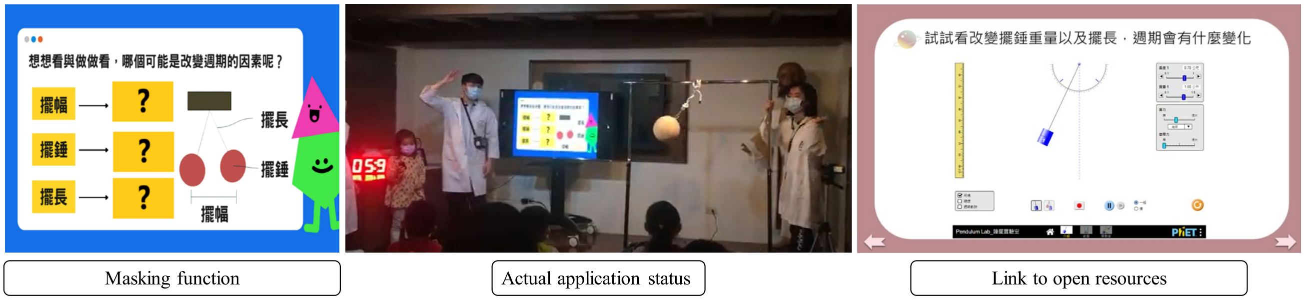

Fig. 3 The function of masking and external link in the interactive e-book. Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (https://phet.colorado.edu)

Any coding inconsistencies were discussed during a meeting with the researchers, and a consensus was reached on the coding content.

Finally, children were invited to write about what they thought they had learned and what they expected to continue learning. They needed to respond to two questions: "What did you learn about science during the activity?" and "If you had another opportunity in the future, what would you like to know more about?". With these two questions, the study analyzed the types of knowledge children gained and wanted to learn. The study used Krathwohl's (2002) categorization of knowledge as (1) factual knowledge, (2) conceptual knowledge, and (3) procedural knowledge; as there was no mention of metacognitive knowledge in the children's feedback, it was not included in this study. According to Krathwohl (2002), factual knowledge refers to the field's terminology, specifics, and essential elements; for example, one child in this study mentioned, "I learned how to set up a pendulum." Conceptual knowledge can be understood as the interrelationships and functions of the details and elements that make up the larger structure. For example, children mentioned, "I learned that no matter how large or small the angle is, it does not affect the cycle of a pendulum" and "Why does the cycle of a pendulum change, and how does it work?". Finally, procedural knowledge discusses the "what" implemented through the "how" process. For example, one child mentioned, "How do I make the cycle last forever?". In order to categorize the types of knowledge mentioned by the children, two additional science education experts were invited to categorize the content proposed by the children. Once they agreed on the coding principles, they began coding independently. The results of the independent coding showed a high degree of consistency between the two, with a Kappa consistency test result of 0.88. Next, both parties began to check the coded content until they ultimately agreed.

Experimental Design

The experimental diagram is shown in Fig. 5. Two science demonstrations were conducted on two different days in this study. The first session was a conventional science demonstration (CSD), while the second session was an interactive e-book science demonstration (ESD). At the beginning of each event, the instructors explained the rules and precautions for the science demonstration and then started the demonstration. In the conventional science demonstration, the instructors told stories, explained scientific concepts, and conducted experiments with scientific instruments. In the interactive e-book science demonstration, the interactive e-book developed by

Fig. 4 The function of quizzes in the interactive e-book

Table 1 The coding scheme of the children's viewing behaviors in the science demonstration

Code	Definition	Description	Example
OI	Focus on the instructors	Children look at or listen to the instructors	The children were attentively watching the instructors and listening to the instructors' explanation
OP	Focus on neighboring people	Children look at or listen to neighboring people	The children turned their heads to look at the nearby individuals and listened to what they were describing
OE	Focus on experiment	Children are attentively observing the experimental phenomenon	The children counted the number of times the pendulum swung back and forth together with the instructors
OQ	Focus on the experimental equipment	Children look at the experimental equipment	The children looked at the timer or the pendulum system as the instructors introduced it
ON	Focus on non-experimental activities	Children are attentively engaged in non-experimental activities	The children closed their eyes and carefully counted 20 s to experience the speed of time
VH	Raise hand	Children listen to the instructors and raise their hands	The children raised their hands to try to answer a question when asked by the instructors
VA	Answering questions	Children answer questions posed by the instructors	The children answered questions posed by instructors about scientific principles or life experiences
VO	One-way sharing with others	Children unidirectionally share thoughts with neighboring people	The children unidirectionally shared the observed phenomena from the science demonstration with neighboring people
VD	Two-way interaction with others	Interaction between the children and the neighboring people next to them	The children and parents shared their answers to questions or observations from the science demonstration
PB	Body participation	Children use their body to represent certain scientific phenomena	The children used their body to imitate the movement pattern of a single pendulum
PS	Stand up for observation	Children stand up to see the demonstration	The children stood up to see the results of the experiment
PC	Confused by the demonstration	Children are confused about the content, explanations, and results of the demonstration	The children scratch their heads when the instructors asked questions
PN	Answer questions in a non-verbal way	Children indicate the answers to the instructors' questions in a non-verbal way	The children used their fingers to point out the correct answers in the interactive e-book

the researchers was displayed on the TV wall in front of the stage. The animations of the e-book accompanied the narration and explanations provided by the instructors. The e-book also presented questions for the public to answer and provided instant feedback. Both demonstrations lasted 30 min, and at the end of each event, participating children were invited to fill out a questionnaire. After completing the questionnaire, the demonstration was completed.

Fig. 5 The experimental diagram

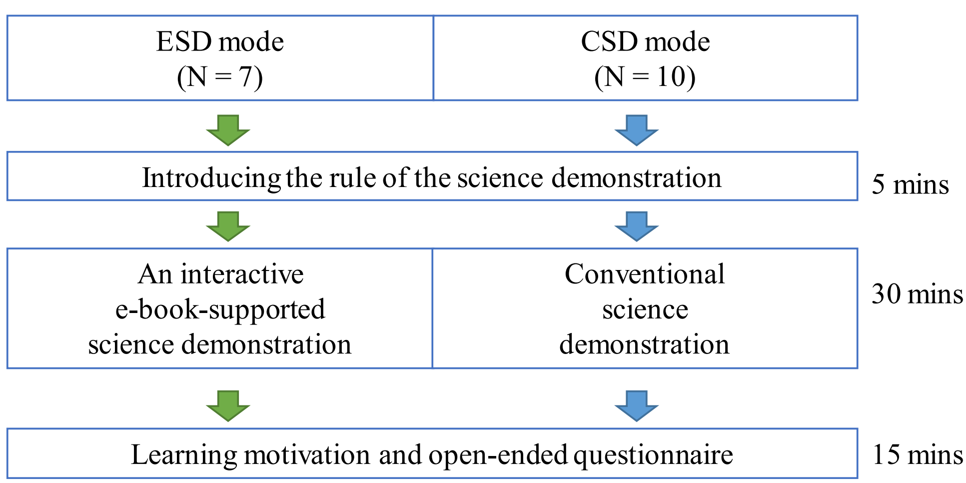

Table 2 The Mann–Whitney *U* test results of the children's perceptions of learning motivation

Aspect	Session	*N*	Mean	S.D	Order mean	Order total	*U*
Self-efficacy	CSD	10	4.30	0.71	8.40	84.00	29.00
	ESD	7	4.46	0.85	9.86	69.00	
Active learning strategies	CSD	10	4.43	0.67	8.65	86.50	31.50
	ESD	7	4.57	0.66	9.50	66.50	
Science learning value	CSD	10	4.43	0.58	8.20	82.00	27.00
	ESD	7	4.61	0.50	10.14	71.00	
Performance goal	CSD	10	4.20	1.01	8.15	81.50	26.50
	ESD	7	4.64	0.63	10.21	71.50	
Achievement goal	CSD	10	4.46	0.60	9.15	91.50	33.50
	ESD	7	4.40	0.61	8.79	61.50	
Learning environment stimulation	CSD	10	4.43	0.68	8.75	87.50	32.50
	ESD	7	4.54	0.53	9.36	65.50	

Data Analysis

In this study, data on children's tendency of learning motivation were collected through post-science demonstration questionnaires. Due to the small sample size, Mann–Whitney *U* tests were used to analyze the data, as recommended by Nachar (2008). On the other hand, this study used descriptive analysis to compare the types of knowledge children gained and expected to learn.

Additionally, lag sequential analysis was employed to investigate the children's viewing behaviors during the science demonstrations. This method is commonly used in digital learning contexts to identify significant behavioral sequences and main behavioral paths (Bakeman & Quera, 1992). The behavioral sequences were calculated and transformed into adjusted residuals (adjusted z-scores). If the adjusted z-score was higher than 1.96 ($p<0.05$), it was considered a significant behavioral sequence.

Result

Result of Learning Motivation

This study employed the Mann–Whitney *U* test to explore the children's tendency of learning motivation in each aspect, including "self-efficacy," "active learning strategies," "science learning value," "performance goal," "achievement goal," and "learning environment stimulation." The *U*-test results of the children's learning motivation showed that there was no significant difference in any dimension for the two sessions ($U=26.50\sim33.50$, $p>0.05$), indicating that the two groups of children had equivalent motivation tendency after joining the science demonstrations (Table 2).

Comparison of the Viewing Behavioral Frequency in the Different Science Demonstration Modes

Two researchers were invited to code all of the children's behaviors, resulting in a total of 374 viewing behaviors. Table 3 presents the frequency and percentage of viewing behaviors from both sessions. The findings revealed that "OI" was the most frequently observed behavior in both activities, indicating that children in both groups paid close attention to the instructors' demonstration.

In the conventional science demonstration (CSD) session, the other most frequent behaviors were "OQ," "OP," and "VD." "OQ" indicated that children focused on observing the science equipment and upcoming scientific phenomena, while "OP" and "VD" indicated that they were intent on the instructor's explanation or their neighbors' (e.g., parents') explanations.

Table 3 The frequency and percentage of the viewing behaviors in the two activities

	OI	OP	OE	OQ	ON	VH	VA	VO	VD	PB	PS	PC	PN
CSD ($N=192$)	53 (28%)	23 (12%)	5 (2%)	28 (15%)	7 (4%)	18 (9%)	7 (4%)	6 (3%)	21 (11%)	2 (1%)	7 (4%)	15 (7%)	0 (0%)
ESD ($N=182$)	51 (28%)	17 (9%)	2 (1.4%)	24 (13%)	7 (4%)	25 (14%)	4 (2%)	6 (3%)	15 (8%)	7 (4%)	1 (0.6%)	19 (11%)	4 (2%)

OI, focus on the instructors; OP, focus on neighboring people; OE, focus on experiment; OQ, focus on the experimental equipment; ON, focus on non-experimental activities; VH, raise hand; VA, answer questions; VO, one-way sharing with others; VD, two-way interaction with others; PB, body participation; PS, stand up for observation; PC, confused by the demonstration; PN, answer questions in a non-verbal way

Table 4 The adjusted residuals table of the CSE children's viewing behaviors

	OI	OP	OE	OQ	ON	VH	VA	VO	VD	PB	PS	PC	PN
OI	−4.41	**1.96**	−1.36	0.72	0.99	0.68	−0.75	1.32	0.22	0.75	−0.75	3.05	0
OP	0.47	−1.84	**2.03**	**3.72**	−0.97	−1.6	−0.97	−0.9	0.43	−0.51	−0.97	−0.61	0
OE	−0.39	−0.84	−0.37	−0.94	−0.44	−0.73	−0.44	−0.41	**2.11**	−0.23	**4.39**	−0.66	0
OQ	−0.21	0.49	**2.99**	−2.32	−1.09	1.05	−1.09	0.19	−0.63	1.47	2.23	−0.08	0
ON	−0.17	0.05	−0.47	−1.19	−0.56	**2.79**	−0.56	−0.52	0.14	−0.3	−0.56	0.5	0
VH	0.78	−1.02	−0.77	1.39	1.6	−1.52	**4.12**	0.51	−1.66	−0.48	−0.92	−1.38	0
VA	0.06	−0.99	−0.44	−0.02	1.53	−0.87	−0.52	1.73	1.52	−0.28	−0.52	−0.78	0
VO	0.06	1.38	−0.44	−0.02	−0.52	−0.87	1.53	−0.48	0.29	−0.28	−0.52	−0.78	0
VD	**3.21**	−0.37	−0.79	−0.7	0.29	0.02	0.29	−0.87	−1.7	−0.5	−0.94	−0.55	0
PB	−0.88	1.66	−0.23	−0.59	−0.28	−0.46	−0.28	−0.26	1.78	−0.15	−0.28	−0.41	0
PS	1.78	−0.99	−0.44	−1.11	−0.52	0.45	−0.52	−0.48	0.29	−0.28	−0.52	0.65	0
PC	1.72	0.17	−0.66	−0.9	−0.78	0.55	−0.78	−0.72	0.31	−0.41	0.65	−1.17	0
PN	0	0	0	0	0	0	0	0	0	0	0	0	0

Values in bold indicate significant sequences

In the interactive e-book science demonstration (ESD) session, the other most frequent behaviors were "VH" and "OQ." Similar to the CSD activity, children focused on the science equipment. Additionally, they frequently interacted with the instructors in this activity, such as raising their hands to get noticed.

This study further employed a Chi-square analysis to compare the different behaviors in the two activities. The results of the Chi-square test indicated that the children's viewing behaviors in the two modes were not significantly different (Chi-square = 16.98, $p > 0.05$), suggesting that the distributions of the viewing behaviors in both activities were similar.

Result of the CSD Children's Viewing Behavioral Pattern

Based on the adjusted residuals table (Table 4), this study identified several viewing behaviors associated with children's participation in CSD. After the instructor invited children to participate in non-science experiences (ON),

Fig. 6 CSE children's viewing behavioral patterns

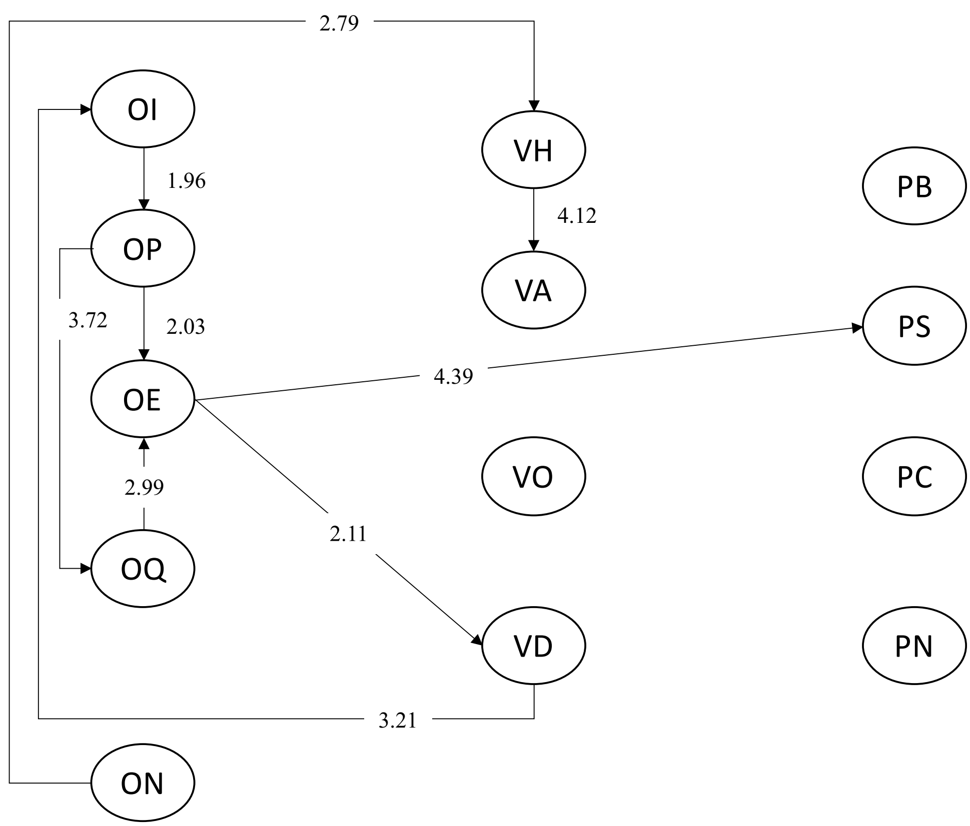

Table 5 The adjusted residuals table of the ESD children's viewing behaviors

	OI	OP	OE	OQ	ON	VH	VA	VO	VD	PB	PS	PC	PN
OI	−5.03	0.03	−0.91	−0.48	**2.51**	1.29	−1.3	**2.06**	**2.15**	1.66	−0.64	1.85	−0.18
OP	0.88	0.45	−0.44	1.46	−0.84	0.61	−0.63	−0.77	−1.26	−0.84	−0.31	−0.57	−0.63
OE	0.7	−0.46	−0.15	1.55	−0.28	−0.57	−0.21	−0.26	−0.43	−0.28	−0.11	−0.49	−0.21
OQ	1.6	1.32	1.55	−2.05	−1.05	0.45	−0.79	0.26	−0.78	−1.05	−0.39	0.35	−0.79
ON	−0.83	−0.87	−0.28	−1.05	−0.54	**4.52**	−0.4	−0.5	−0.81	−0.54	−0.2	0.34	−0.4
VH	−0.48	1.23	−0.57	**2.36**	−1.08	−2.15	**5.07**	−0.99	−0.83	1.16	−0.4	−1.13	−0.81
VA	−0.14	−0.65	−0.21	**2.20**	−0.4	−0.81	−0.3	−0.37	−0.61	−0.4	−0.15	−0.69	**3.15**
VO	**3.07**	−0.8	−0.26	−0.97	−0.5	−0.99	−0.37	−0.46	−0.75	−0.5	−0.19	0.51	−0.37
VD	1.68	−1.3	−0.43	0.02	0.59	−0.83	−0.61	0.76	0.75	−0.81	−0.3	−0.5	−0.61
PB	−0.83	0.46	**3.41**	−1.05	1.46	−1.08	−0.4	−0.5	0.59	−0.54	−0.2	0.34	**2.22**
PS	−0.63	−0.32	−0.11	−0.39	−0.2	−0.4	−0.15	−0.19	**3.35**	−0.2	−0.07	−0.34	−0.15
PC	**2.74**	−0.58	−0.47	−0.27	−0.89	−0.34	−0.67	−0.83	−1.34	0.4	**3.03**	−0.71	−0.67
PN	0.99	−0.65	−0.21	−0.79	−0.4	−0.81	−0.3	−0.37	1.23	−0.4	−0.15	−0.69	**3.15**

Values in bold indicate significant sequences

they would typically raise their hands (VH) and attempt to answer the instructor's questions (VA). Initially, they focused on observing the operation of scientific equipment (OQ) and the process of the scientific experiment (OE). Following the observation of experimental phenomena, they typically discussed the results with nearby partners (e.g., family members) (VD). After the discussion, they shifted their focus to the instructor's instructions (OI). Upon listening to the instructor's explanations, some children turned their attention to sharing concepts with those around them

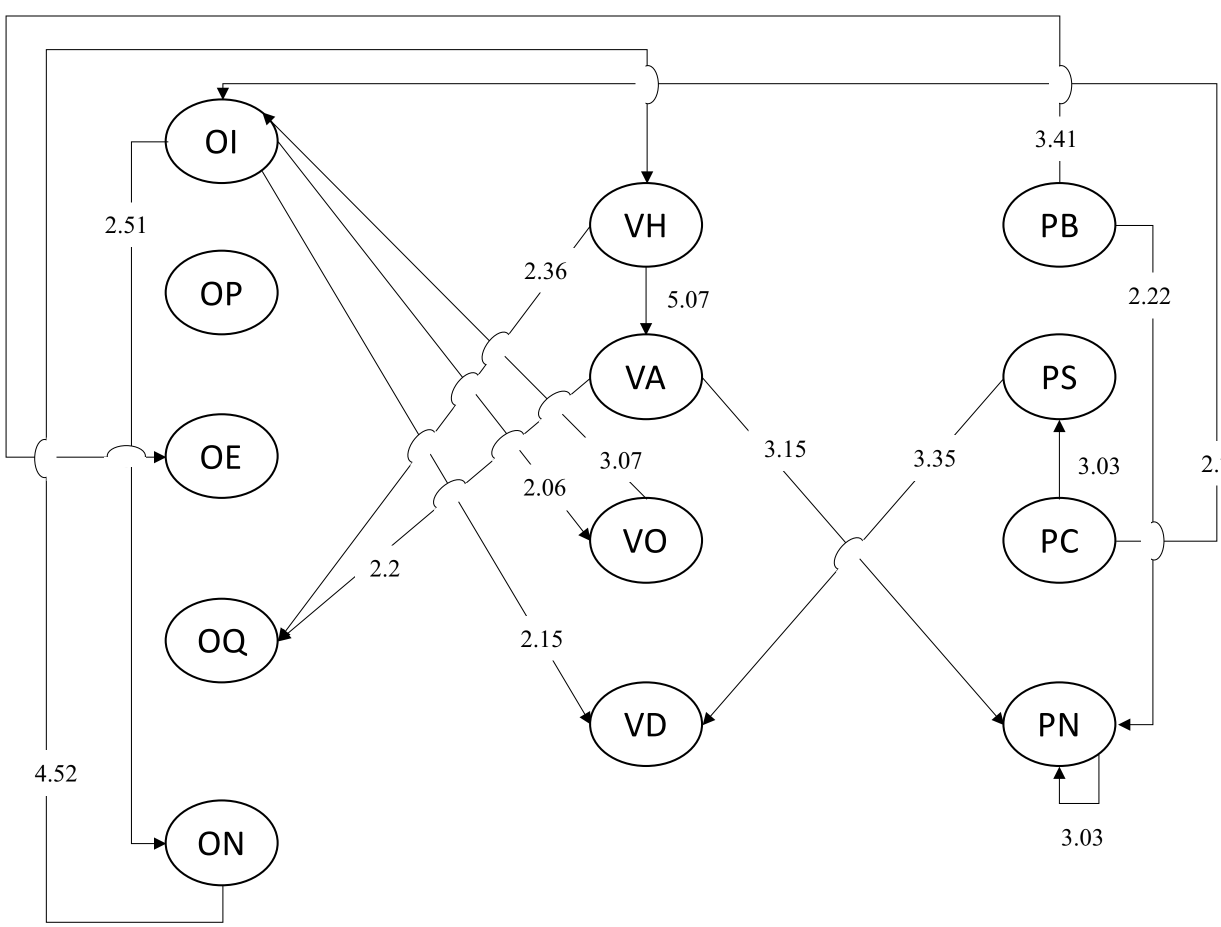

Fig. 7 ESD children's viewing behavioral patterns

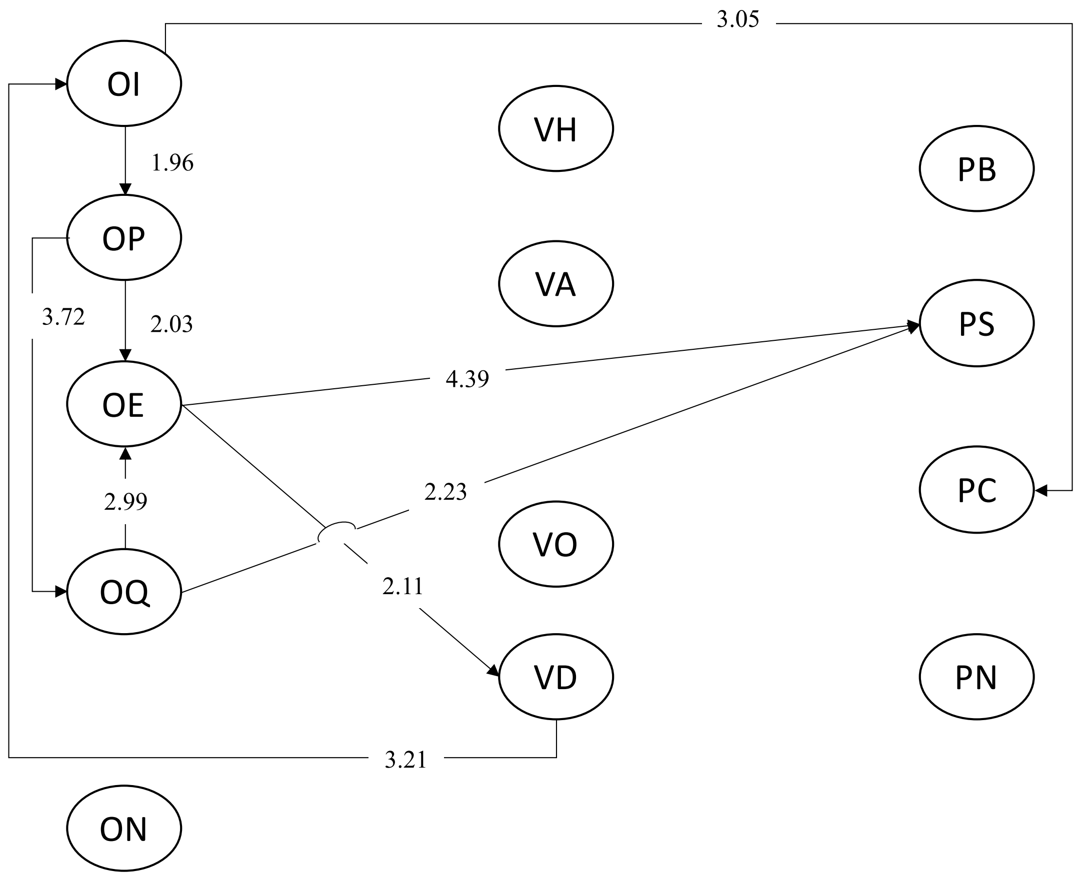

Fig. 8 Significant behavior sequences that only occurred in the CSD group

(OP), while others appeared confused about the content (PC). Additionally, after listening to others' concepts (OP), children often refocused on the experimental process (OE) and scientific equipment (OQ) and sometimes even stood up (PS) to observe the experimental activities on stage.

The study examined the viewing behaviors of CSE children by analyzing the adjusted residuals table. As shown in Fig. 6, behaviors OE, OQ, and OP were found to have a high level of interactivity with other behaviors such as engaging in scientific experiments, observing scientific equipment, and actively listening to others' responses. The results found that listening and observing behaviors are crucial in conventional science demonstrations, serving as important bridges for children to engage in other viewing behaviors.

Result of the ESD Children's Viewing Behavioral Pattern

This study analyzed the viewing behavior of children in the ESD group, and the adjusted residual table is shown in Table 5. The table shows that there are greater sequences of significant viewing behavior than in the CSD group. After the children raised their hands to try to answer questions (VR), they would try to answer questions (VA) or focus on the operation of the scientific equipment (OQ). After focusing on the instructors (OI), children may interact with other nearby public members (VD), participate in non-experimental activities (ON), or share with others (VO). When children have finished answering a question (VA), they then focus on the scientific equipment (OQ) or use their bodies to deliver an answer (PN). After children have participated in the physical activity guided by the instructor (PB), they participate in the experiment (OE) or use their bodies to answer a question (PN). After the children have stood up to observe the demonstration (PS), they engage in an interactive discussion with the neighboring public (VD). After they have participated in a non-experimental activity (ON), they raise their hands to try to answer a question (VH). Finally, after children have answered a question using their body, they are likely to be confused (PC) and then they will either focus more on the instructors (OI) or stand up and focus on the observation (PS).

Figure 7 depicts the viewing behavior transition of ESD children, revealing that they exhibit more physical movement, verbal interaction, and active participation during the activity. Specifically, they engage in activities such as answering questions (VA), using body language to communicate answers (PN), physically participating in the experimental equipment (PB), and using body gestures to answer

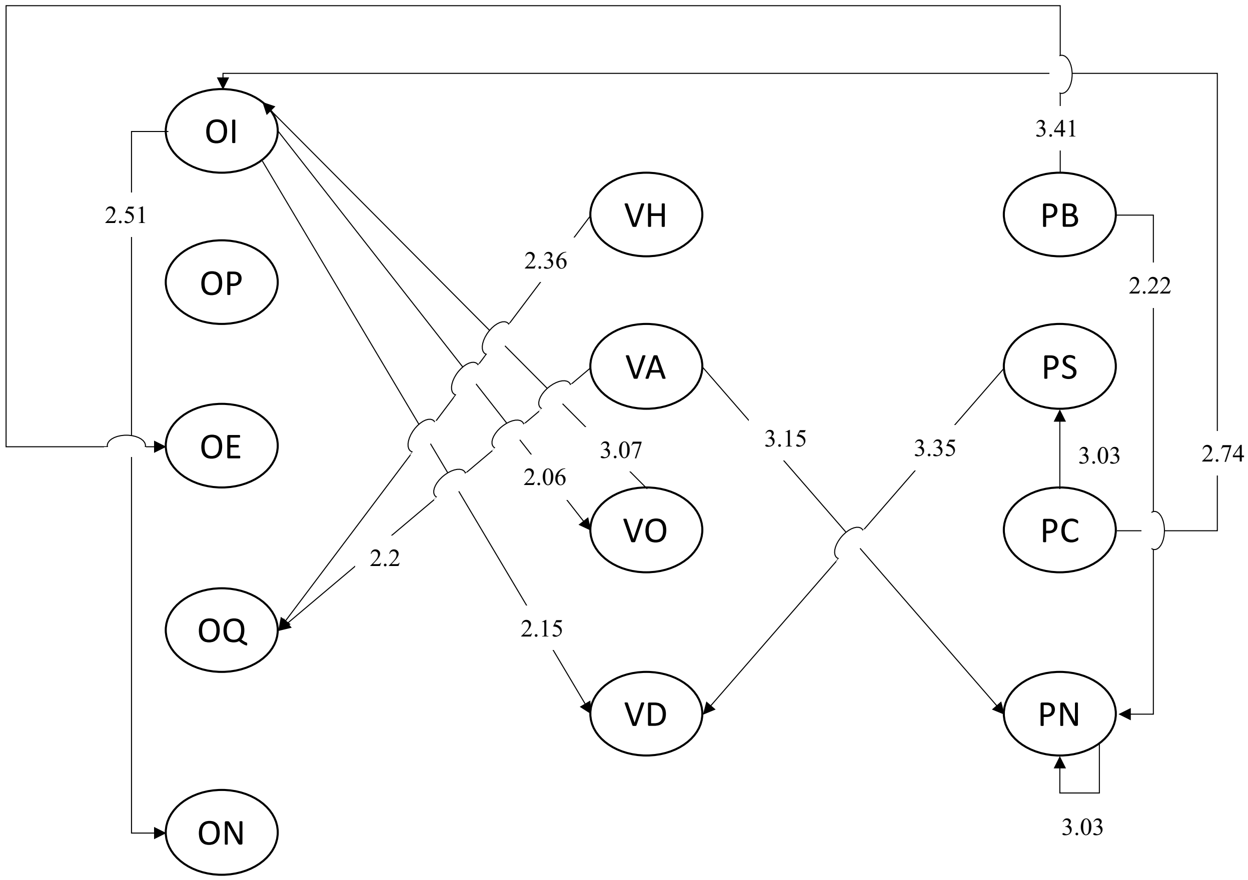

Fig. 9 Significant behavior sequences that only occurred in the ESD group

questions (PN). The figures also demonstrate that the children's sequence of behaviors during the science demonstration combined with the e-book is more intricate.

Comparison of the Different Behavioral Patterns in the Different Demonstration Approaches

The present study conducted a detailed examination of behavioral sequences that were unique to a specific group, revealing two distinct sequences in the CSD group. First, while engaging in scientific experiments (OE), they exhibited bidirectional interaction (VD) to discuss and observe the experiment. Then, they refocused on the content of the scientific demonstration (OI) and attentively listened to the speech of others (OP). Finally, they redirected their attention towards the experiment (OE) or the scientific equipment (OQ). Second, while observing the experiment (OE), if necessary, they would stand up to obtain a clearer view of the stage performance (PS) (Fig. 8).

On the other hand, using e-books for science demonstrations generated four behavioral paths. First, when children focused on the instructors' content (OI), they engaged in non-science experimental activities (ON) or unidirectional interaction with the person next to them (VO). Second, when children raised their hands (VH), they concentrated more on the operation of scientific equipment (OQ). Third,

Table 6 Descriptive result of the knowledge types the children learned and wanted to learn

	Learned				Wanted to learn			
	ESD group		CSD group		ESD group		CSD group	
Factual knowledge	2	29	4	40	2	29	3	30
Conceptual knowledge	2	29	6	60	2	29	6	60
Procedural Knowledge	4	43	0	0	4	43	1	10

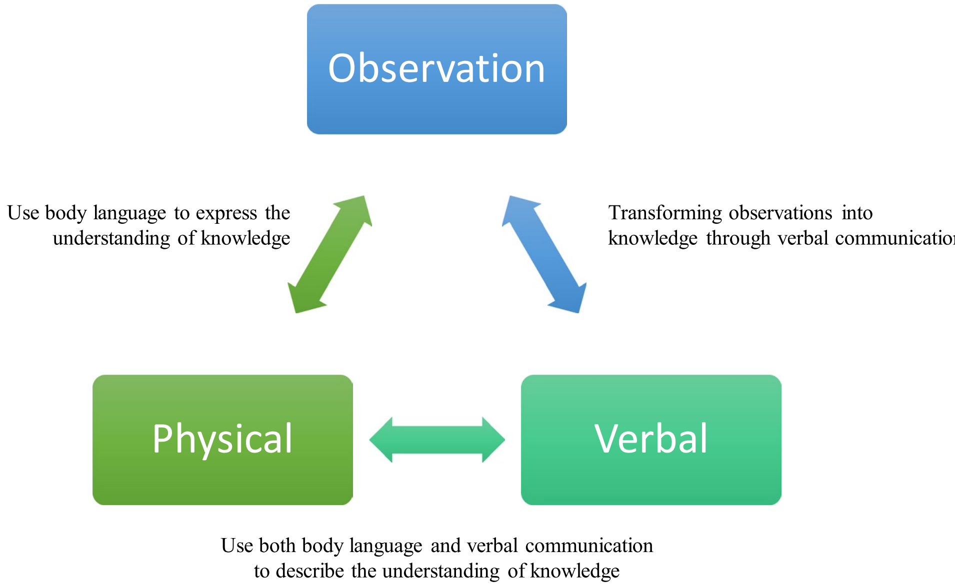

Fig. 10 The framework of interactive e-book support science demonstration

they participated in demonstrations with their bodies (PB), then engaged in experiments (OE), or used their bodies to answer questions (PN). Fourth, after answering a question (VA), they focused on the operation of the scientific equipment (OQ) or attempted to answer the question again using their bodies (PN). Subsequently, they may become confused about the demonstration's content (PC) and refocus on the instructors' content (OI) or stand up to have a clearer view (PS) and engage in discussion with others (VD) (Fig. 9).

These findings suggest that conventional presentation methods facilitate interaction patterns that emphasize participation and verbal communication among children. Conversely, e-book-supported science presentation methods also facilitate focused participation and verbal discussions but with added participation through body language.

Result of Types of Knowledge Gained and Expected to be Learned

According to the children's open-ended questionnaire content, this study examined the different perceptions of the two groups of children regarding what types of knowledge they had gained and expected to learn. Table 6 shows that children in both groups perceived most of what they had learned as conceptual knowledge (ESD group 71%; CSD group 60%). Following this was factual knowledge (ESD group 29%; CSD group 40%). It can be seen that the two groups of children expressed similar content about what they had learned in the activity; for example, in terms of factual knowledge, both groups of children said, "I learned that a pendulum is set up in this way" and "I found out that there are many pendulum-like objects in our life and that a pendulum is a way of counting time." On the other hand, in terms of conceptual knowledge, children said, "I understand that no matter what the angle size is, it does not affect the period of a pendulum" and "I know that different methods can be used to check what affects the period of a pendulum."

On the other hand, this study explored what children wanted to learn after participating in the activities. According to Table 6, the percentages of the ESD group learners who wanted to know more about factual, conceptual, and procedural knowledge were 29%, 29%, and 43%. For the CSD group, they were 30%, 60%, and 10%, respectively. The percentage results show that the ESD group had an equal percentage of wanting to know, and the percentage of wanting to know was more for procedural knowledge. On the other hand, the CSD group had the same percentage as the learned percentage and wanted to know more about conceptual knowledge.

Discussion and Conclusion

This study examined the impact of using both conventional science demonstration models and interactive e-books integrated into science demonstration models on children's viewing behavior. Based on the data collection and analysis results, this study discusses the experimental findings as follows:

Different demonstration modes may result in similar effects on children's learning motivation and conceptual understanding

According to the survey results of this study, the impact of the two different demonstration modes on the children's motivation was similar. This research result is similar to that of Chen et al. (2022) and Zaharias et al. (2013). According to Bandura (1986) and White (1995), motivation is an individual's response to environmental changes and represents the interaction between individuals and the environment. From the results of this study, it can be inferred that the environmental coping modes generated by these two science demonstration modes for the children were similar. Therefore, the conceptual understanding and motivation expressed by the children were comparable. The result mirrors Boschman et al. (2015), who stated that technology is a part of the teaching and learning process, and how the activities are designed may be more critical.

Despite this, we found differences in the types of knowledge children expected to learn. The group that adopted the interactive e-book learning mode expected more procedural knowledge, whereas the conventional group wanted conceptual knowledge. A similar result was explained in the study by Beeler et al. (2023). In their study, when conceptual and procedural knowledge gained a more robust connection, it could enhance learners' learning of procedural knowledge. In the current study, the interactive e-book might help the children link conceptual and procedural knowledge, for example, observing a simulated pendulum swing, making predictions, and answering questions. Thus, children were provided with many opportunities to validate the information and were stimulated to think more procedurally.

The conventional science demonstration mode emphasizes demonstration content and interaction

From the sequence of behaviors, it can be seen that the two modes had different viewing effects. In the conventional science demonstration mode, this study found that the children paid more attention to the content of the science demonstration. The reason may be that the instructors and the demonstration content were the source of scientific information that the children accepted, so they focused on listening to and observing what was happening on the stage. In addition, we also found that discussions with neighboring people played an essential role in leading the children back to the demonstration content and scientific activities. Therefore, people around the children, such as peers, parents, or teaching assistants, may also need to participate actively in the demonstration activities. This result is consistent with Howell et al.'s (2023) and Zhou et al.'s (2022) studies that peer assistance and parental conceptualization of science learning are critical in influencing students' constructed knowledge. It may also provide suggestions for museum staff who design science demonstrations in the future. In addition to focusing on the experimental process and interaction with the children, demonstration activities can also invite people in the surrounding area to participate and think together to increase the children's participation in the science demonstrations.

Using interactive e-books enhances the children's physical engagement

This study introduced interactive e-books into science demonstrations, which not only presented scientific knowledge through a slideshow but also included related Q&A and animations that generated feedback based on the children's or instructors' input. According to the analysis of behavioral patterns, this model increased the physical engagement of the children and led them to focus on the science demonstration activities. These physical involvements included pointing their fingers to the correct answers in the interactive e-book, swaying their bodies according to the experimental phenomenon, and even scratching their heads when the answers did not match their expectations. As described by Herianto et al. (2022), interactive e-books enhance students' scientific curiosity. This study suggested that the integration may lead children to have deeper cognitive engagement (such as head-scratching and tilting). Based on these results, it is suggested that in the future, interactive e-books or other visualization technologies can be introduced to science demonstration activities to include more cognitive and physical interactive content for the children. For example, this study included Q&A and the direction of the swing of a pendulum in the interactive e-book and used visual tools to present virtual content, allowing the children to learn knowledge through multiple channels (Mayer & Moreno, 1998).

In summary, this study drew an interactive framework of observation, verbal, and physical involvement, as shown in Fig. 10. In the conventional science demonstration activity, the model included the patterns of observation and verbal interaction. When the interactive e-book was added, the children were also physically engaged in the demonstration activity. This embodied the process of the involvement of motor messages in conceptual processing. In addition, this study also found that the behavior of observing the experimental demonstration (OE or PS) was less than observing the lecturer, for both groups; the reason for this was that the demonstration was often paired with a lecturer or other supporting tools to explain the phenomena, which also showed the importance of lecturer training.

By comparing two different science demonstration models, this study discussed the demands and important behavioral sequences of the children under two different science demonstration models. Although this study used a random sampling method, the sample size was small and could not be generalized to the entire population participating in science demonstrations. At the same time, this study did not use actual evaluations to verify the relationship between the children's viewing behavior and cognitive development. Therefore, more research on the related cognition, emotions, and behavioral engagement of children and in-depth discussion of the effects of this interactive content on public museum learning are encouraged.

Author Contribution Conceptualization: Hsiang-Wei Chen and Chiu-Lin Lai; methodology: Zi-Ning Huang, Chiu-Lin Lai, and Hsiang-Wei Chen; formal analysis and investigation: Zi-Ning Huang and Chiu-Lin Lai; writing—original draft preparation: Zi-Ning Huang and Chiu-Lin Lai; writing—review and editing: Zi-Ning Huang, Chiu-Lin Lai, and Hsiang-Wei Chen. In addition, the authors would like to thank Hou-Chun Kao and Pin-Wei Wang for their assistance in conducting the science demonstrations.

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Availability of Data and Material The analyzed data can be provided upon requests via sending e-mails to the corresponding author.

Declarations

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare no conflict of interests.

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