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Designing an IoT-Based 3D Pop-Up Book to Engage Children in English Vocabulary Learning

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Abstract: The purpose of this study was to use the Internet of Things (IoT) technology to engage elementary school children in English vocabulary learning through a pet-care game. An IoT system consisting of a three-dimensional (3D) pop-up book, a toy character, an educational robot, and a near-field communication wire network was developed. Based on this proposed IoT-based language learning environment, interactions among individual learners, an educational robot (accompanied by a tablet), and the 3D pop-up book augmented by a sensor network were induced. Two fourth graders followed the English robotic prompts, which were simple sentence structures embedded with target vocabulary, to interact with the 3D pop-up book so that each learner carried out daily life tasks under robotic guidance and human facilitation. A video analysis revealed that the IoT-augmented 3D pop-up book game effectively provided a learning environment for behavioral, cognitive, and emotional engagement. It is thus concluded that creating an IoT-based game environment for young learners and engaging them in interactions can enhance their performance in English vocabulary learning. Instructional designers may find the outcomes of this study useful for creating language learning opportunities with the support of IoT-based technology.

Keywords: Engagement, gamification, IoT-based learning, robotic guidance, 3D pop-up books

1. Introduction

Alternative instructional modes with the support of technology can effectively facilitate language learning. As English continues to be the lingua franca in the world, Taiwan has also joined the move toward a bilingual nation in English and Chinese (Ministry of Education, 2019). This language policy has resulted in an early start of English learning. In primary education, vocabulary acquisition and sentence formation serve as the main learning content in the English subject. As such, how to effectively facilitate language development among young learners becomes a crucial task for English practitioners in this context. With the advancement of sensor technology (Wang, Lin, Hwang, & Liu, 2019), educational robots (Cheng, Sun, & Chen, 2018), and the Internet of Things (IoT; Gomez, Huete, Hoyos, Perez, & Grigori, 2013), more possibilities in language education arise. The affordances of IoT and sensor technology allow for sensory-based interactive learning, which provides opportunities for practitioners to experiment with well-crafted learning networks.

Vocabulary development for English as a foreign or second language learners requires time, but young learners often perceive it to be a boring process that demands them to attend to lexical meanings (Nation, 2001). Unsatisfactory outcomes thus often result due to insufficient contact with target words and memory loss over time (Zou, Huang, & Xie, 2019). Despite previous efforts with digital game-based learning designs for vocabulary learning (e.g., Chen, Liu, & Huang, 2019), a new learning environment utilizing interactive pop-up books, educational robots, and IoT technology remains absent. This study intends to create embodied cognition (Chao, Huang, Fang, & Chen, 2013) via a multimedia environment. It is expected that through physical movement and stimulus materials enabled by the IoT-based pop-up book, meaningful English vocabulary learning will occur. The authors seek to understand how children learn and what they need to learn via *design for learning*, which is a branch in instructional design that conceptualizes learning as 'engagement, transformational processes, sign making, and meaning making' (Selander, 2008, p. 148). By integrating new forms of technology based on the concept of *design for learning*, problems concerning boredom with vocabulary learning and difficulty with memory retention might be solved. This paper therefore presents the design of an instructional mode with the support of technology to effectively engage Taiwanese children in English vocabulary learning.

Vocabulary learning is important for young learners. Recent years have witnessed increasing popularity of digital game-based learning for second language vocabulary acquisition (Tsai & Tsai, 2018). The design of digital game-based learning can be divided into two main types － drill- and task-based games (Chen, Tseng, & Hsiao, 2018). Drill-based games offer repetitive practice opportunities to learners on target words through games such as matching, while tasked-based games lead to real outcomes through goal-oriented activities (Willis, 1996). Task-based games further provide critical thinking and problem-solving skill training through role-play, strategy application, and adventures, all of which place an emphasis on meaning over form (Homer, Plass, Raffaele, Ober, & Ali, 2018; Vahdat & Behbahani, 2013). In addition, the importance of noticing and retrieval was addressed. Noticing refers to repeated exposures, retrieval, and generative use that lead to successful vocabulary acquisition (Schmitt, 2008). According to noticing, learners can become aware of different nuances of a word's meaning as they pay attention to the word form or any cues associated with its meaning (Schmidt, 2010). Retrieval, on the other hand, is the process by which learners access stored information and connect the associative cues to the retrieved knowledge, leading to better vocabulary retention (Nation, 2001).

The Internet of Things (IoT), when applied in educational settings, makes use of network computing, sensors, online platforms, and even artificial intelligence for transforming real-world objects into intelligent ones to facilitate learning (Abdell-Basset, Manogaran, Mohamed, & Rushdy, 2019). IoT technologies combine physical, digital, and biological spheres in people's daily lives (Schwabs, 2015), and is one of the forces that shape the future of education. In an IoT-based setting, educational aids such as toys, educational robots, and sensor technology can be applied to foster cognitive development is enhanced by motor and sensory exploration (Dauch et al., 2018). Toys, for one, bear features that can lead to growth in cognition, social skills, and motor skills among children. They also bear cultural beliefs and add to children's play experience (Trawick-Smith, Wolff, Koschel, & Vallarelli, 2015). In addition, Bikowski and Casal (2018) on non-native English speaking undergraduates studying in the U.S. reported that as learners engaged in using an interactive digital textbook on iPads, measures on their engagement levels categorized them into emergent and proficient learners. Example engagement behaviors included putting efforts into assignments, taking good notes, thinking about course materials outside class, and desiring to learn course materials. The proficient learners were the ones that displayed more engagement behaviors and conscious use of strategies to help them benefit from the new way of learning with the use of the digital textbook.

The purpose of this study was to engage elementary school children in English vocabulary learning through a pet-care game in an IoT system consisting of a three-dimensional (3D) pop-up book, toy character, educational robot, and near-field communication wire network. The research questions were therefore formulated as follows:

RQ 1. How was an Internet of Things (IoT) system consisting of a three-dimensional (3D) pop-up book, a toy character, an educational robot accompanied by a tablet, and a near-field communication wire network developed?

RQ 2. How can the designed learning activity of an IoT-based 3D pop-up book effectively engage Taiwanese two fourth graders in English vocabulary learning?

2. Method

2.1 Augmenting the Three-Dimensional Pop-Up Book with IoT Technology

In the proposed IoT-based system network, circular near-field communication (NFC) tags, a touch sensor, a NFC reader, and a Raspberry Pie were embedded in a commercial pop-up book in order to create a sensory-motor environment for English vocabulary learning. The IoT-based game consisted of the pop-up book, an educational robot, a tablet PC, and a rabbit doll. The robot's features included two flexible hands and wheel legs that instructed learners with vivid gestures. Beside the robot, a 9.7-inch tablet PC was used to help learners with visual cues for task completion. Both the pop-up book, the robot, and the tablet PC were scripted in English. As for visual effects that increased learner appeal and motivation, the colorful pop-up book, along with a well-dressed male rabbit doll, was able to attract learners' attention and enhance their learning desire. The rabbit doll was connected to a NFC reader. On the 3D pop-up book, 12 circular stickers could be found. These were embedded NFC tags that provided audio feedback when a learner tried to perform a task. The NFC tags were connected wirelessly to a Raspberry Pie hidden at the bottom of the pop-up book, while the NFC reader on the rabbit doll was connected to the Raspberry Pie with wires in the IoT augmentation of the pop-up book.

2.2 IoT-Based Interaction Framework

The authors proposed an IoT-based interaction framework whereby three main entities interacted with each other in the process of language learning. The three entities were the learner, the educational robot aided by a tablet, and the 3D pop-up book. The learner is a child who is engaged in a sensory-motor learning activity in the IoT-augmented environment in the form of a 3D pop-up book consisting of a house with tangible objects and toy-like living space. The robot and the tablet serve as one entity that provided instructional aids. Figure 1 illustrates the framework components and their main functions. The design of the learning activity, the pet-care game, is based on the postulations that (a) with tangible playable objects, the learner will be highly engaged in receiving language input under appropriate instructional guidance; and (b) as learners receive feedback from the robot and tablet, they will be able to go reach the correct target object through trial and error, and ultimately learn the target vocabulary in authentic play context.

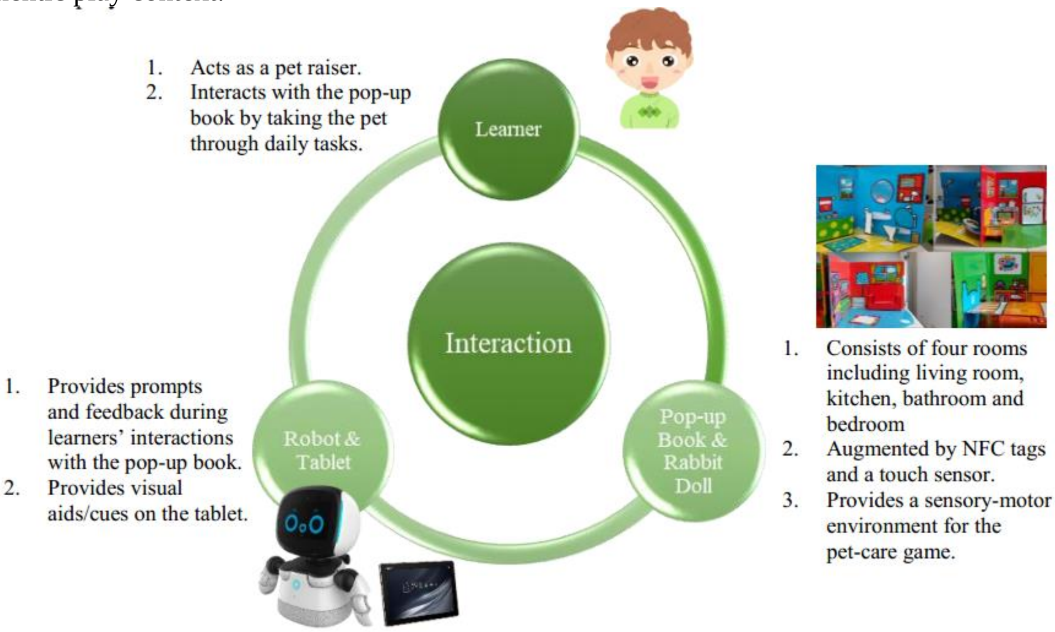

Figure 1. IoT-Based Interaction Framework for Language Learning

2.3 Game-Based Design of the IoT 3D Pop-Up Book

It is challenging for children to learn new English vocabulary in daily life settings. Previous research (Lenhart, 2019) shows that based on the instructional sequence of say-tell-do-play (STDP), guided play enhances learners' word awareness. To help children learn English vocabulary in a fun way, sociodramatic play, a common practice among children's daily play, was adopted for the design of the IoT-based learning in this study. Children, along with their parents and siblings, live in their own house where as the most familiar environment to learn vocabulary in early childhood development. This echoed the digital game design concept of relating the learning content to daily life situations (Shi & Hsu, 2016). The selected commercial 3D pop-up book was therefore connected to the learning content with a domestic theme in the game environment. The central theme of the game involved pet-care, as pets are children's favorite company. Moreover, some children have experience playing pet-care games. Therefore, the rabbit doll served the pet role to engage target learners in pet-raising as a process for them to learn vocabulary in the familiar environment resembling their own home. It was expected that the design of the IoT-based pet-care game would strengthen their listening competence as they carried out tasks following the robotic instruction in English. Figure 2 presents the set-up of the IoT-based system with the augmented components.

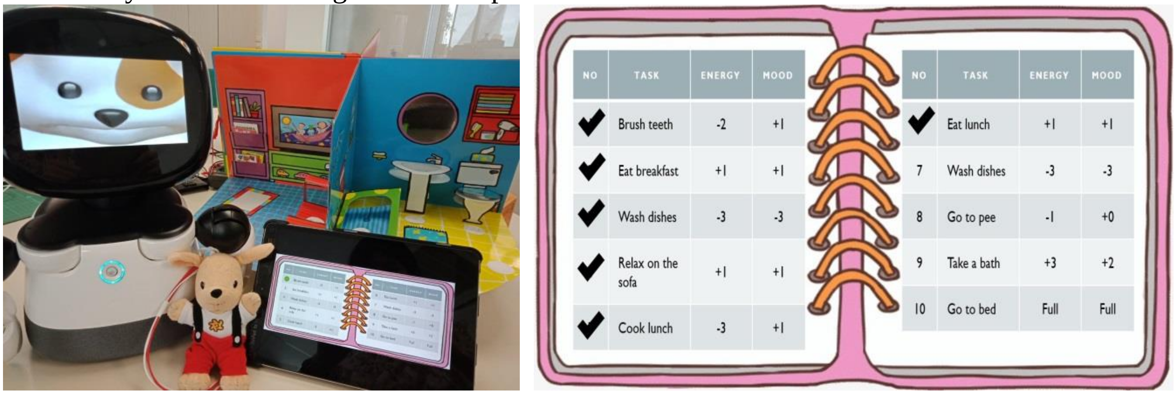

Figure 2. The Set-Up of the IoT-Augmented 3D Pop-Up book and an Example Guidebook Page

2.4 The Pet-Care Learning Game

The pet-care game required each learner to engage in role-play. To fulfill the task-based game design, the pop-up book, which was a 3D house equipped with four rooms (a living room, kitchen, bathroom and bedroom), was embedded with IoT components (a Raspberry Pie, a NFC wire network, and a touch sensor on the guidebook). A rabbit character served as a token for children to navigate through each room, taking the rabbit to touch different objects. Moreover, an educational robot and a tablet PC served as educational aids in the game-based learning environment. When a learner touches the guidebook, the tablet will display a Guidebook page to show them which tasks they are on, as shown in Figure 2. In terms of the learning content, vocabulary items related to different rooms in a house were used. Table 1 presents a task list developed for the pet-care game as well as the target words to be introduced and learned. required the learner to act as a pet raiser by following robotic instructions to tend to the daily needs of the pet, the rabbit doll. To guide learners through this role-play,

Table1. *Task List for the Pet-Care Game*

TASK NUMBER	TASK	TASK NUMBER	TASK
1	Brush teeth* (*sink, *brush, *teeth)	**6**	Eat lunch **(***eat, *lunch, *yummy)
2	Eat breakfast (*eat, *breakfast, *full)	**7**	Go to the bathroom (*bathroom)
3	Wash dishes (*wash, *dish, *cook)	**8**	Go to pee (*pee, *feel, *better)
4	Relax on the sofa (*relax, *comfortable)	**9**	Take a bath (*take, *bath)
5	Cook lunch (*cook, *lunch, *smells)	**10**	Go to sleep (*sleep, *bed, *night)

NOTE: An asterisk (*) indicates a target vocabulary in the learning module

Under robotic instruction and visual aids on the tablet, each learner was expected to complete the game autonomously. An example page of the Guidebook is shown in Figure 2. The pet-care game consisted of four stage. The first stage, the Warm-Up, involved the robot's greetings to the learner and introduction of the pet. The second stage, the Introduction, involved the robot's introduction of the game rules. The third stage, the Trial, provided a scaffold for the learner to complete an initial task. In the last stage, the Exploration, the learner must explore the pop-up book by carrying out the tasks in the pet-care game. Figure 3 shows the game flow for the Trial and Exploration sessions.

The robotic guidance was entirely scripted in English and the guiding mechanisms were divided into three types, each serving a specific function. The first type of guidance introduced the learners to the game (e.g. "Hi, my friend is traveling. She has a pet. Can you help take care of it?"). The second type of guidance prompted the learner to take action (e.g. "Please go to the bathroom. Find the Guidebook and touch it."). The third type of guidance provided feedback on each learner response to the prompt during an interaction with the pop-up house. If the learner responded correctly, a reward was provided (e.g. "Wow! Good job! Let me give you a star. You can get stars if you do a good job. Stars are good. You can upgrade each room with stars."). On the other hand, if the learner's response was incorrect, the robot would instruct the learner to turn to his/her attention to the tablet (e.g. “Check the Guidebook again.”).

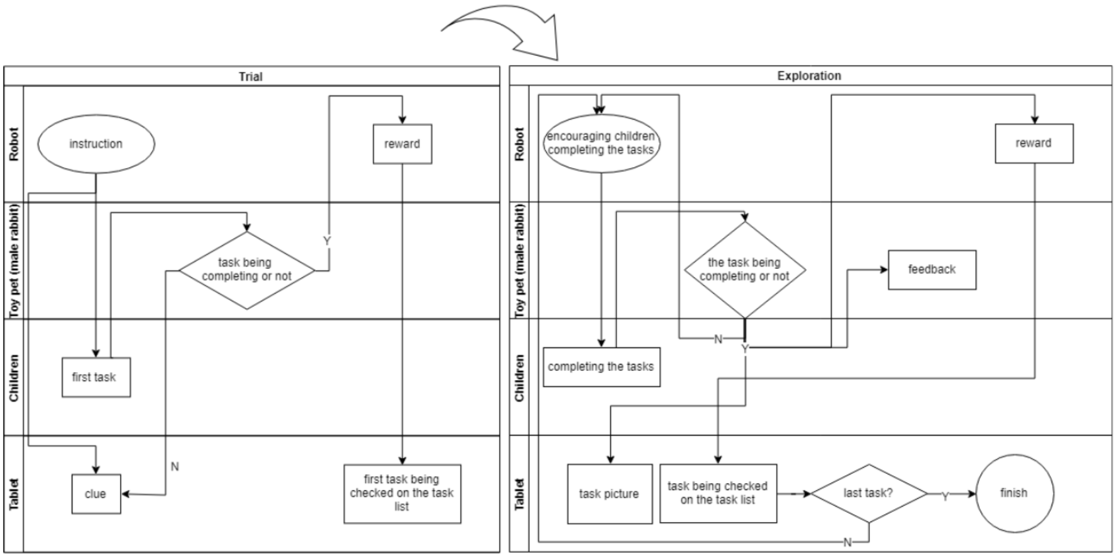

Figure 3. Flow Chart for the Trial and Exploration Stages

2.5 Participants

Two male fourth graders who attended public elementary schools in central Taiwan were recruited to each participate in a role-play game session using the proposed IoT pop-up book. The two participants underwent similar English curriculum at school, which expected them to own a vocabulary of 100 to 200 words. Based on the General English Proficiency Test for Kids, both learners reported an equivalent proficiency of A1 on the Common European Framework of Reference Test. Specifically, Learner A achieved 72%, while Learner B achieved 100% in the Listening Section; and for the Reading and Writing Section, Learner A achieved 48%, which was higher than Learner B’s performance (28%). It was likely that Learner B’s weekly verbal interactions with a native English-speaking tutor and daily interactions with his Mandarin-English bilingual mother allowed him to perform better in listening. On the other hand, Learner A received intensive reading instruction at school and from a tutor with a degree in Applied Foreign Languages. Both learners frequently used multimedia tools (e.g., computers and iPads) to play games or watch videos. Learner A completed the session in his own home, while the other (Learner B) in a playroom at a Research Center for Smart Learning. One author served as a facilitator during the two game sessions. Figure 4 provides photographs of both learners’ engagement in play sessions.

Figure 4. Learner A (left) Checking the Guidebook & Learner B (right) Checking with the Facilitator

2.6 Instruments and Analyses

This study mainly employed a video analysis (Debski, 2019) to examine learner engagement in the IoT-based pet-care game. The recording involved the participants’ play sessions during all four stages of the game. Four learning trials were carried out by Learner A and two trials were undertaken by

Learner B due to system overloads caused by the learners' repeated response errors. Two of the authors viewed the two video recordings several times and discovered that both learners were intensely focused on the game sessions. Consequent investigation on specific movements as engagement patterns was therefore carried out. They classified the learners' engagement using a criteria list adapted from a previous study by Yang (2011), who examined language learners' engagement from behavioral, cognitive, and emotional perspectives (Fredrick, Blumenfeld, & Paris, 2004). As such, the two learners' physical, facial, and gestural acts (Lavelli et al., 2019; VanDerHeyden, Snyder, Sevin, & Longwell, 2005) were categorized as behavioral engagement; their reactions toward the task demands prompted by the robot (e.g. taking the rabbit doll to eat in the kitchen) were categorized as cognitive engagement; and their facial expressions were considered as emotional engagement. The time elapsed for each engagement instance was also added up and converted to percentages as part of the entire play time (excluding the system breakdown time). The total valid play time was 26 minutes and 27 seconds for Learner A and 19 minutes and 46 seconds for Learner B. Mainly, the authors examined both learners' reactions to the robotic instruction and prompts for interacting with the pop-up book, and tried to measure the proportion of time spent on each type of engagement. The classification of engagement types is shown in Table 2 in the result section. For example, an instance of behavioral engagement was touching any part of the pop-up book, the number of times the learner touched the pop-up book was recorded, then the elapsed time for all the instances of this act were converted to a percentage for assessing whether the learners spent a long time on a specific type of engagement instance. In contrast, disengagement was also observed and analyzed. However, only one instance was identified when the learner was not looking at the pop-up book, rabbit doll, the educational robot, tablet PC, or the facilitator. In summary, the video analysis included two aspects — (a) the frequency of engagement instances, and (b) the accuracy of response to robotic prompts for Learner A and Learner B.

3. Results

A preliminary video analysis led to analytical findings on engagement, including (a) frequency of cognitive, behavioral, and emotional engagement, and (b) response accuracy in the multimedia, sensory-motor learning experience facilitated by the IoT-based 3D pop-up book.

First, in terms of frequency analysis, the results show that both learners were highly engaged throughout their respective play session. Specifically, two engagement instances, *touching the pop-up book* (an instance of behavioral engagement) and *responding to robotic prompts* (an instance of cognitive engagement) were identified as the most frequent actions taken by both learners. There was only one disengagement instance (when the learner was not looking at anything in the IoT system), which occurred four times for Learner A.

Figure 5 shows graphically the frequency of major instances identified by the authors. The major instances identified belong to either behavioral or cognitive engagement. There was also an interrelationship between behavioral and cognitive engagement. When learners responded to robotic prompts, they were actually trying to use the rabbit doll to touch the correct NFC sensor, or turning the pop-up book to face the target room for task completion. It was also found that the time spent on these two behaviors (touching the pop-up book and responding to robotic prompts) occupied a relatively large proportion of the entire play session for both learners. Other engagement instances were *looking at the tablet*, *looking at any part of the pop-up book*, and *holding onto the rabbit doll*. Again, these instances show that the learners were trying to collect information using visual cues from the tablet PC in order to respond correctly to the robotic prompts.

Secondly, concerning the accuracy in responding to robotic prompts, the accuracy rate for both learners increased as time passed by over their respective game session. By the end, Learner A responded accurately to 43.6% of the prompts in the four learning trials (17 correct and 22 incorrect responses), and Learner B responded accurately to 70.3% of the prompts in the two learning trials (26 correct and 11 incorrect responses).

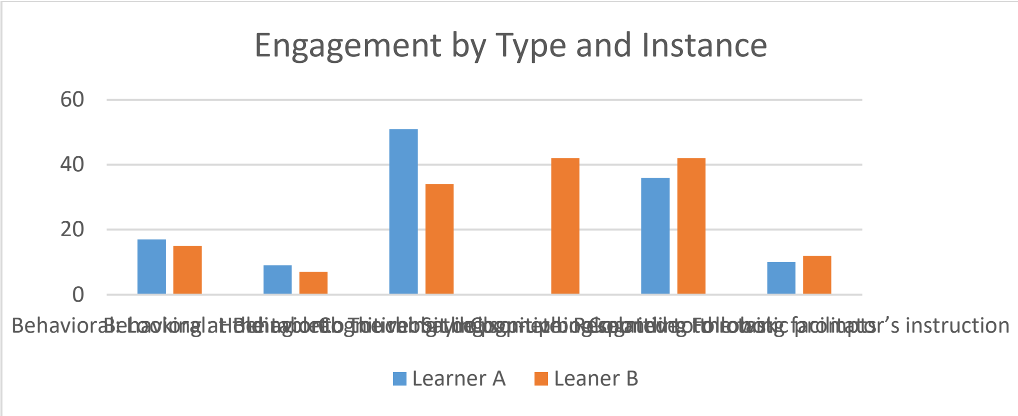

Figure 5. Behavioral and Cognitive Engagement during the Pet-Care Game

Table 2. *Frequency of Engagement Instances*

Engagement Type	Actions Taken during the Pet-Care Game	Learner A	Learner B
	Specific Instances of Engagement		
Behavioral	Holding onto the rabbit doll	9	7
	Looking at a specific part of the pop-up book	20	5
	Looking at the tablet	17	15
	Touching the pop-up book	51	34
	Looking at the facilitator	2	4
	Nodding Head (Signal: Feeling accomplished)	0	2
	Shaking head (Signal: Feeling frustrated)	0	1
	Shrugging (Signal: Seeking help from the facilitator)	0	1
Cognitive	Saying something related to the task	0	42
	Responding to robotic prompts	36	42
	Following the facilitator's instruction	10	12
Emotional	Facial expressions showing feelings of joy (+)	0	3
	Facial expressions showing feelings of surprise (+)	0	1
	Facial expressions showing feelings of accomplishment (+)	2	1
	Facial expressions showing feelings of frustration (-)	0	2
	Total Number of Engagement Incidents	**147**	**172**

Two instances of cognitive engagement, *saying something related to the task* and *following the facilitator's instruction*, yielded interesting findings. Concerning Learner B's verbal reaction of talking about the task, the authors identified his high cognitive engagement through talking in the role-play activity. Learner B would ask questions from the perspective of the pet-raiser. He was into the role and would say aloud target words that were unfamiliar to him, for example, as he took the rabbit doll into the Kitchen, he showed that he did not know the meaning of the word *cook* by asking "*Cook*? What is that [What does that mean]?" However, as he looked at the guidebook's kitchen-related visual cues, he was able to connect the target vocabulary to the actual kitchen in the 3D pop-up book. He also asked questions in Mandarin Chinese during the pet-care game procedure, such as "Which room should we go now?" when prompted to go to another room, or "Why don't you want to brush your teeth?" when the IoT system gave him feedback on touching the wrong NFC sensor for a task (Brushing Teeth). On the contrary, Learner A remained speechless throughout the play session. This finding revealed that verbal expression, was an instance of cognitive engagement, was learner-dependent. This specific kind of cognitive engagement ultimately affected task performance. As shown by Figure 6, on the accuracy of responses to robotic prompts, Learner B, who was highly engaged in *saying things related to the task,* performed better than Learner A.

With regards to *following the facilitator's instruction*, both learners benefitted greatly from the facilitator's assistance, which was an external facilitation mechanism of the IoT system. The facilitator provided verbal cues to both learners under specific circumstances such as when the learner repeatedly used the rabbit doll to touch NFC tags but could not reach the correct sensor that matched the prompt. The facilitator would say in English (indicated by italicized text) the target vocabulary such as "*Lunch*" in a question phrased in Mandarin Chinese "Where would you eat *lunch*?" Then the learner would think about the clue and then find the right NFC sensor to complete the task accurately. For the instance on *following the facilitator's instruction*, Learner B actively asked the facilitator questions and got more cues to complete the game than Learner A. This engagement act, along with his higher listening proficiency than Learner A, might be the reason that Learner B achieved a higher accuracy rate than Learner A. This finding implies that even though the learners were highly engaged with the 3D pop-up book learning activity through role-playing and task completions, they still relied heavily on feedback from a human facilitator. One important implication concerning the design of such IoT-based pop-up books is the potential of inserting human-like questions that would guide learners through tasks as they made errors. The questioning mechanism could be added in future designs of similar game-based activities.

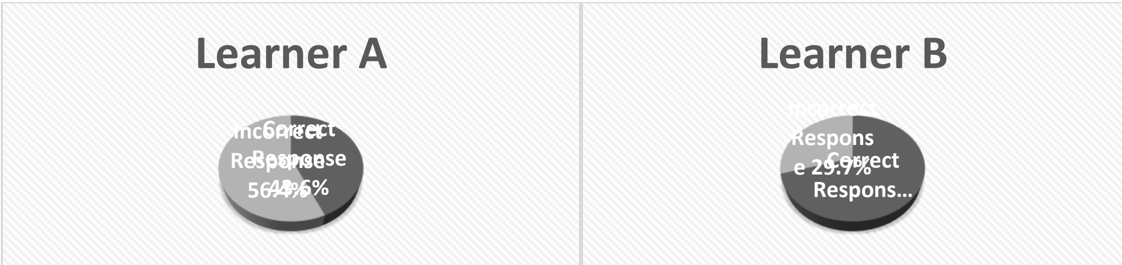

Figure 6. Accuracy of Responses to Robotic Prompts

Overall, the augmented IoT-based 3D pop-up book scripted in English provided a sensory-motor interactive learning experience that effectively engaged target fourth-graders. In particular, physical and cognitive behaviors such as touching the pop-up book and following robotic prompts to fulfill the daily life tasks engaged learners in listening to English vocabulary, testing their vocabulary knowledge by identifying the correct NFC sensor. Moreover, as the analysis on Learner B's verbal reactions demonstrated, the role-playing activity could effectively engage children in responding verbally. That is, Learner B would talk about target learning content as he tried to respond to the robotic prompts. The video-based observations therefore led to the finding that as both learners gained more experience playing the pet-care game throughout the game session, they became more capable of following the English robotic prompts and reacted more quickly and accurately toward the end of the game.

5. Discussion

The first research question investigated how English practitioners could design and develop an IoT system that included various components such as a 3D pop-up book, a toy character, educational robot, and a NFC sensor network. In response, the development of such a learning system can adopt an interaction-based learning framework that consists of three main entities － the learner, the toy, and the educational aid (e.g., a robot accompanied a tablet PC). With this game-based learning activity design, the affordances of toys and the IoT learning environment could be utilized. In the case of the pet-care game, providing a rabbit doll character allows the learner to be a pet-raiser and take the rabbit to different places of the 3D pop-up house for daily tasks. In these interactions, the learners' listening comprehension skills in vocabulary and sentences can be improved through trial and error under the robotic instruction.

The feedback mechanism from the robot gave the learners an opportunity to practice English listening in the zone of proximal development (ZPD; Vygotsky, 1978) provided by the IoT-augmented pop-up house. As put forth by Vygostky (1978), when learners engage in problem-solving tasks beyond their actual ability level, appropriate guidance such as scaffolding activities can help them achieve the task successfully, thereby increasing their knowledge or skills in the process. Developing an IoT sensor network to create a ZPD with role-play and the four progressing stages (Introduction, Warm-Up, Trial, and Exploration) was a useful strategy for engaging children in authentic listening with context-specific target vocabulary.

In addition, a common pattern identified in both play sessions revealed that the accuracy rate of responding to robotic prompts was much higher in the last trial for both learners. This implied that as the learners interacted with the IoT-augmented game environment, their English listening and responding abilities improved as they progressed through the scaffolding mechanisms. It was found that the learners gradually accepted the new mode of learning with a sensory-motor, stimulus-response manner.

The second research question probed into learning activity design for engaging the two target fourth graders in learning English vocabulary. In this regard, it was found that three types of engagement (behavioral, cognitive, and emotional) could be enhanced with an IoT-augmented game to help learners gain vocabulary about different rooms and objects in a house. Among behavioral, cognitive, and emotional engagement, cognitive engagement stood out to be the most frequent of the interactions (e.g. responding robotic prompts, following facilitator's instruction, verbal expressions), followed by behavioral, and emotional engagement. Such findings about the IoT-augmented pet-care game echo claims about the effectiveness of using play-based instruction to engage children in cognitive and social-emotional development (Cielinski, 1995). As the learners went through role-play tasks, they were also involved in social-interactional play-based learning. It has been argued that intelligence is connected to play (Piaget, 1962). Beneficial outcomes on child development have also been reported when children are engaged during play; as they interact with physical and social elements of the environment, they undergo challenging learning experiences and develop cognitively, emotionally, socially, and physically (Dauch et al., 2018). To summarize, effective design of IoT-augmented games should bear features that can lead to child play. Specifically, activity design should focus on creating scaffolding mechanisms for (a) physical interactions with toys via multimedia affordances, (b) cognitive engagement through listening to prompts and eliciting verbal learner responses, (c) stimulating social interactions, and (d) fostering positive emotions.

6. Conclusion

This study presented the design of a pet-care game on a 3D pop-up book augmented by an IoT sensor network. The participants fulfilled the role of a pet-raiser, and simultaneously listened to English instruction from the Guidebook from the IoT system. The learners' duty was to take a rabbit doll to touch various NFC tags in the 3D pop-up book. Both learners were highly engaged with cognitively and behaviorally. Findings also revealed that such an IoT-augmented role play game environment could effectively engage children in sensory-motor reactions that ultimately led to improvement in English vocabulary and listening. Surprisingly, the study also identified the importance of human facilitators in IoT-based games. Future studies can examine how learners' immersion into role-play (e.g., verbal interactions) may enhance cognitive engagement and therefore game performance and language learning outcomes in an interactive IoT environment. Finally, it will be worthwhile to investigate how instructors may serve as effective facilitators during IoT-based language learning.

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