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Exploring the Impact of Designing a Robot as a Pet with Interdependence Theory on Long-Term Relationships and Learning Performance

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Abstract: Educational robots have shown promise in enhancing learning performance; but, many of these robots function solely as companions or tutors and rely on novelty to attract attention, making it challenging to maintain long-term relationships. Although pet robots have been utilized to create relationships with users, their potential in education remains underexplored. This study addresses this issue by designing a robot as a pet, applying the interdependence theory to establish lasting relationships and improve learning performance. The interdependence theory suggests that relationships between individuals can be strengthened through mutual dependence and the fulfillment of each other's needs. In this study, learners were prompted to engage in continuous care for their pet robots, receiving emotional reinforcement from them seamlessly across both virtual and tangible forms enabled by the ChatGPT API. To culminate their learning process, learners presented their ultimate learning outcomes alongside their pet robots, enacting situational dramas for their classmates. To evaluate the effectiveness of this approach, a quasi-experiment was conducted with 100 undergraduate learners enrolled in a Japanese for Hospitality and Tourism course in Taiwan. Results indicate that robots designed as pets, leveraging interdependence theory, significantly yield positive effects on learners, encompassing improved learning outcomes, extended interaction rates, and heightened satisfaction with their study journey compared to conventional robots. The study concludes by discussing research limitations and offering suggestions for further enhancements to this approach.

Keywords: Educational Robots, Pet Robots, Long-Term Relationships, Interdependence Theory, Situational Learning, Human-Robot Interaction

1. Introduction

In recent years, the use of robots to support learning has gained significant attention among scholars (Belpaemae et al., 2018; Mubin et al., 2013). Previous studies have demonstrated the potential of robots to engage learners and stimulate their interest in interacting with learning materials (Al Hakim et al., 2021; 2022a; Lin et al., 2022). However, since learning often requires several weeks or months to complete, it is essential for robots to develop enduring relationships with learners to maintain their engagement for an extended period.

Establishing long-term relationships with robots has been identified as a significant factor in the realm of robotics (Westlund et al., 2018; Leite et al., 2013). This is because learning and behavioral changes often require continuous engagement and repetition, rather than just a single interaction. However, as the frequency of interactions increases, the initial novelty effect may diminish, potentially affecting the efficiency of learning.

One promising approach to cultivating long-term relationships is drawing inspiration from the bond between pets and their owners (Díaz-Boladeras, 2022). Research has shown that treating robots as pets can elicit positive emotional engagement and attachment (Westlund et al., 2018). The relationship between pet owners and their pets is well-documented, with pets providing emotional support and interacting with them fulfilling social needs, promoting happiness, and fostering healthier personality traits (McConnell et al., 2011). A well-known illustration is Tamagotchi, a virtual pet that sends reminders to users for their care (Lawton, 2017). Despite its simple design, users often interact with Tamagotchi extensively, creating a connection where they care for the pet and receive emotional support. In education, interdependence was studied by Johnson & Johnson (2009), highlighting its importance for successful ongoing collaboration.

Building upon the groundwork laid by Al Hakim et al. (2023) regarding pet-like robot models, our study bridges gaps by investigating their impact on education. Through a novel learning design rooted in interdependency, seamless integration of technology for ubiquitous learning, and a comparative evaluation, we aim to enhance educational robot design. Specifically, we explore learners' potential to establish lasting relationships with pet-like educational robots. By imbuing robots with needs like feeding, we stimulate interaction rates. Furthermore, the robot's presence may provide emotional support, enhancing satisfaction with the experience and covered material. This study is guided by the research questions:

(1) Does a pet robot established with an interdependence mechanism enhance learning outcomes more effectively than a conventional robot?
(2) Does a pet robot established with an interdependence mechanism increase interaction rates more effectively than a conventional robot?
(3) How does the use of a pet robot with an interdependence mechanism, in comparison to a conventional robot, impact learners' acceptance of learning?

2. Related Works

2.1 Robots in Education

Robots have emerged as a prominent area of research in education, witnessing significant growth and diverse applications. They have been explored as tutors or peer learners, yielding positive outcomes in cognitive and emotional outcomes comparable to human tutoring (Belpaeme et al., 2018). They can also serve various functions and be applied in different areas of education, including language, science or technology education (Mubin et al., 2013). Despite the numerous studies on educational robots, there is still a lack of study concerning the establishment of long-term relationships with these devices. To address this, it is crucial for robots to have specific roles and interaction modes that can sustain user engagement. Previous research has mainly focused on the role of educational robots as a tutor or friends with personal conversation (Ligthart et al., 2023), or storyteller companions (Calvo-Barajas & Castellano, 2022), which relies solely on social and affective behaviors.

2.2 Pet Robots and Long-Term Relationships

The introduction of Bandai's "Tamagotchi" in 1996 marked a significant milestone in the acceptance of virtual pets, owing to their portability and sociability (Lawton, 2017). As a result, many studies related to artificial pet have become popular topics of study. Bylieva et al. (2019) conducted a literature review that traced the development of artificial pets from the 1990s to the 21st century. They identified social interaction as a crucial factor in sustaining relationships with artificial pets. However, the exact definition of a "long-term relationship" remains a topic of debate within the domain of human-robot interaction (Díaz-Boladeras, 2022). While there is no consensus on the specific duration or number of interactions required, a long-term relationship is generally believed to emerge when the user becomes accustomed to the robot and the novelty effect no longer influences their perception of it (Leite et al., 2013). Díaz-

Boladeras (2022) suggests measuring the long-term relationship based on changes in behavior, such as the rates of use, rather than relying solely on the time span.

Furthermore, the relationship mechanism between a user and a robot is a vital aspect to consider. Frude and Jandrić (2015) introduced the concept of "animism," which suggests that humans tend to attribute life and consciousness to non-living objects, thereby fostering emotional bonds. This concept highlights the potential for users to form attachments with robots. Similarly, Heljakka et al. (2021) discovered that the relationship between users and robot dogs can deepen over time as they spend more time together. However, the precise mechanisms underlying the establishment and maintenance of such relationships have yet to be fully explored in these studies.

2.3 Interdependency Theory

The concept of interdependence was first introduced by John Thibaut and Harold Kelley in 1959, encapsulating elements such as dependence, power, norms, rules, cooperation, and coordination. It explains the extent to which two or more individuals rely on each other to achieve their goals within a specific context (Van Lange & Rusbult, 2014). Furthermore, Johnson and Johnson (2009) found that positive interdependence in cooperative learning can enhance individual responsibility and achievement and foster long-term group cohesion.

When it comes to pet robots, the concept of interdependence is crucial to consider. If an owner is tasked with caring for a pet robot and the robot reciprocates by providing companionship, the resultant interdependence can foster a long-term relationship. This imbues the owner with a sense of responsibility and enhances their willingness to learn with the robot. As such, this could increase the overall interaction rate between the learner and the robot, leading to a stronger relationship and potentially improved learning outcomes.

2.4 Situational Learning

Situational learning is an active learning approach that emphasizes the application of real-world experiences and practical knowledge. It was first introduced by Brown et al. (1989) and draws on the principles of apprenticeship, imitation, and practical thinking, as identified by Lave and Wenger (1991). In situational learning, learners are immersed in hands-on activities and real-life scenarios, providing them with opportunities to solve problems and apply theoretical concepts they have learned.

One of the key features of situational learning is its versatility, with researchers leveraging drama and role-playing to create scenarios that allow learners to showcase their learning outcomes. By embedding the learning material in dialogues within a structured script, learners are guided through interactive exchanges and scenarios that facilitate effective learning. For example, Erbay and Doğru (2010) used drama to have learners perform together, fostering both subject knowledge acquisition and social interaction. Similarly, Al Hakim et al. (2022a) proposed an interactive situated learning approach using a real-time feedback mechanism to guide and evaluate learners' knowledge application through interactions with robots, virtual objects, and virtual characters based on textbook context and content to enhance learning performances. By providing opportunities for learners to engage in role-play activities and real-world problem-solving, situational drama learning helps learners develop a deeper understanding of course material and cultivate particular skills.

2.5 Summary

The literature review highlights that robots have a positive impact on education, but the use of pet robots in education and research on establishing long-term relationships with them is limited. The potential benefits of utilizing pet robots in education are apparent, and this study aims to use interdependence to create a lasting relationship between the robot and the evident. Such a relationship would enhance the user's learning experience and outcomes. Finally, learners can apply their learning results by participating in situational drama role-playing scenarios with their pet robots, showcasing their ability to use the skills and gained knowledge.

3. System Design and Implementation

3.1 Learning Design

The aim of the devised learning design was not to supplant teachers' instructional approaches, but rather to employ the learning system as a means to amplify the efficacy of their teaching. Our learning design focused on fostering interdependence between learners and robots, nurturing lasting relationships and enhancing learning performance. The design integrated collaborative cooperation and mutual reliance on incentives (Johnson & Johnson, 2009; Van Lange & Rusbult, 2014), aligning learners and pet robots toward the shared objective of maintaining the pet's well-being through collaborative learning tasks that yielded food rewards. Learners, assuming roles as caregivers and trainers, engaged in interactive tasks simulating pet care duties, directly influencing the pet robot's well-being and its performance in situational dramas. In this dynamic, pet robots served as companions and performance partners, providing emotional support, companionship, and feedback. Learning materials, encompassing foundational knowledge and a dialogue-based script, expertly curated by teachers, were seamlessly integrated into a comprehensive learning script. This script served as both presentation material and guidance, to be learned by both pet robots and learners for their ultimate situational drama presentations.

3.2 Seamless Technical Design

To overcome the limitations of physical pet robots, virtual pets were introduced as a complementary solution, seamlessly integrated with the physical pet robots. They were powered by the ChatGPT API, which is an interface that allows developers to integrate the ChatGPT language model into their applications, providing advanced language capabilities, contextual understanding, and dynamic interactions. The virtual pets enabled ubiquitous communication and interaction, providing flexibility in terms of availability, capabilities, and class usage time. In the execution of the ChatGPT API program utilizing Python 3.11.3 and the GPT-3.5-turbo model, teachers effortlessly uploaded scripts in PDF, Word, or XLS formats to a designated server PC directory, establishing a custom knowledge base for the AI model.

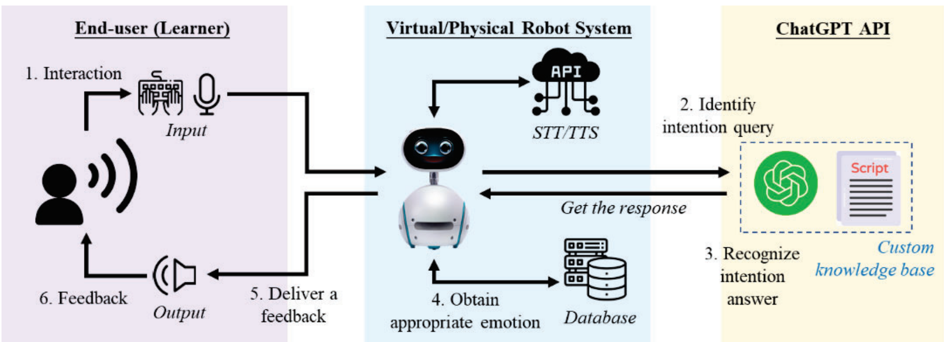

Figure 1. Communication mechanism linking the learner and the robot.

The ChatGPT API not only produced text responses from the custom knowledge base but also played a pivotal role in instructing the virtual and physical pet robots to express emotions through facial cues and body movements (as depicted in Fig. 1). For instance, when a learner posed a question that elicited the response "I feel sad now," the API could include instructions like "*Exhibit a [sad] facial expression while [nodding] in disagreement.*" This integration empowered the robot to not only respond textually but also embody emotions and actions, elevating interaction and immersing students in a more engaging learning experience.

Throughout the study, virtual pets accompanied learners during their out-of-class study sessions, fostering continuous engagement and interaction. Ultimately, the virtual pets seamlessly merged with the physical pet robots, allowing learners to showcase their final learning outcomes through captivating situational dramas in front of the class.

3.3 System Structure

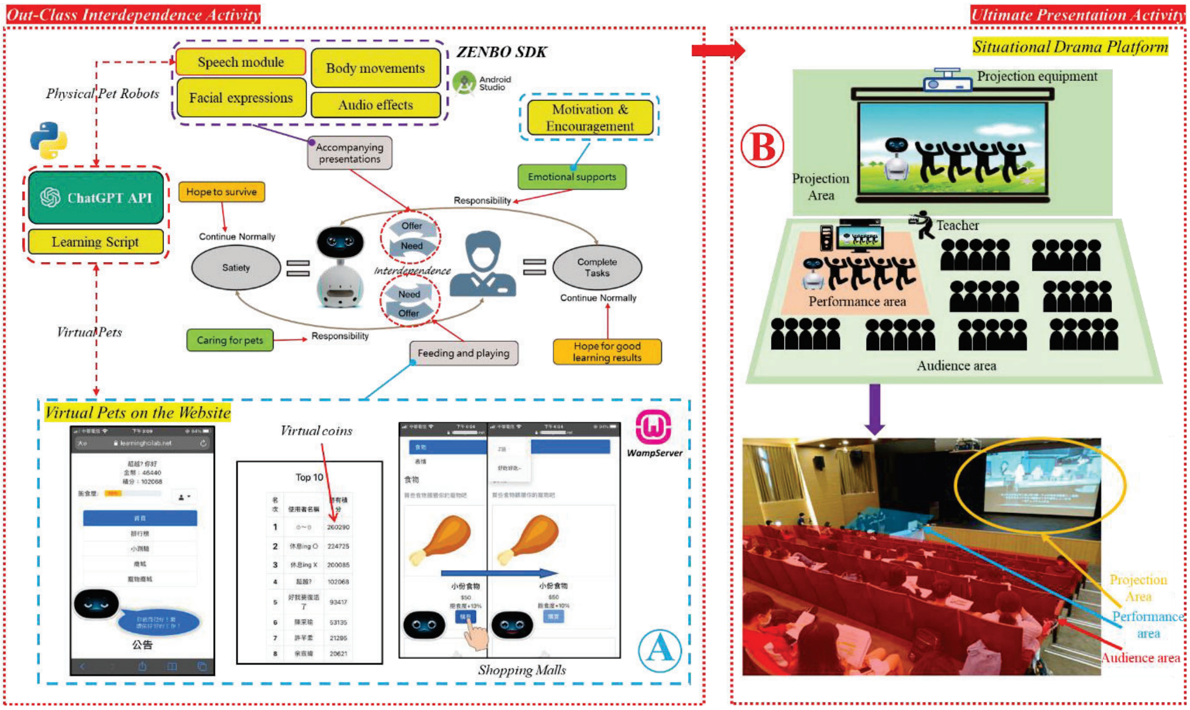

Figure 2. System architecture of pet robot with an interdependence mechanism.

The system, built upon the foundation of the Al Hakim et al. (2023) model, comprised three integral components: a virtual pet embedded within a website (Fig. 2 [A]), a dedicated situational drama platform (Fig. 2 [B]), and a physical pet robot.

The web-based online learning platform was developed using WAMP and offered quizzes and a shopping mall. This platform empowered learners to engage in independent study outside the classroom while fostering a sense of companionship with their virtual pets. Teachers could easily insert quizzes through a user-friendly interface, customizing question content, answer choices, and feedback. Each completed quiz rewarded learners with virtual coins. The shopping mall provided an opportunity for learners to use their earned coins to purchase pet food and accessories. Through the web platform, virtual pets acted as supportive companions, offering encouragement and assistance to learners in their learning journey.

The situational drama platform to enable learners to showcase their learning outcomes through interactive drama performances. The platform is an immersive computer-based system that seamlessly connects a tablet app and the physical robot, allowing the design and performance of various learning scripts. This integration enabled learners to create interactive presentations that incorporated the physical pet robot, ultimately enhancing their learning experience and promoting their understanding of the material presented.

In this study, the ASUS ZENBO robot served as the foundation for developing the physical pet robot, establishing a tangible connection with its virtual counterpart. The developed pet model was meticulously integrated with the ZENBO SDK, harnessing its capabilities in facial expressions, body movements, audio effects, and speech module. Notably, the speech module was seamlessly integrated with the developed ChatGPT API model, enabling the physical pet robot to receive and process the user's voice, facilitating advanced language recognition and understanding. Consequently, the physical pet robot would react with a captivating array of vibrant expressions, speeches, and bodily gestures, faithfully replicating the actions and demeanor of the virtual pet. This cohesive integration between the tangible and virtual pets cultivated an exclusive and dynamic bond, enabling learners to engage in an interactive educational voyage that effortlessly traversed the confines of both the virtual and physical dimensions.

4. Method

4.1 Participants and Learning Materials

The study involved 100 university learners enrolled in Japanese for Hospitality and Tourism in Taiwan. They were divided into two groups, namely the experimental group (21 females and 29 males) and the control group (23 females and 27 males), which were further subdivided by the teacher. The groups were kept separate from each other during the experiment to ensure unbiased evaluation of the results. All participants were approximately 20 years old.

The focus of the study was on managing hospitality in Japanese restaurants that are pet-friendly. The study material encompassed several topics such as the culture of Japanese restaurants and the application of courteous expressions, all of which were incorporated into the learning script and inserted into the quizzes in the website. During the drama presentation, learners and the robot engage in a restaurant scenario. Below is an excerpt of the dialogue-based script about the culture of Japanese restaurants (translated from Japanese).

ZENBO: ("excited expression" and "spinning around") Hi there, nice to meet you!

Waitress: (surprised) Oh, a talking pet! That's amazing. Well, we're happy to have you both. Just to let you know, we do allow pets in our restaurant, but we ask that they remain on a leash and well-behaved.

Customer: Thank you for letting us know. I promise to keep him on a leash. And while we're waiting for our food, could you tell us a little more about Japanese restaurant culture?

Waitress: Of course! In Japan, it's considered polite to use honorific expressions when addressing others, especially in a formal setting like a restaurant. So instead of saying "you," we use "anata" or "omae." And it's also important to show gratitude and respect to our customers, so we always strive to provide the best service possible.

4.2 Measuring Tools

To evaluate the learners' learning outcomes, interactions, and acceptance, multiple assessment tools were employed. These included pretest and posttest questionnaires that had 15 questions each and a maximum score of 100. The teacher developed these tests and administered them before and after the experiment. In addition, database logs were used to measure interaction rate, while a five-point Likert scale questionnaire was employed in the after the experiment to measure learning acceptance. The questionnaire was based on the owner-pet relationship (McConnell et al., 2011) and learning technology acceptance (Hwang et al., 2011), modified to suit the context of the study, and consisted of 18 questions categorized into three dimensions: robot design, co-learning with the robot, and learning uses online platform. The questionnaire in this study showed high reliability with a Cronbach's α value of 0.907 (N=100). The reliability of the three dimensions was confirmed by the Cronbach's α values, which were 0.88, 0.90, and 0.83, respectively. Interview questions based on Al Hakim et al (2022a) were also adapted to explore factors that may impact learners' willingness to learn with proposed approach. It consisted of six questions that were open-ended, such as "Overall, what do you think are the advantages of learning with the system?".

4.3 Procedure

The experiment spanned over six weeks and consisted of four stages, each with two hours of classes per week, followed by mandatory online practice.

- Stage I occurred during the first week and involved a pre-test, introduction to learning scripts, and an overview of the study's system and online learning website.

- During the second to fourth weeks (Stage II), learners continued to learn course materials and practiced using the online learning website independently.
- Stage III took place during the fifth week and involved drama rehearsals where learners became familiar with the situational drama performance process and practiced with the robot under the teacher's guidance.
- The final stage, Stage IV, was the official drama performance that occurred during the sixth week. Learners demonstrated their final learning results with the robot on situational drama platform, with each group performing independently without assistance. Post-tests, questionnaires, and interviews were conducted after the performance.

Both the experimental and control groups followed the same four-stage experimental process, were taught the same materials by the same teacher, and used online learning websites. However, the experimental group used a learning website with a virtual pet robot that required learners to obtain virtual coins during online practice to purchase food and take care of the virtual robot's cages. The control group used a website without a virtual pet robot for learning. During the drama performance, the experimental group used a physical robot with pet characteristics that displayed lively expressions and actions according to the script, while the control group used a general robot that only read script lines and did not have pet functions.

5. Findings

5.1 RQ1: Learners' Learning Outcomes

The analysis employed analysis of covariance (ANCOVA) to compare the post-test scores of the experimental and control groups, with the pre-test scores used as a covariate. The homogeneity test of intra-group regression coefficient revealed no significant interaction between the two groups and the pre-test scores (F = 0.42, p = 0.29 > 0.05), allowing the use of pre-test scores as a covariate. Subsequently, ANCOVA was utilized to analyze the post-test scores of the two groups. The results of the statistical analysis, as displayed in Table 1, indicate a significant difference in the mean scores between the experimental and control groups (F = 2.19, p = 0.01 < 0.05). This suggests a notable disparity in the post-test scores between the two groups.

Table 1. *ANCOVA result of learners' learning outcomes*

Group	N	Mean	SD	Adjusted mean	F	η^2
Experimental	50	80.98	4.89	81.03	2.19*	0.07
Control	50	76.21	6.89	75.46		

*p < 0.05

The findings support the claim that a pet robot equipped with an interdependence mechanism is a more effective tool for improving learning outcomes compared to a conventional robot. These results align with earlier investigations (Chen, 2012; Lin et al., 2022) that have demonstrated the positive impact of including a pet-like interaction mode in the learning system, which enhances learners learning achievement. By taking care of their virtual pets, learners felt a sense of responsibility, knowing that neglecting their pet would result in its demise, thereby encouraging them to learn and earn virtual coins to buy supplies. Assigning each learner an interdependent pet can, therefore, foster a sense of duty towards the pet and their own learning, ultimately leading to improved learning outcomes.

5.2 RQ2: Interaction Rates

The average daily interaction in learning activities was recorded for both the control and experimental groups across four stages. Results show that the experimental group had significantly higher activity levels than the control group (see Fig. 3). This suggests that the presence of the pet robot served as a stimulus for the learners to engage more actively in the learning process. This phenomenon is attributed to the reciprocity of pet care (Lawton, 2017; Chen, 2012), where pupils engage in more interactions to take care of their pets by feeding and playing with them. In this study, learners increase learning frequency to earn coins and purchase pet food due to the need to take care of the pet robots, while pet robots provide feedback and support to learners at all times, forming a positive interactive relationship that keeps learners engaged in learning activities. Notably, based on the Figure 2, it was observed that the interaction rate among the experimental and control groups continued to increase in the final stage, that is official drama performing. This might attribute to the motivation-driven effect (Al Hakim et al., 2022b), which compelled learners to study before the final exhibition with the robots to be displayed to classmates and teachers.

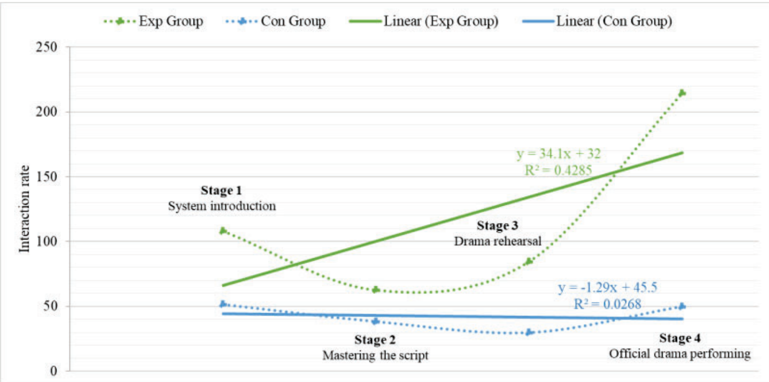

Figure 3. The average daily interaction in learning activities among groups.

5.3 RQ3: Learners' Acceptance of Learning

The responses to the questionnaire were analyzed with independent *t*-test to compare the learners' acceptance of learning after the treatment. A shown by Table 2, in terms of the design perception of the robot, both groups interacted with the physical robot and had similar perceptions, with no significant difference found (p = 0.620 > 0.050). It means that both of groups felt that the appearance, expression, voice, and interaction of the developed robot models, whether it has pet feature or not, were similar. In terms of co-learning with the robot, both groups scored higher than the average level, with the experimental group having a significantly higher average score (M = 4.130) than the control group (M = 3.850), indicating that pet robots can provide a better educational encounter for learners. On the other hand, there was no significant difference between the two groups in terms of user acceptance when using the online learning platform with or without the pet robot function (p = 0.220 > 0.050).

Table 2. *T-test result of learners' acceptance of learning*

Dimension	**Group**	**Mean**	***SD***	***F***	**Sig.**
Robot design acceptance (e.g., *I find ZENBO's appearance and expressions adorable, like a pet*)	Experimental	3.70	0.76	0.253	0.617
	Control	3.61	0.79		
Satisfaction of co-learning with the robot (e.g., *Having ZENBO as a companion has helped me learn the materials better*)	Experimental	4.13	0.66	8.91	0.004*
	Control	3.85	0.94		
Satisfaction of using the online platform (e.g., *The online learning platform has enhanced my learning experience*)	Experimental	3.61	0.45	1.523	0.222
	Control	3.60	0.59		

*p < 0.05

Furthermore, to gain a better understanding of how learners perceive the proposed learning approach, ten-minute interviews were conducted with six learners from the experimental group, representing high, medium, and low academic achievement. The outcomes of these interviews revealed intriguing findings. Firstly, learners expressed their fondness for the pet robot's cute appearance and lifelike behavior, finding them highly appealing. Motivated by a sense of responsibility towards their virtual pet and a genuine fear of it going hungry, learners engaged with the robot more earnestly. They also highlighted the seamless connection between the virtual and physical pet robots, enabling them to extend their emotional bond from the virtual realm to the physical world. However, some interviewees suggested that incorporating more pet-like facial expressions and personalized interactive modes could greatly enhance the enjoyment factor of interacting with pet robots. Specifically, they expressed their desire for interactive behaviors like cuddling and spinning, which would further enrich the design and interaction possibilities of the pet robot.

These insightful interview responses indicate that the proposed learning approach not only captivates learners by leveraging the novelty of the robot but also fosters motivation through a heightened sense of responsibility towards their virtual pets. Furthermore, learners expressed their anticipation for more design options and personalized responses from their pet robots, reflecting their eagerness to have a unique and customized pet robot that builds upon the established relationship.

6. Conclusion, Drawbacks, and Further Research

This study presents a novel approach to educational robot design by integrating interdependence theory. The aim is to develop pet robots that establish enduring relationships with learners, thereby enhancing their learning performance. The interdependent pet mechanism, encompassing the owner's responsibility for the pet's care and the pet's provision of emotional support, is seamlessly integrated into both virtual and physical platforms, along with situational drama learning presentations. This integration empowers learners to take care of their pet robots anytime, anywhere, fostering a sense of responsibility for their own learning.

The results of the experiment indicate that robots designed as interdependent pets have a more positive impact on learners in terms of learning outcomes, long-term interactions, and acceptance of learning than conventional robots. The study provides a new insight on the use of robots in education, combining generative AI, mobile and reality technologies, and practices, resulting in an intelligent learning environment where robots act as interdependent pets. Educators and system developers can incorporate this approach into the learning system to create a highly engaging and interactive learning experience for learners, enabling them to establish lasting relationships with learning agents and improve their learning performances.

However, this study was limited conducted on a Japanese for Hospitality and Tourism course for university learners, making it uncertain whether the findings can be generalized. Further experiment could explore the potential of this approach for other age groups and subjects. Also, future studies should consider several potential enhancements to pet robot design based on valuable feedback received from learners. Firstly, there is a need to expand and enhance the range of pet-like features beyond basic interactions such as satiety and basic expressions. Incorporating a broader spectrum of pet emotions, improved cleanliness, and more specific behaviors and attire could potentially increase user interest and willingness to engage with the pet-like robots. Secondly, strengthening the connection between virtual and physical robots can be achieved by assigning unique names, distinct speech patterns, and individual personalities to each pet, ultimately would enhance the personalization and deepen the connection between the virtual and physical manifestations of the robots.

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