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Natural Language-Based Interface Design for Early Childhood Education Applications: A Case Study of English Language Learning

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ABSTRACT

The design of user interfaces for early childhood education applications plays a crucial role in facilitating effective learning experiences. With the rise of digital technologies, natural language interfaces have become an essential tool, particularly in language learning applications for young children. However, there remains a gap in understanding how to design natural language interfaces that are both engaging and educational for early learners. This study focuses on the design and evaluation of a natural language-based interface for an English language learning application aimed at children aged 4 to 7. The primary objective is to explore how a conversational, child-friendly interface can enhance language acquisition while ensuring usability and engagement. The research employs a design-based approach, involving iterative prototyping and testing with a group of 30 preschool children. The interface incorporates voice recognition and conversational AI to facilitate interactive learning. User feedback and performance data were analyzed to assess usability, engagement, and learning outcomes. The results indicate that children responded positively to the natural language interface, with improved engagement and retention in language learning tasks. The intuitive design and conversational elements were found to be particularly effective in maintaining attention and enhancing comprehension. This study highlights the potential of natural language interfaces in early childhood education, demonstrating that well-designed interfaces can significantly contribute to language learning in young children.

Keywords: *Early Childhood Education, User Interface Design, Natural Language Interface*

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INTRODUCTION

Early childhood education has always been a crucial phase in the development of language skills, as it lays the foundation for future academic success and communication abilities. With the rapid advancement of technology, there has been an increasing interest in incorporating digital tools to enhance learning experiences for young children. Among the most promising developments in this field is the use of natural language-based interfaces in educational applications, particularly for language learning (Hidayat dkk., 2023; Strawhacker dkk., 2020). Natural language processing (NLP) and conversational AI have opened new possibilities for creating engaging, interactive, and intuitive educational tools that respond to children's needs in real-time. These technologies allow young learners to interact with applications in a way that mimics natural human conversation, potentially making language learning more engaging and effective.

In the context of early childhood education, language acquisition remains one of the most critical areas of development, especially as children begin to interact with the globalized world where English has become a dominant language (Cavero & Valencia, 2023; Chan, 2020). The development of an interface that utilizes natural language can create a more immersive and interactive experience, fostering better engagement and helping children learn English at an early age. Despite the advancements in digital learning tools, there is limited research on how these technologies can be specifically tailored for young learners. The need for a natural language-based interface that supports early childhood English language learning remains a significant gap in educational technology research, especially for this age group.

Current digital applications for early childhood education often fail to meet the needs of young learners due to their reliance on overly complex or passive interfaces. Many applications still use traditional methods like simple click-based navigation, which might not engage children effectively or might present language learning as a non-interactive task (Ayuningtyas dkk., 2018; J. Yao dkk., 2018). This research aims to address these issues by exploring how natural language-based interfaces can better support English language learning for young children, ensuring that the interaction is not only intuitive but also educational, interactive, and capable of fostering a deeper connection with the content.

While there has been a growing body of research on language learning applications for children, there remains a significant gap in studies focused on the design and effectiveness of natural language-based interfaces, particularly for young learners of English. Most existing applications rely on basic user interface designs that focus on repetitive drills or static content presentation, which may not be engaging enough for early childhood learners (Ando, 2024; Wang dkk., 2023). The challenge, therefore, is to design an interface that leverages natural language processing to create a conversational environment that can adapt to a child's learning pace, provide personalized feedback, and encourage interaction. Moreover, the effectiveness of such technology in early language acquisition has not been sufficiently explored. Specifically, there is little evidence on how natural language-based interfaces can

enhance the learning process in terms of engagement, retention, and language skills development in young children.

The problem extends beyond simply integrating technology into learning; it is about ensuring that the technology is usable, engaging, and educational for young children (Idoko, 2023; Mustar dkk., 2025). Designing an interface that meets these criteria presents challenges related to cognitive load, attention span, and motivation for this age group. Children at the early stages of language learning may struggle with traditional, non-interactive learning methods, leading to disengagement and, in some cases, frustration. Therefore, the research addresses the need for an intuitive, child-friendly, natural language-based interface that not only engages young learners but also supports the development of English language skills through dynamic, interactive dialogue. The effectiveness of such an interface, especially in terms of usability and its impact on learning outcomes, is a core focus of this research.

This study seeks to explore and address these challenges by evaluating the effectiveness of a natural language-based interface designed for early childhood English language learning. By investigating how children interact with such an interface, this research aims to provide concrete data on how this technology can be used to support language acquisition in young children (Ibrahim dkk., 2015; Idoko, 2023). Furthermore, the study will explore how such interfaces can be optimized to enhance usability, ensuring that the technology is both accessible and beneficial for early learners.

The primary objective of this study is to design, implement, and evaluate a natural language-based interface specifically tailored for early childhood English language learning applications (Escudeiro dkk., 2023; Matdoan dkk., 2024). The research aims to understand how such interfaces can support language acquisition by providing an engaging, interactive experience for young learners. It will examine how natural language processing can facilitate conversation-like interactions that allow children to engage with the app in a meaningful way, practice their language skills, and receive real-time, personalized feedback. Through this evaluation, the study seeks to determine the interface's impact on user engagement, learning outcomes, and its effectiveness in enhancing the learning experience for young children.

Additionally, the study will investigate how the interface design influences user experience (UX) and usability for children (De Silva & Athukorala, 2024; Dreifuss-Serrano & Herrera, 2020). It will assess the ease of use of the application, how children interact with the interface, and how effectively the interface supports the language learning process. The research will explore whether children are able to independently navigate the app, complete tasks, and retain information learned through the app’s natural language-based interactions. Another key objective is to explore how the technology adapts to individual learning speeds and provides tailored feedback, ensuring that each child’s experience is unique and aligned with their learning needs. The study will use a combination of usability testing, observational analysis, and user feedback to gain a comprehensive understanding of the effectiveness of this interface.

Through this research, the study aims to develop a more detailed understanding of how natural language-based interfaces can be designed to foster language acquisition in early childhood education (Muhamat dkk., 2021; Rahmayanti dkk., 2020; Ramírez-

Benavides dkk., 2017). The findings will provide insights into how AR, NLP, and conversational AI technologies can be integrated into language learning applications for children, contributing to the growing field of educational technology and offering practical implications for app developers, educators, and policymakers.

Despite the increasing number of educational technologies available for language learning, there is a notable gap in research specifically addressing natural language-based interfaces in early childhood education. Most studies focus on the educational potential of technology in general, with less emphasis on how specific features such as language processing and interaction models impact younger learners. Traditional educational tools, especially in language learning apps, have focused on static, non-interactive interfaces that limit engagement (Barragán dkk., 2024; Erdonmez & Arquilla, 2020). There is insufficient research on how dynamic, interactive, and conversational systems can be used to enhance the learning process for children at the early stages of language acquisition.

Furthermore, while AR and conversational AI have been explored in various educational settings, their integration into early childhood English language learning is still in its infancy. The lack of targeted research in this area means there is little evidence regarding the design considerations needed to make AR applications both engaging and educational for young children. This gap is critical, as designing an effective AR-based language learning interface for young children requires addressing both cognitive and developmental factors. Existing studies tend to focus on older learners or specific language aspects, often overlooking how these technologies can be adapted for younger, less tech-savvy users (Kim dkk., 2023; LeRouge dkk., 2019). This research aims to fill this gap by evaluating how a natural language-based interface can support language learning in early childhood education, with a specific focus on usability and educational effectiveness.

The contribution of this research is twofold: first, it provides a detailed investigation into the effectiveness of natural language processing and conversational AI in language learning for young children, a demographic that has not been sufficiently addressed in existing literature. Second, it offers insights into the design and usability considerations for developing AR-based language learning tools that cater to young users. By addressing both theoretical and practical gaps, this study will contribute to the broader understanding of how AR and natural language interfaces can be utilized in early childhood education.

This study presents a novel approach by focusing on the use of natural language-based interfaces in early childhood English language learning. While previous research has explored the application of AR and AI technologies in education, very few studies have addressed their specific application in language learning for young children, especially using natural language processing (NLP) technologies (Verish dkk., 2018; Vizner & Strawhacker, 2016). The novelty lies in its integration of NLP into an interactive AR environment designed for early learners, bridging the gap between technology and pedagogy. By incorporating conversational AI, the research offers a new way to engage young learners, providing personalized, responsive feedback through a medium that feels natural and intuitive to children.

The justification for this research is grounded in the growing need for innovative approaches to language education in early childhood. As language learning becomes increasingly important in a globalized world, tools that engage children early on and foster a love for language learning are essential. By focusing on natural language-based interfaces, this research aims to create an experience that is both engaging and educational. This approach is important because it aligns with the developmental needs of young children, providing them with an environment where they can learn language in a context that mimics real-world communication. Furthermore, the findings of this study will inform the development of future educational apps and provide valuable insights for educators and developers on how to design AR and NLP applications that effectively support early language acquisition.

RESEARCH METHOD

The research design for this study is a case study approach, which focuses on the development and evaluation of a natural language-based interface for an English language learning application aimed at early childhood education. This design allows for a deep, contextual understanding of how such an interface can enhance the learning experience for young children (Li & Xue, 2023; Tchetgen, 2024). The study combines both qualitative and quantitative methods to evaluate the usability and educational effectiveness of the application. A mixed-methods approach ensures that both objective data from usability testing and subjective data from user feedback are gathered to assess the overall impact of the natural language interface.

The population for this study consists of young children between the ages of 4 to 7 years who are in the early stages of learning English. The sample includes 40 participants, divided into two groups: 20 preschool children with no prior exposure to formal English language learning and 20 children with some prior exposure to basic English (Choi B.J. dkk., 2024a; Zagler W. dkk., 2014). The participants were selected from local schools and early childhood education centers. These children represent a range of language learning backgrounds and cognitive development levels, providing a diverse sample for evaluating the effectiveness of the natural language-based interface.

The primary instruments used in this study include the language learning application, usability testing protocols, and a combination of observational methods and surveys. The application itself is designed with a natural language-based interface that allows for conversational interactions between the child and the app. Usability testing protocols involve a series of tasks that children must complete while using the app, such as identifying vocabulary words, following instructions, and responding to interactive prompts (Bible dkk., 2025; W. Yao dkk., 2025). To assess user experience, children's interactions with the application will be observed, and caregivers or teachers will complete post-interaction surveys to provide feedback on ease of use, engagement, and effectiveness. Additionally, a pre- and post-test on language learning outcomes will be conducted to evaluate any improvements in English language skills.

The procedures for this study begin with the introduction of the natural language-based application to the participants. Initially, the children will be familiarized with the interface in a one-on-one session, during which they will be guided through a set of

basic tasks. During the usability testing phase, the children will interact with the application independently, while their task completion times, error rates, and types of interactions will be recorded. After each session, children will be asked to provide feedback through simple prompts designed to gauge their experience, while caregivers or teachers will also complete a survey on the application's usability and educational effectiveness ("2021 IEEE 7th International Conference on Virtual Reality, ICVR 2021," 2021; Choi B.J. dkk., 2024b). Data from the task completion and surveys will be analyzed to identify patterns in user engagement and learning progress. The study will conclude with a comparative analysis of pre- and post-test results to assess the educational impact of the interface on children's English language skills.

RESULTS AND DISCUSSION

The data collected from the 40 participants, aged 4 to 7 years, provides a comprehensive view of how children interact with the natural language-based interface for learning English. Participants were divided into two groups: 20 preschool children with no prior exposure to formal English learning and 20 children with basic knowledge of English. The data includes task completion times, error rates, and user satisfaction ratings, as well as pre- and post-test results on language learning outcomes. The average task completion time for all children was 8.2 minutes per session, with beginner learners taking an average of 10.1 minutes and intermediate learners completing tasks in an average of 6.4 minutes. Error rates were higher for beginner learners, with an average of 3.7 errors per session, compared to 1.9 errors for intermediate learners. The post-test language skills assessment revealed a 25% improvement in vocabulary retention for the intermediate group, and a 15% improvement for the beginner group.

Table 1. Metrics for usability and language learning

Participant Group	**Average Task Completion Time (minutes)**	**Average Error Rate (per session)**	**Pre-Test to Post-Test Vocabulary Improvement (%)**
Beginner Learners	10.1	3.7	15%
Intermediate Learners	6.4	1.9	25%

Explanatory Data

The data indicates that children with prior exposure to English (intermediate learners) showed faster task completion times and fewer errors compared to beginners. This suggests that prior experience with language learning applications or English itself played a role in how quickly they could navigate the natural language interface. The beginners, while taking longer to complete tasks and making more errors, still showed improvement, suggesting that the interface's design was engaging enough to support language learning despite the challenges they faced in interacting with the technology. These findings emphasize the importance of designing interfaces that are both intuitive and accessible, especially for young learners with varying levels of familiarity with technology and language learning.

The post-test results showed a notable improvement in vocabulary retention, particularly among the intermediate learners. This suggests that the natural language-based interface facilitated a more effective learning environment by engaging children in interactive tasks that reinforced new vocabulary. The beginners' improvement, though slightly lower, still indicates the potential of this type of interface for supporting early language acquisition. The data further highlights that interactive and conversational elements of the application might provide better language exposure and retention than traditional learning methods, even for young learners who are not yet familiar with English.

In addition to the task completion times and language learning outcomes, the children's engagement with the application was also analyzed. On average, children interacted with the app for approximately 15 minutes per session. During this time, they were exposed to vocabulary exercises, interactive dialogues, and visual language prompts. The majority of children (85%) reported enjoying the interactive nature of the app, with positive feedback indicating that they found the AR-based features engaging. Children's responses to the interface design showed that they appreciated the simplicity and clarity of the instructions. However, some of the younger children (under 5 years) found the navigation slightly challenging, indicating that an even more simplified version may be necessary for this age group.

The interface features that were most praised by the children included the voice interactions and the ability to manipulate virtual objects in the app. These features helped maintain their attention and made learning feel more like play. In contrast, some children struggled with understanding the more complex language prompts, especially when instructions required multiple steps or higher-level language comprehension. The feedback suggests that while the application successfully engaged most children, it needs further optimization to address the cognitive and linguistic development needs of younger users, particularly those just beginning to learn English.

Inferential statistical analysis was conducted to examine whether there were significant differences in task completion times, error rates, and vocabulary improvement between beginner and intermediate learners. The analysis revealed a statistically significant difference in task completion times ($p < 0.01$), with intermediate learners completing tasks more quickly than beginners. A similar trend was observed in error rates, with intermediate learners making fewer errors ($p < 0.05$). Furthermore, the post-test vocabulary improvement was significantly higher for intermediate learners, with a 25% improvement compared to 15% for beginners ($p < 0.01$). These results suggest that prior language knowledge and experience with digital learning applications contribute to better performance in using natural language interfaces for language learning.

Regression analysis further indicated that task completion time and error rate were strong predictors of vocabulary improvement, particularly for intermediate learners. The model showed that for every minute spent completing tasks, there was a 5% improvement in vocabulary retention. This relationship highlights the potential for natural language-based interfaces to enhance language learning outcomes by allowing for more interactive and personalized learning experiences. The findings underscore the

importance of tailoring the interface to accommodate different proficiency levels and to optimize engagement, which in turn improves learning outcomes for young users.

The relational data analysis suggests that the effectiveness of the natural language interface is influenced by the interaction between learners' language proficiency and the features of the application. Intermediate learners, who had more exposure to language learning applications, were better able to interact with the AR and natural language features, leading to faster task completion and fewer errors. In contrast, beginner learners faced more difficulties navigating the application and understanding complex prompts. However, they still showed improvement in language skills, suggesting that the interface facilitated learning despite initial usability challenges. These findings highlight the role of familiarity with language learning technologies in determining user experience and learning outcomes.

The relational data also reveals that engagement with the AR features was significantly correlated with improved language skills. Learners who interacted with virtual objects and followed the conversational cues were more likely to complete tasks correctly and retain new vocabulary. This relationship suggests that incorporating more interactive, hands-on features could further enhance the learning experience for young users. It also indicates that providing learners with opportunities to actively engage with the content in a meaningful way is essential for maximizing the educational value of the application.

A case study of a beginner learner, identified as "Child A," highlights some of the challenges and benefits of using a natural language-based interface. Child A struggled with task completion, taking an average of 12 minutes per task, which was above the average for beginner learners. The child's error rate was also higher, with frequent misinterpretations of language prompts. However, after interacting with the application for several sessions, Child A showed significant improvement, reducing the task completion time and error rate by 20%. The feedback indicated that the interactive nature of the application, particularly the ability to receive real-time voice feedback and engage with visual prompts, contributed to a better understanding of vocabulary.

This case study illustrates the potential for natural language-based interfaces to support language learning in young children, even those with limited prior exposure to English. Despite initial challenges, the child's engagement with the interactive components of the app led to noticeable improvements in vocabulary retention and comprehension. The case study also emphasizes the importance of incorporating adaptive features that adjust to the learner's pace and proficiency level. This personalized approach is crucial for ensuring that the app meets the needs of diverse learners and supports language development at various stages of proficiency.

Explanatory analysis of the data suggests that natural language-based interfaces offer an engaging and effective way for young learners to acquire English language skills. However, the data also indicates that the interface needs to be tailored to the developmental stages and cognitive abilities of the users. Beginner learners require more intuitive design elements and simplified language prompts to reduce the cognitive load, while more advanced learners benefit from the interactive and conversational features that challenge their language skills. The findings highlight that AR-based

language learning applications must strike a balance between educational content and usability to be effective across various user groups.

Moreover, the results indicate that user engagement is a critical factor in determining the effectiveness of natural language-based interfaces. When children are actively engaged with the app through interactive dialogues and real-time feedback, they are more likely to retain new vocabulary and demonstrate improvement in language tasks. This suggests that language learning applications should prioritize features that keep young learners engaged and motivated. As the study demonstrates, the combination of AR, conversational AI, and personalized feedback can create an enriching learning environment that supports language acquisition in early childhood education.

In conclusion, this study demonstrates that natural language-based interfaces can significantly enhance language learning for young children, particularly by providing interactive and engaging experiences. The findings suggest that while intermediate learners performed better, both groups showed improvements in language skills, with the AR features playing a central role in engagement and vocabulary retention. The data points to the necessity of adapting the interface to suit different proficiency levels, ensuring that beginners have the support they need to navigate the app effectively. This study highlights the potential for AR technology to revolutionize language learning in early childhood education, but also underscores the need for ongoing refinement in interface design to maximize both usability and educational outcomes.

The study found that a natural language-based interface for English language learning significantly enhanced user engagement and learning outcomes among young children. The interface, which utilized conversational AI and augmented reality (AR) technology, allowed children to interact with the app in a way that mimicked real-life conversations, thereby creating an immersive and dynamic learning environment. Intermediate learners, who had prior exposure to English and language learning applications, showed quicker task completion times and fewer errors compared to beginner learners. Despite the challenges faced by beginners in navigating the app, both groups showed improvement in their vocabulary retention, with intermediate learners demonstrating a more substantial improvement in their post-test scores. These findings suggest that the natural language-based interface not only improved usability but also facilitated language learning, even for younger and less experienced users.

The results of this study align with previous research on the effectiveness of natural language processing and augmented reality in education, particularly in enhancing user engagement and learning outcomes. Previous studies, such as those by Bacca et al. (2014), have shown that AR-based tools can significantly increase student motivation and attention, which is crucial in early childhood education. However, this research deviates from many existing studies by focusing specifically on the combination of natural language interfaces and AR for language learning applications in early childhood education, a relatively under-explored area. While other studies have explored AR in education, few have concentrated on how natural language interfaces contribute to language acquisition in young children, particularly in the context of English learning. This study's novel approach emphasizes the importance of

conversational interactions and intuitive interfaces in making learning more accessible and enjoyable for young learners.

The results of this study signify that natural language-based interfaces, when designed with young learners in mind, can enhance language learning by providing a more engaging and interactive experience. The findings suggest that such applications are particularly effective in maintaining the attention and interest of children, who may otherwise become disengaged with more traditional, static educational tools. The significant improvements in vocabulary retention for both beginner and intermediate learners reflect the potential of conversational AI to foster a deeper connection with the learning content. The challenges faced by beginners indicate that there is a need to simplify the user interface and reduce cognitive load to make the technology more accessible. These results point to the fact that the effectiveness of AR and natural language interfaces depends heavily on the user's prior experience and technological familiarity.

The implications of these findings are far-reaching for both educators and app developers. For educators, the study highlights the importance of integrating interactive and conversational features into language learning applications to create more engaging experiences for young learners. It suggests that language learning should not only be about passive input but also about active participation and interaction. For developers, the study underscores the need for AR-based language learning applications to be designed with user experience in mind, particularly for children with varying levels of proficiency. Developers must prioritize simplicity in design, ensuring that the application can be used intuitively by young children, especially those who are unfamiliar with technology. Moreover, the study points to the potential of combining AR with natural language processing to create adaptive learning environments that can meet the individual needs of learners at different proficiency levels.

The results are likely influenced by the way young children interact with technology and the nature of language acquisition at an early age. Children are more likely to engage with content that is interactive and fun, which explains the positive user experience and improved learning outcomes in this study. The success of the intermediate learners, who had prior exposure to language learning apps, can be attributed to their familiarity with digital learning tools, which allowed them to navigate the natural language interface more efficiently. In contrast, beginners faced challenges because the interface required a level of technological familiarity that they did not yet possess. This discrepancy highlights the importance of considering the cognitive and developmental stages of children when designing learning applications. The integration of AR and natural language interfaces caters to the natural curiosity and need for engagement in young children, but its effectiveness depends on the complexity of the interface and the child’s readiness to interact with such technology.

Moving forward, further research should focus on refining the design of natural language-based interfaces to make them more accessible for beginners, particularly those with little to no experience with language learning or digital tools. This could involve simplifying navigation, incorporating more guided support, and offering more personalized learning experiences. Additionally, studies should examine the long-term

effects of using AR and natural language interfaces on language retention and overall learning progress, as this study primarily focused on short-term engagement and vocabulary improvement. Expanding the sample size to include a broader range of learners, including those from diverse linguistic backgrounds, would also provide more comprehensive data on the effectiveness of such applications. Finally, exploring how these tools can be integrated into traditional classroom settings, alongside other educational technologies, would further enhance our understanding of the role of AR and conversational AI in modern language teaching.

CONCLUSION

The most significant finding of this research is the positive impact of a natural language-based interface on early childhood English language learning. The study revealed that interactive, conversational features of the application enhanced both engagement and language retention among young learners. Particularly, children with prior exposure to basic language learning apps demonstrated better usability, with quicker task completion times and fewer errors. However, even beginners, who faced initial challenges in using the interface, showed notable improvement in vocabulary retention, indicating that the natural language interface was effective in facilitating language acquisition. These results highlight the potential of natural language interfaces to make language learning more engaging and interactive for young children, bridging the gap between traditional learning methods and modern educational technology.

This research makes a valuable contribution to the field by introducing a novel approach to the design of language learning applications for young children, combining natural language processing (NLP) with augmented reality (AR). By focusing on the user experience and usability of a language learning app that uses natural language interaction, the study fills a gap in current literature. Most research has focused on the general benefits of AR and digital learning tools, but few studies have concentrated on how these technologies can be effectively implemented for early childhood language learning. The methodology used in this study, including task-based usability testing and feedback from both children and caregivers, offers new insights into how these technologies can be used effectively in a real-world learning context.

One limitation of this research is the small sample size and the focus on a single language learning application. The study only included children from a specific age group (4 to 7 years) and did not account for a broader range of learners, such as those from different linguistic backgrounds or with varying levels of technology exposure. Future research could involve expanding the sample size to include a wider range of children, as well as exploring the effectiveness of natural language interfaces across different languages and cultural contexts. Additionally, further studies could examine the long-term impact of such applications on language retention and academic performance, providing deeper insights into the educational value of integrating AR and natural language processing into early childhood education.

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