Learn with *Lumipal*: Designing Learner-Centered Experiences Through AR Companions

Jiatong Gou, Jiayu Liu, Shencheng Fu, Katy Ye, Yuting Hong
Teachers College, Columbia University
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Introduction and Problem Statement

Extended Reality (XR) is increasingly being used in education to create immersive and interactive learning experiences (Mohsen et al., 2024). Through technologies such as augmented reality and virtual reality, learners can engage with educational content in more dynamic and engaging ways than traditional learning environments. Recent studies have also shown that XR learning companions can improve learner motivation, engagement, and feelings of social presence by providing personalized support and interaction (Liao et al., 2019).

However, immersion alone does not always lead to effective learning outcomes. Poorly designed XR companions may distract learners, increase cognitive overload (Sweller, 1988), and create an illusion of learning in which students feel engaged without deeply understanding the material (Bojorque et al., 2025). When learners must divide their attention between educational content and unnecessary interactive elements, the learning experience can become overwhelming rather than supportive.

To address these challenges, this paper proposes LumiPal, a newly designed AR learning companion application that focuses on balancing immersion with pedagogical support. LumiPal is designed to provide learners with appropriate scaffolding, guidance, and interaction during the learning process. By intentionally reducing unnecessary distraction and managing cognitive load, the application aims to create a more effective and supportive learning experience that leads to improved learning outcomes.

Overview of LumiPal

LumiPal is an AR learning companion application designed for elementary and middle school students. The app supports students through interactive guidance and personalized learning activities that combine educational content with immersive AR interactions.

LumiPal includes multiple functions such as a “learning by teaching” mode where students explain concepts to the AR companion, a companion study mode that provides emotional and motivational support during studying, gamified practice activities, learning progress tracking, and companion care features that encourage long term engagement. In addition, the app includes an admin mode that allows teachers to manage learning materials and monitor student progress.

Through scaffolded AR interactions and personalized support, LumiPal aims to help students develop a deeper understanding of learning concepts while maintaining motivation and reducing cognitive overload.

Why AR Accompany

AR offers a strong balance between presence, interaction, accessibility, and real-world learning support. Compared with a normal 2D app, AR makes the companion feel more present in the learner’s real space. Instead of staying only inside the screen, LumiPal can appear on the child’s desk or study area. This creates the feeling that LumiPal is “learning with me,” which may help children build a stronger emotional connection with the companion. Research on AR learning suggests that presence is an important factor in how learners experience computer-mediated educational environments (Campo et al., 2023). AR also supports more active forms of learning. In a 2D app, children may mainly tap buttons, watch animations, or read information on the screen. In AR, children can observe, explain, and interact with LumiPal in their own physical environment. This makes the learning experience feel more embodied and playful. At the same time, AR is more practical than VR for children’s everyday learning. VR can create immersive experiences, but it often requires headsets and may feel isolating or overwhelming for younger learners. AR does not fully block the real world. Children can still see their books, notebooks,

desks, and surroundings while interacting with LumiPal. Therefore, AR is a suitable choice because it makes the companion feel present and interactive while keeping the learning experience practical, familiar, and connected to the learner's real study space.

LumiPal: Prototype Walkthrough & Design Rationale

Learning Mode 1: Learning by Teaching AR LumiPal

LumiPal's primary learning mode is "learning by teaching". Unlike many existing AI-powered educational companion apps that design virtual characters as "tutors" or "guides" to support the learning process through explanations, instruction, or feedback, LumiPal intentionally moves away from this traditional schema. Instead, Lumi is positioned as a "learner" or "student," allowing users to reinforce their own understanding by actively explaining and teaching the material to the agent. Specifically, after selecting their grade level and the specialized subject they wish to review with Lumi, users are directed to the main interface (*Figure 1*), where they can choose from a list of subject-specific content. Upon the selection, users enter an AR world in which Lumi appears at the center (*Figure 2*). To scaffold the interaction, simple guiding questions are presented in a speech bubble above Lumi, inspiring users to begin their explanation. Users can choose to either type or speak to Lumi as they carry out their teaching. After completing the session and clicking "Finish Lesson," the system generates flashcards based on their chat history to help consolidate their learning. , allowing users to consolidate and review key concepts. Additionally, users can also always access flashcards for previously studied topics by clicking the "Practice" button on the home bar at the bottom.

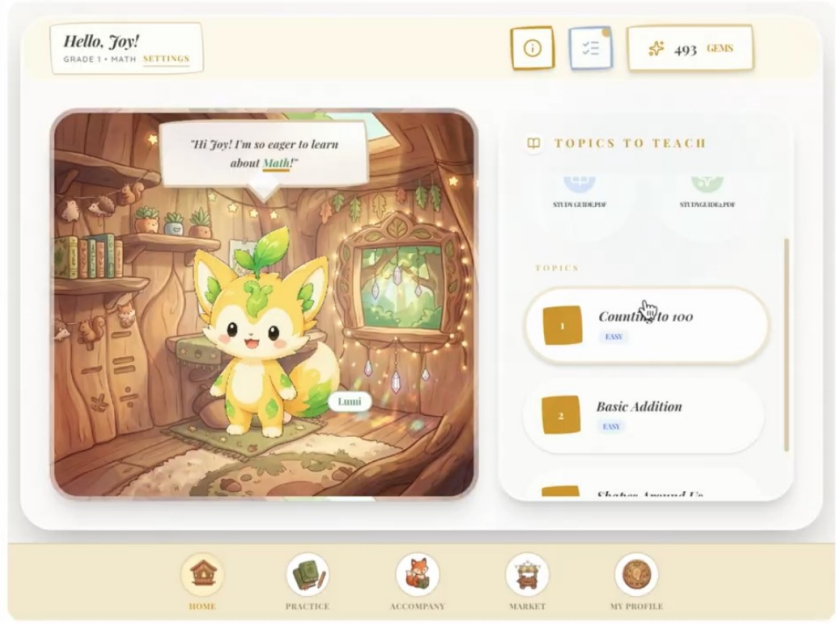
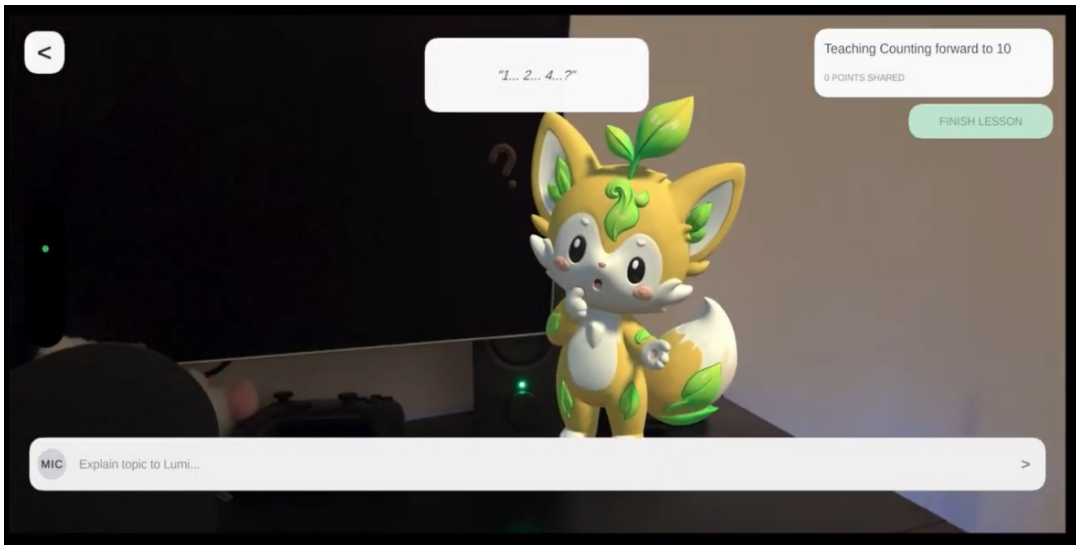


Figure 1 Main Interface

Figure 2 “Learning by Teaching” AR Mode



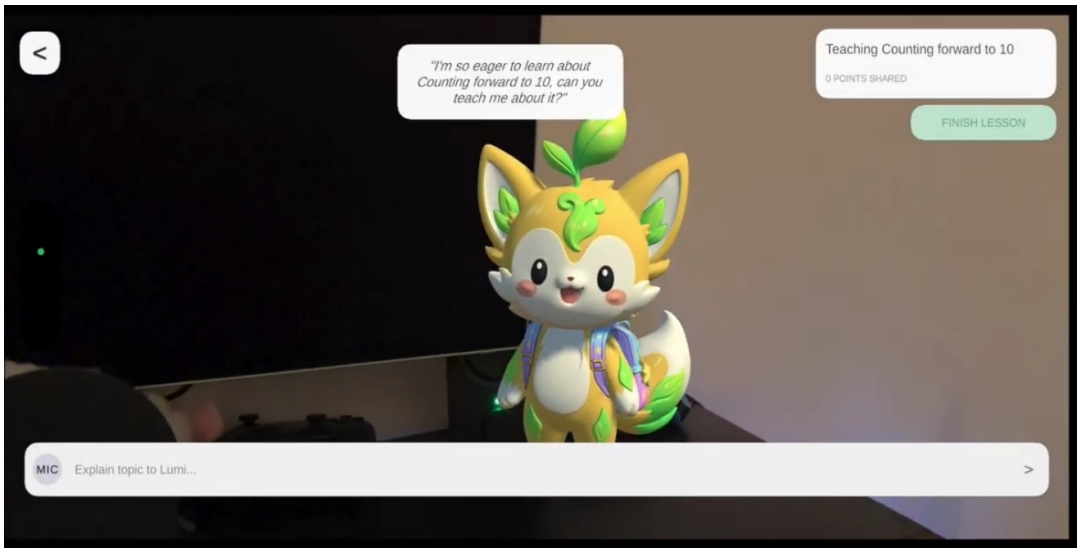
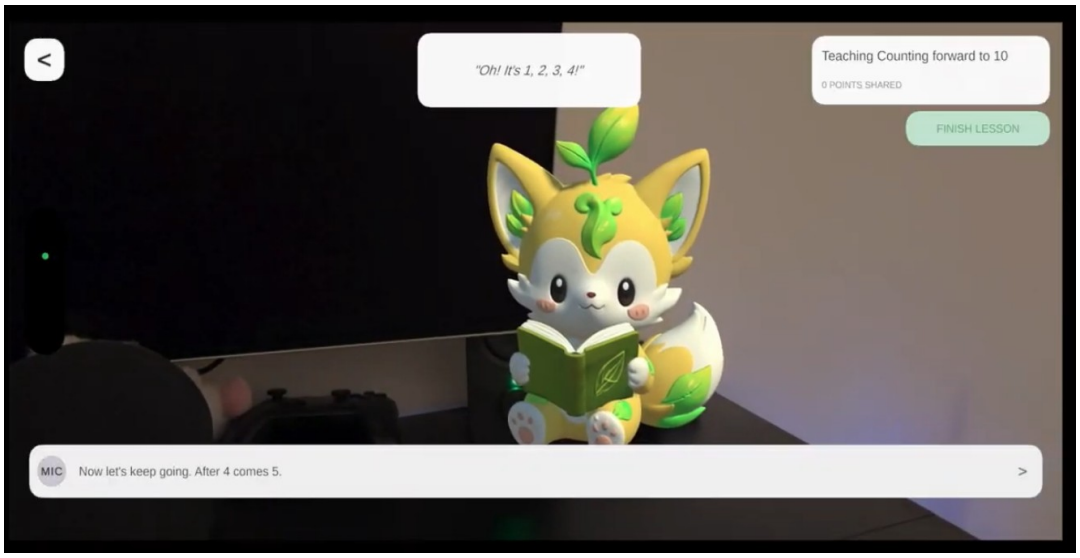


Figure 2 "Learning by Teaching" AR Mode

The core rationale behind this design decision is that when learners are placed in the role of "explainers" or "teachers," they are required to actively retrieve all the relevant information and organize it to generate meaningful explanations, a process that fosters deeper understanding. Bjork (1994) argues that introducing moderate cognitive challenges into the learning process, while reducing learning fluency in the short term, can significantly enhance long-term memory and knowledge transfer. In contrast, overly smooth and effortless learning experiences often lead learners to overestimate their level of understanding, thereby creating an "illusion of learning" (Parong & Mayer, 2021). This issue is even much more common in XR learning environments, where immersive and visual representations can make learning content fun and appear easy to grasp while failing to promote deep cognitive processing. To address this challenge, we deliberately add desirable difficulty into the system by asking children to "teach Lumi." When learners explain concepts to Lumi, they must actively structure their knowledge, articulate their reasoning, and identify gaps in their understanding throughout the process. This activity exemplifies generative learning, encouraging a shift from passive reception to active knowledge



construction. As a result, learners are more likely to develop robust and transferable knowledge structures, rather than relying on superficial comprehension.

Furthermore, this design also addresses research on social presence in XR learning. Prior research has indicated that virtual companions or learning partners can significantly enhance learners' engagement and willingness to interact (Liao et al., 2019; Wu et al., 2025). Compared to positioning Lumi as an versatile tutor, shaping it as a learning partner in need of support can help reduce psychological pressure, enhances children's willingness to express themselves and their motivation to participate, making interactions more natural and sustained.

Learning Mode 2: Study with AR LumiPal

Another key function of LumiPal is the "Study with LumiPal" mode (*Figure 3*), which can be accessed through the Accompany button (*Figure 4*) on the bottom navigation bar. In this mode, LumiPal appears in AR and quietly studies with the learner. The child can choose a 25-minute study session, and LumiPal stays beside them as a calm study companion. After completing the session, the learner earns points or gems that can be used in the companion-raising system.

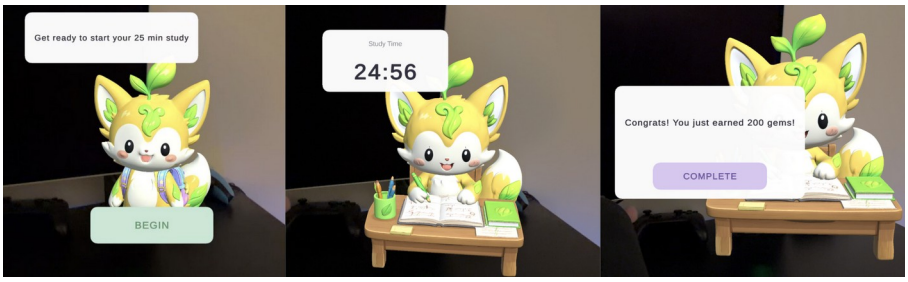


Figure 3 "Study with LumiPal" Mode

Figure 4 Accompany Button on the Bottom Navigation Bar

This design is inspired by the Pomodoro Technique, a time-management method that organizes work into focused intervals, usually around 25 minutes, followed by short breaks (Cirillo, 2018). The 25-minute structure gives children a clear and manageable study goal. Instead of asking children to study for a long time, the app helps them focus on one short learning period. This can reduce pressure and make self-study feel more achievable. Biwer et al. (2023) found that breaks during self-study can be understood as an effort-regulation strategy, helping learners manage mental effort during study sessions.

Other Features

1.Progress Dashboard

LumiPal includes a learning data analysis page in the profile page (*Figure 5*). This page records daily missions, learning history, gems earned, lessons taught, knowledge points, and study streaks. The daily mission system gives learners small goals, such as teaching LumiPal a new concept or reviewing flashcards. The learning history chart helps students see their progress over time. This connects with gamification research, which identifies points, levels, feedback, challenges, and progress indicators as common game elements used in digital learning

environments (Khaldi et al., 2023). However, LumiPal uses these rewards carefully. Children earn points by completing meaningful learning behaviors, not only by playing with the companion.

Figure 5 Progress Data Dashboard in My Profile

2.Companion Care

LumiPal also incorporates a companion-care system to support learners' motivation by making the learning experience emotionally engaging and rewarding. Specifically, users can choose a LumiPal character they would like to accompany them and personalize it by giving it a name (*Figure 6*). As learners engage in study sessions, such as teaching Lumi, completing study sessions, and reviewing content, they earn rewards, which we call gems, that can be used to buy food, clothes, and caring activity for their companion in the market (*Figure 7*).

Figure 6 LumiPal Assets

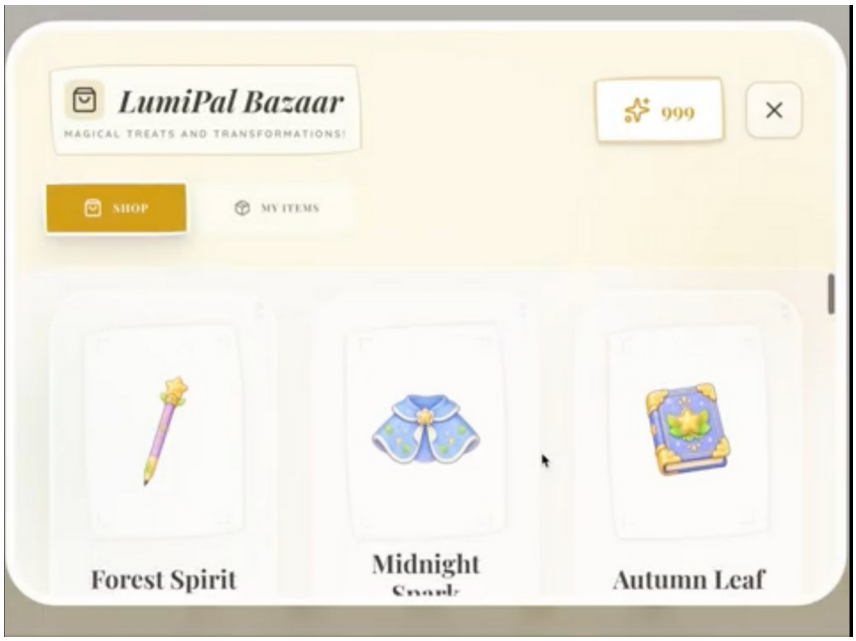


Figure 7 LumiPal Market View

Additionally, as users spend more time and energy with a particular pal, different developmental stages and emotional states would be unlocked (*Figure 8*). This design is grounded in Self-Determination Theory, which posits that motivation is enhanced when learners experience competence, autonomy, and relatedness (Ryan & Deci, 2000). In LumiPal, competence is reinforced through progress and achievement, autonomy is supported through choices in customization and interaction, and relatedness emerges as learners build an ongoing emotional bond with their companion. Through this system, learning is not only cognitively engaging but also effectively meaningful, encouraging sustained participation over time.

Figure 8 LumiPal Growing Cycle

3.Admin System

LumiPal also includes an admin system designed for teachers to support customized classroom use. Through this interface, teachers can enter their school, create class groups, add students, and upload relevant learning materials (*Figure 9*). Based on these inputs, LumiPal automatically generates lists of topics and content that students can choose from, otherwise, it shows a default list based on a general interest. This feature ensures that learning activities are aligned with certain classroom goals while still allowing students to engage with LumiPal in an interactive and personalized way.

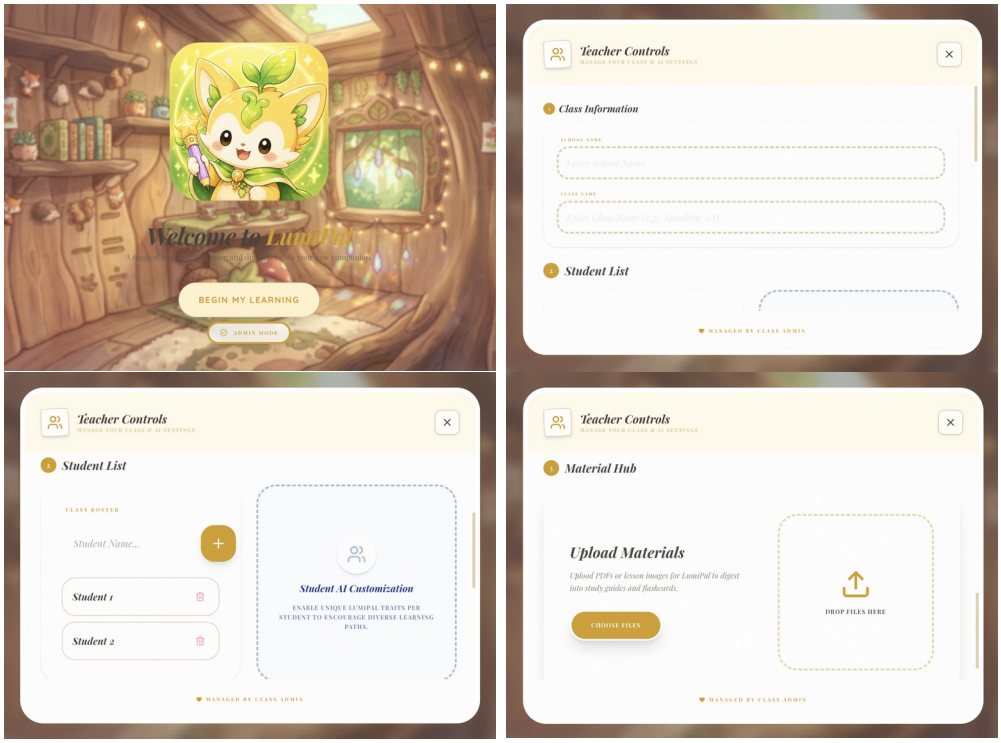


Figure 9 LumiPal Admin Mode

Ethical, Cognitive, Social, and Cultural Considerations

While the preceding sections have established what LumiPal does and why it was designed the way it was, several considerations shaped those design choices from the start. Four are addressed below, spanning ethical, cognitive, social, and cultural dimensions of the design.

Ethical: designing for a child user

Because LumiPal's users are children in Grades 1-8, ethical requirements were built into the architecture rather than layered on at the end. Compliance with COPPA and GDPR-K sets the floor: parental consent, age-appropriate handling of any personal information, and clear limits on what is collected. To go beyond procedural consent, the design follows a principle of data minimization - only the information needed to support scaffolded learning is retained, and AR camera frames are processed locally rather than stored as raw video. Khadka and Das (2026) note that XR systems for young children tend to default to broad data capture unless designed against it, so this constraint is treated as a feature, not a limitation. The Companion Care system is structured as a closed in-app reward loop, with no behavioral advertising and no commercialization of child data. In Admin Mode, teachers can see aggregate progress for their class but are bounded by what is necessary for instructional support, and the interface

communicates to the child in age-appropriate language what LumiPal "remembers" and what is shared.

Cognitive: keeping the companion in service of learning

Immersive media can support learning, but only when designed in line with what is known about how attention and working memory function (Makransky & Petersen, 2021; Sweller, 1988). Buchner et al. (2022) show that AR's effect on cognitive load depends on whether visual cues are spatially and temporally aligned with the target content, and LumiPal applies this directly: the companion's animations, dialogue, and the learning artifact are co-located in the child's space so attention does not need to be re-bound across separate elements. Decorative behaviors are kept minimal and tied to learning moments rather than running continuously. The Learning-by-Teaching mode is grounded in evidence that explaining material to another agent produces deeper understanding than passive review, and LumiPal's prompts are designed to ask follow-up questions and surface gaps rather than only affirm — so the interaction supports genuine comprehension rather than the sensation of it. As the child demonstrates mastery, scaffolding is intended to step down, letting LumiPal's role shift from co-thinker to occasional check-in.

Social: an emotionally supportive companion that complements human relationships

LumiPal's emotional design draws on motivation theory (Maslow, 1943): a learner who feels connected and cared-for is more willing to engage with difficult material. The Companion Care system- choosing a LumiPal, feeding it, watching it grow - is built to channel this connection into sustained study habits. Because younger children form bonds with responsive agents readily (Namvarpour et al., 2026), the design is deliberate about keeping LumiPal in a supplementary role rather than a substitutive one. The companion's state and progression respond to learning quality - the depth of an explanation, evidence of conceptual progress - rather than raw time on task, so the reward loop reinforces substantive engagement instead of session length. Admin Mode keeps teachers and parents visible in the learning flow, so the child's study experience remains embedded in their real social environment rather than standing apart from it.

Cultural: accessibility, representation, and pedagogical fit

Several cultural and contextual factors shaped LumiPal's design. Phones and tablets were chosen over VR headsets because they are far more widely available across schools and households, which makes the experience accessible to children who would otherwise be excluded from immersive learning tools. The Companion Care system is built around customization so that children can shape LumiPal's appearance and items to reflect their own preferences and contexts, rather than being asked to adapt to a single default look. On the pedagogical side, Learning by Teaching is well-supported in research but reads differently across classroom cultures - some emphasize teacher authority, others emphasize student-led inquiry. Admin Mode is built to let teachers configure how directive or how Socratic LumiPal's prompts are, so the app supports rather than overrides the teacher's pedagogical approach. Together, these choices aim to make LumiPal usable across a range of classroom and home environments rather than fitting only a narrow set of them.

Limitations and Future Directions

Scaffolding Mechanisms

Our current design mostly limits learners to interacting with the learning companion through text-based and conversation-based formats. Moreover, we have only provided one way

for learners to review the lesson, which is through the flashcard mode. These limitations may affect learners' understanding of the knowledge and reduce their opportunities to revisit the lesson and reflect on how much they have achieved.

In the future, it would be helpful to incorporate more multimodal scaffolding throughout the lesson, including AI-generated AR visual cues, diagrams, and step-by-step overlays. These features could better attract learners' attention and improve their learning process. At the same time, we do not want to overload them with too much information, so it would be useful to allow users to adjust the amount of interaction or visual cues they would like to receive. Additionally, in terms of reviewing concepts and lessons, it would be beneficial for learners to access other forms of practice, such as multiple-choice questions and fill-in-the-blank exercises. This would help them become more familiar with the knowledge and receive more targeted feedback.

AR Companion Interactivity

Regarding AR companion interactivity, Lumipal's current movement is limited to changes in appearance and facial expressions. This may not provide a fully engaging experience for learners because they cannot receive active, simultaneous feedback from the companion. In the future, we would like to enable skeleton-based movement and real-time feedback so learners can interact more naturally with Lumipal and feel a stronger sense of companionship throughout the learning process. We would also like to allow the companion to speak back, rather than only displaying text on the screen, since younger children may be more comfortable receiving auditory input than focusing entirely on reading. Moreover, we would like to further improve Companion Care by making the companion's status more visible. For instance, each companion could have an energy level, and learners would need to feed it, finish tasks, or complete lessons in order to maintain its energy.

Learning Progress Visualization

Our current prototype displays learning progress on the profile page by showing information such as daily time spent, completed lessons, and total hours. However, as mentioned earlier, we want to reduce unnecessary information and avoid overwhelming users' cognitive load. Therefore, we would like to consider a simpler visualization design that is helpful for all users, including teachers, parents, and children. For instance, instead of presenting multiple panels, the page could include one large graph showing the overall learning curve, with clickable features that allow users to explore different learning outcomes in more detail. This would make the interface more straightforward, easier to navigate, and more accessible for different types of users.

Conclusion

To conclude, *Lumipal* addresses the limitations of earlier XR companion designs by integrating learning theory and a clearer learner-focused pathway to reduce cognitive load while preserving immersive AR interactions. AR L*earning Mode* provides children with opportunities to actively engage in the learning process by asking questions and working through key concepts. Meanwhile, *Companion Care* helps learners build emotional attachments with their companions, which can further motivate learning. *Admin Mode* also makes the app applicable to traditional classroom settings by allowing teachers to manage learning materials and support students beyond their physical presence. Our design ultimately demonstrates how AR companions can support more learner-centered, accessible, and emotionally meaningful learning experiences for young learners.

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