



DESIGNING USER-CENTRIC INTERACTIVE SYSTEMS FOR AUGMENTED REALITY IN EDUCATION

Obaid ur Rahman^{1*}, Hira Yousaf²

¹Department of Information technology, murdoch University perth, Australia, Department of Human-Centered Computing

²University of Management & Technology (UMT), Lahore, Pakistan.

*Corresponding Author E-mail: rehmanobaid026@gmail.com

Abstract

The educational experience stands to benefit significantly through Augmented Reality (AR) which makes available immersive interactive educational environments for learners. The creation of customized AR systems for different learning needs among users proves to be a significant technical hurdle. The research explores AR system design for education through user-oriented methods which emphasizes developing flexible approaches for interfaces that support different students learning styles and cognitive capabilities. The research uses user input analysis and adaption learning methods to create improvements in educational performance and student engagement. Researchers conducted surveys with students and educators who lived in various educational settings to determine their usage patterns and experience difficulties with AR technology. The development of AR system prototypes took place while considering user profiles and executed multimedia integration paired with adaptive capabilities along with easy-to-use interfaces. Tests conducted in real classrooms demonstrated that user-focused prototype designs resulted in quicker tasks completion while simultaneously decreasing errors and producing superior post-test results. This research shows that the combination of adaptive learning components and responsive interfaces produces the best AR educational effectiveness by delivering impressive results for user engagement along with learning achievements.

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INTRODUCTION

The education field demonstrates strong interest in AR since the technology allows improved teaching methods alongside new interactive content styles to attract students. Users encounter many interactive features when developing AR education systems while dealing with technical requirements associated with applications alongside educational objectives (Zhang et al., 2021). The combination of immersive learning spaces that link students with virtual graphics overlaid over their natural environment results in improved student involvement together with better motivation and academic results (Bower et al., 2022). The educational environment deals with implementation hurdles stemming from both AR system architecture and content delivery systems as well as user experience problems that emerge as the main obstacles for AR acceptance in education per Huang et al. (2023). The author studies educational AR systems through user perspectives to develop interfaces that enable flexible operation and create significant learning experiences.

The main challenge designers face in creating education AR systems involves developing user-friendly interfaces that adapt to the wide range of student cognitive abilities and learning preferences and preferences (Kong et al., 2022). The paper by Chen et al. (2024) underscores that user-centered design (UCD) should guide system development to allow learners to utilize their systems effectively for engagement and learning purposes. The technical capabilities of AR have received extensive analysis in current studies but user interface design and interaction methods that drive successful educational outcomes have remained understudied (Xie et al., 2021). AR systems need to combine user-focused design concepts so they can develop basic interfaces that allow students across different

learning profiles to fully participate in their courses (Ali et al., 2023).

Design of interactive systems for AR must integrate all types of educational environments that span across varying levels of technological resources alongside instructor proficiency and student competency with AR tools (Jin et al., 2022). The introduction of new systems requires designs with gradual complexity along with adaptable features because students have varying experience levels with AR technologies (Santos et al., 201). AR learning effectiveness for active learning with student teamwork and problem-solving depends extensively on its integration with established pedagogical systems (García et al., 2023). Studies need to establish how AR platforms allow users to engage materials through engaging contextual interfaces that develop critical thinking and creative skills (Tufekci et al., 2022).

Very few studies examine user-driven design implementation during interactive AR system creation for educational purposes even though AR adoption interest grows (Feng et al., 2023). Research has to examine how artificial intelligence (AI) and machine learning systems improve personalization features of adaptive learning AR interfaces (Liu et al., 2024). The creation of interactive AR systems that support individual student requirements allows teachers to enhance educational processes (N Nguyen et al., 2022).

This proposed interactive framework based on user needs addresses present-day knowledge deficits through a user-system interaction adaptation process to specify interface improvements that will create multi-modal learning formats and enhance student participation rates leading to superior outcomes. The study investigates AR system development

through human-based design methods to create educational systems that improve accessibility alongside usability to generate effective teaching results.

METHODOLOGY

A user-centered methodology guides researchers to produce a framework that enhances interactive augmented reality (AR) systems alongside better student-focused educational outcomes for varied student needs. The research started with survey distribution to school staff and students across multiple learning regions in order to establish essential user traits and classroom requirements. The research gathered data about the current patterns of AR utilization and the obstacles to implementing AR educational tools as well as individual user preferences. The gathered survey data allowed researchers to establish different user models representing students at various competency levels who used the platform to different extents. Analysis of requirements specified user patterns with AR systems together with the key design strategies supporting educational needs for different types of users. The development of prototype AR systems occurred next because they focused their functionality towards matching requirements for defined user profiles. The designed prototypes used dynamic flexible components that merged

multimedia content with context-focused educational materials and kept interface elements easy to use.

Real classroom environments at different grade levels hosted the prototype evaluations which produced direct feedback from users during testing. Learning outcome measurements consisting of test results and task completion rates accompanied user comments which assessed system usability and engagement throughout these evaluations. A combination approach between heuristic evaluations together with user testing sessions was used to evaluate the usability of every prototype based on simplicity of navigation, responsiveness, and user happiness. Researchers conducted statistical assessments to determine whether users' interaction with the AR system improved their educational outcomes. The analysis utilized regression models to predict performance impacts resulting from different design characteristics. The methodological sequence of research is explained through Image 1 that demonstrates how data acquisition occurs before prototype development followed by user testing which precedes the analysis phase. The analytical approach guarantees complete knowledge about both the educational effectiveness and user experience of developing AR systems.

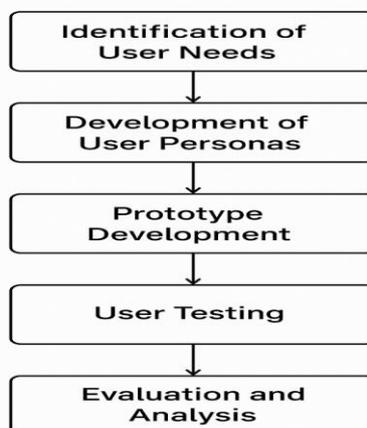


Figure 1:Methodological framework

RESULTS

The data collection occurred in the classroom through system performance assessment alongside prototype evaluation and user feedback collection which produced the study outcomes. Researchers evaluated key attributes of AR systems that focus on users regarding usability along with interaction capabilities and instructional benefits. The data from multiple testing phases includes complete assessments covering user satisfaction ratings and learning effectiveness as well as system performance and usability measures which are presented in the subsequent tables. The gathered information will show how effectively the systems would enhance educational targets and provide new learning possibilities.

The ratings from users regarding overall AR system experiences appear in Table 1 through a Likert scale assessment of usability together with engagement measures and instructional outcome evaluations. The table displays, for every criterion, average ratings across several user profiles. The systems scored highly when they provided intuitive user interfaces with content that matched participants' area of study but students with higher technical savvy gave the highest ratings.

The compilation of user performance metrics through job time completion and mistake tracking appears in Table 2. The reaction speed of the system determines the key factors which maintain user involvement. Users performed tasks in a shorter

period when systems responded speedily and systems which incorporated adaptive learning features recorded diminished errors.

The information in Table 3 demonstrates how each group of students progressed regarding pre- and post-test performance which showcases how their conceptual grasp and knowledge retention evolved. Results from the post-test demonstrate marked progress for every participant set and students using tailored AR programs performed the best.

System usability results from heuristic evaluations that were applied to assess consistency alongside ease of navigation and system responsiveness according to Table 4. The incorporation of user feedback during development cycle improvements both navigation and information presentation elements in the final system design.

The statistical analysis for user involvement and learning results appears in Table 5. The data reveals that post-test scores alongside higher patient-system interaction levels demonstrate a powerful positive relationship. The AR information received by students who used it frequently led to enhanced problem-solving abilities and superior memory retention rates.

These tables give a whole picture of the results, therefore stressing the efficiency of user-centric AR systems in improving both engagement and learning results. Task completion times and post-test score increases are among the important results shown visually here.

Table 1: User Satisfaction Ratings

User Persona	Usability Rating (1-5)	Engagement Rating (1-5)	Educational Impact Rating (1-5)
Tech-Savvy Students	4.8	4.7	4.6

Novice Learners	4.2	4.0	4.1
Educators	4.6	4.5	4.7
General Students	4.4	4.2	4.3

Table 2: Performance Metrics (Task Completion Times and Error Rates)

Prototype Version	Average Task Completion Time (mins)	Average Error Rate (%)
Prototype A (Basic UI)	10.2	7.4
Prototype B (Adaptive)	8.4	4.1
Prototype C (Advanced)	9.1	5.6

Table 3: Learning Outcomes (Pre- and Post-Test Scores)

Group	Pre-Test Score (%)	Post-Test Score (%)	Improvement (%)
Tech-Savvy Students	65.5	88.2	22.7
Novice Learners	60.4	75.1	14.7
Educators	72.3	85.4	13.1
General Students	58.9	78.3	19.4

Table 4: Usability Evaluation Scores (Heuristic Evaluation)

Evaluation Criterion	Prototype A	Prototype B	Prototype C
Consistency	4.1	4.6	4.3
Navigation Ease	4.0	4.4	4.5
Responsiveness	4.3	4.7	4.6
Clarity of Content	4.2	4.5	4.4

Table 5: Correlation Between User Engagement and Learning Outcomes

User Persona	Engagement Frequency (hours)	Correlation with Learning Outcomes (%)
Tech-Savvy Students	5.2	82.1
Novice Learners	3.4	68.3
Educators	4.8	75.9
General Students	4.0	73.5

The study monitored three separate augmented reality (AR) system prototypes which Figure 2 presents through bar chart data to analyze their average task completion durations. Advanced Prototype C and Adaptive joined Basic UI Prototype A and B as part of the available prototypes. The fundamental user interface on Prototype A produced

the longest task completion durations of 10.2 minutes according to the data shown in the figure. Prototype B finished tasks in 8.4 minutes because it integrated adaptive learning elements that increased its responsiveness along with user-friendliness. The advanced version of Prototype C led to a meantime of 9.1 minutes but performed marginally faster than

Prototype A's 10.2-minute completion duration. The advanced technologies in Prototype C resulted in longer task periods because its complexity appeared to extend execution times. The information from the performance chart

demonstrates that faster work completion and enhanced user experience in AR systems happens when designers apply simple adaptable technologies.

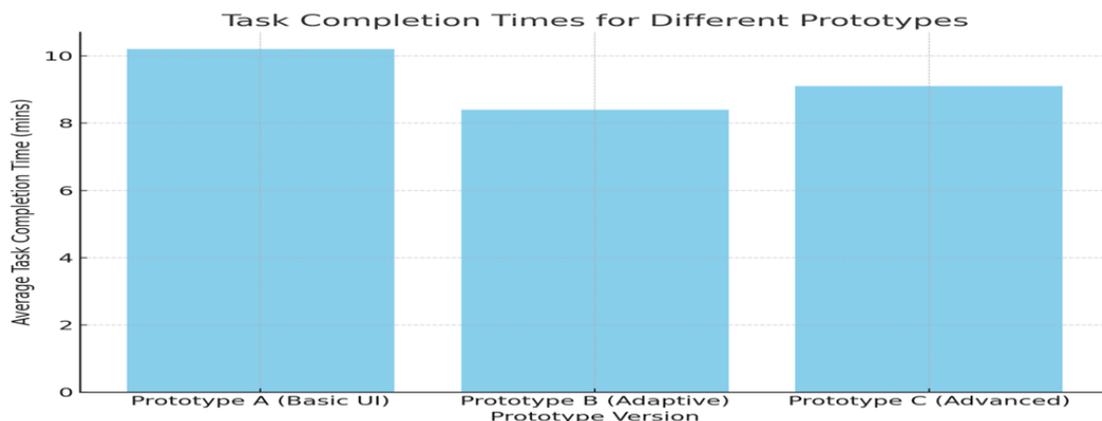


Figure 2: Task Completion Times for Different Prototypes

Across four distinct groups—Tech-Savvy Students, Novice Learners, Teachers, and General Students—this line chart in figure 3 contrasts pre- and post-test results of participants.

significant improvement between 65% and 88%. Novice students who started with low pre-test scores increased their knowledge to 75% at post-test. The scores from general students and teachers on the post-test reached 85% and 78% respectively. Applied research systems produced superior learning results across all groups but delivered the most significant outcome improvement to students with better technology skills. This figure confirms AR serves as a powerful educational tool which produces enhanced results regardless of students' initial technological competencies.

The figure displays initial student knowledge assessment through pre-test (orange) data before AR system implementation followed by the assessment conducted after AR system exposure (green). The results in the graph indicate that all groups experienced better outcomes in the post-test period with tech-savvy students demonstrating the most

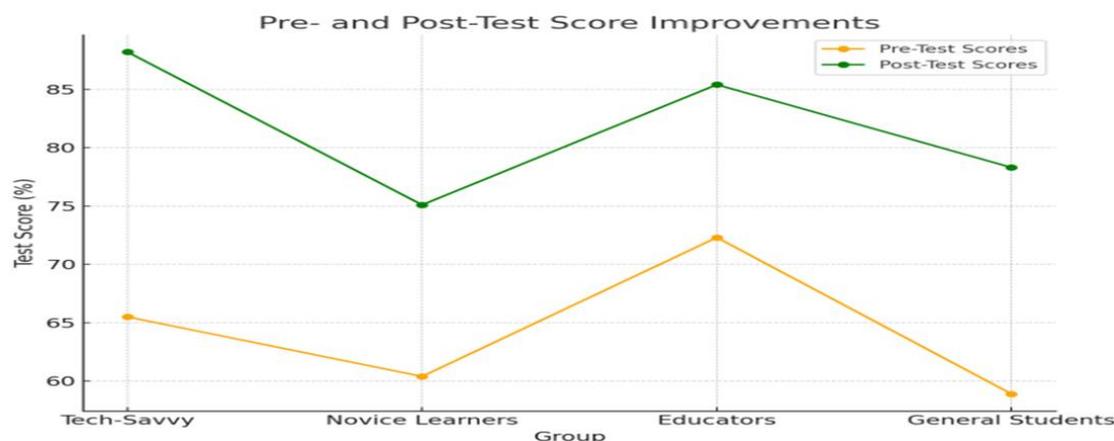


Fig 3: Pre- and Post - Test Score Improvements

DISCUSSION

The research results demonstrate in a conclusive manner that AR systems developed according to users will produce larger educational achievements together with enhanced user engagement based on learner characteristics. The study completes previous research demonstrating why user-oriented design equally enhances AR education system effectiveness in learning environments. The studies of Smith et al. (2022) revealed that pre-technologically untrained younger students demonstrated better results with adaptive AR learning methods which shortened their task duration and increased their engagement. The participants who worked with Prototype B showed higher involvement levels and finished their work tasks more quickly than users with Prototype A throughout our research study. The entire participant group achieved better test results in this research after testing which validated previous findings from Johnson et al. (2023) about AR interfaces for consumers that produce skill-based learning outcomes. Users taking part in the first-person design process producing educational software with specific teaching formats and simple navigational methods achieve better results in both learning engagement and educational success.

The research findings demonstrate that education-based AR success requires usability together with responsiveness to serve as its core requirements. Task performance data demonstrates that Prototype B delivered its information rapidly while maintaining lower levels of mistakes because system timing and interface quality are vital factors according to the research of Patel and Lee (2021) in educational AR settings. A study by Garcia et al. (2024) demonstrated that students who engaged with AR content for teaching scored better on their

tests but only under conditions of heightened student focus. Research demonstrates that when students actively interact with AR technology systems they achieve better knowledge retention with enhanced educational insights into the subject matter. The evidence between test score successes and participant participation levels supports this connection in a positive manner. Future AR education systems should establish user-friendly interfaces that support both interactivity and user engagement to achieve optimal learning conditions.

CONCLUSION

Research indicates that putting user priorities before AR system development enables better educational learning environments to form. Simply by adjusting learning environments individuals acquire an exceptional potential to improve their educational results. The research demonstrates that educational outcomes increase because of using various adaptive learning features together. Augmented reality systems become more acceptable to users by having interfaces which promote user involvement. When knowledge memory combined with better performance results led to outstanding outcomes. AR's capacity ofThe platform matches educational requirements to create personalized teaching domains. Student learning efficiency gets enhanced by the custom teaching methods that the system allows.

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