Acta et Commentationes, Exact and Natural Sciences
Volume 18(2), 2024, Pages 114–124
CZU: 004.94
ISSN: 2537-6284
E-ISSN: 2587-3644
DOI: 10.36120/2587-3644.v18i2.114-124

User perception analysis of the developed AR applications: satisfaction and development directions

Inga Titchiev and Olesea Caftanatov

Abstract. This article explores the application of Augmented Reality (AR) in education, specifically focusing on the use of AR-based flashcards to support deep learning of mathematical concepts (geometry, Pi number) and vocabulary acquisition (metaphorical terms). AR flashcards offer an innovative solution by integrating dynamic, multimedia-rich content, which enhances understanding and engagement. Prototypes were tested with various user groups, including middle school and university students, who provided valuable feedback through surveys. The SWOT analysis revealed strengths such as clarity and usefulness, particularly in subjects like mathematics and biology, but also identified areas for improvement, such as technical issues and interface design. Based on user input, the design of animal-themed markers was refined to better align with user preferences by more relevant and specific imagery. The findings emphasize the importance of continuous refinement of AR applications to enhance their educational impact and accessibility.
2020 Mathematics Subject Classification: 68U15, 68T30.
Keywords: user perception, deep learning, augmented flashcards, user satisfaction.

Analiza percepției utilizatorilor asupra aplicațiilor AR dezvoltate: satisfacție și direcții pentru dezvoltare

Rezumat. Acest articol explorează aplicarea Realității Augmentate (AR) în educație, concentrându-se pe utilizarea cardurilor AR pentru a sprijini învățarea profundă a unor concepte matematice (geometrie, numărul pi) şi achiziția vocabularului (termeni metaforici). Cardurile AR oferă o soluție inovatoare prin integrarea de conținut dinamic și multimedia, care îmbunătățește înțelegerea și angajamentul. Prototipurile au fost testate cu diverse grupuri de utilizatori, inclusiv elevi de gimnaziu și studenți, care au furnizat un feedback valoros prin sondaje. Analiza SWOT a evidențiat punctele forte, cum ar fi claritatea și utilitatea, în special în domenii precum matematică și biologie, dar a identificat și zone de îmbunătățire, cum ar fi problemele tehnice și designul interfeței. Pe baza feedback-ului utilizatorilor, designul markerilor cu tematică animală a fost îmbunătățit pentru a se alinia mai bine la preferințele utilizatorilor prin imagini mai relevante și specifice. Rezultatele subliniază importanța rafinării continue a aplicațiilor AR pentru a spori impactul lor educațional și accesibilitatea.
Cuvinte-cheie: percepţia utilizatorilor, învăţare profundă, carduri augmentate, satisfacția utilizatorilor.

1. Introduction

In recent years, there is an increasing interest in applying Augmented Reality (AR) to create engaging, unique, and interactive educational environments [1, 2]. During the last three years, the research areas of our team are also related to the integration of Augmented Reality (AR) technologies in the educational field. This exploration has involved the design and implementation of various learning style scenarios aimed at enhancing user engagement with educational content [3]. Through this process, we have gained valuable insights into both the potential and the challenges associated with AR applications in education [4]. Our primary objective has been to develop AR applications that cater to diverse learning styles, thereby increasing user engagement. By creating immersive and interactive learning environments, we sought to make educational content more accessible and appealing to students. This approach has led to the development of scenarios that are not only visually engaging but also pedagogically effective, leveraging the unique capabilities of AR to provide enriched learning experiences.

We developed mobile applications to learn both math [5] and languages[6]. For mathematics learning, AR technology has been applied to topics related to geometry and exploring the world of Pi, offering a dynamic and immersive approach in the two developed applications: Learning Styles with AR and The Mysteries of Pi. In these applications, students can interact with various 2D and 3D geometric figures, as well as the number of Pi, in a creative and interactive way, developing a deeper understanding of these concepts.

For language, learning specifically includes apps like the Etymology app, which uses augmented flashcards, and Marker-Based approach. In the context of deep learning of a language, one of the most critical aspects of mastering a language is building a strong vocabulary. The size and depth of an individual's vocabulary significantly influence his ability to develop the four core Romanian skills: listening, speaking, reading, and writing. As teachers have consistently emphasized, expanding one's vocabulary accelerates overall language proficiency, improving comprehension and communication alike.

However, the process of vocabulary acquisition is not without challenges, particularly when it comes to learning metaphorical terms, which play a pivotal role in enriching language use and fostering nuanced understanding. Metaphorical expressions often carry meanings beyond their literal definitions, making them particularly difficult for learners to grasp. For students, deciphering and internalizing such terms can feel overwhelming because of cultural differences, abstract meanings, and limited exposure to contextual usage.

To address these challenges, innovative methods are required to support vocabulary learning. One promising approach is the use of augmented flashcards. Unlike traditional flashcards, augmented flashcards integrate dynamic, context-rich content-such as images, examples, and interactive exercises-helping learners connect abstract or metaphorical terms with concrete and memorable experiences. By combining technology with effective teaching strategies, augmented flashcards can transform vocabulary acquisition into a more engaging and accessible process, empowering students to overcome obstacles and expand their linguistic horizons.

In the early stages of our research, we successfully designed a series of augmented flashcard prototypes. These prototypes focus on various categories of metaphors, including mythological, sacred, anthropomorphic, chromatophore, and artifact metaphors, see Fig.1. Some flashcards are dedicated to conveying a single meaning, while others address multiple interpretations, resulting in tailored designs for each variation. To enhance comprehension and engagement, each flashcard is enriched with multimedia elements such as videos, GIFs, and images, providing vivid visual representations of the metaphorical terms.

Figure 1. Customized flashcards for learning the etymology of metaphorical terms

The customized cards feature homograph words that also represent metaphorical terms. When scanned using the developed mobile application, these cards generate augmented flashcards, as shown in Figure 2. For the sacred metaphor ”Romanița” (b), the front side of the flashcard displays the type of metaphorical term, the Moldovan-Romanian homograph word, and a video illustration of the term. Swiping the card reveals the back side, where a description with etymological explanations of the term is provided. These descriptions are translated into three languages, with the Spanish (a), Russian (b), and English (c) versions displayed in Figure 2.

However, to date, there is a lack of studies analyzing these applications that identify factors such as usability, satisfactions, advantages, limitations, effectiveness, challenges,

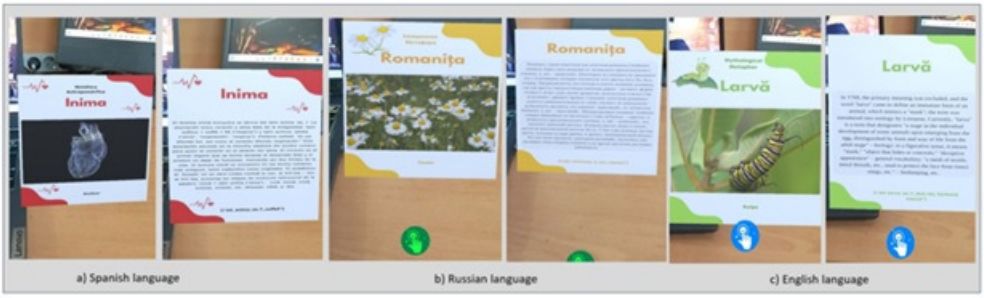

Figure 2. Screenshots from the augmented flashcard application

and features of augmented reality in educational settings. Personalization for promoting inclusive education using AR is also an area of growing interest. Thus, this article aims to shed light on some of these aspects.

In this regard, the applications have been subsequently tested with users of various age groups. The test was carried out with middle school students (grades 6–8) at IP Gimnaziul nr. 42, university students from the Technical University of Moldova under the supervision of Dr. Victoria Bobicev, and 70 students from Isen University in Cartagena and the University of Murcia in Spain, guided by Dr. Lucia Amaros. Student feedback has been collected through an opinion survey.

2. Analysis methodology

In the beginning, we will make a general presentation of the two sets of data that represent the answers provided by respondents from the Republic of Moldova and abroad. The first data set consisted of 70 respondents (from abroad), and the second data set consisted of 33 respondents (from Republic of Moldova). Both groups answered a set of 12 basic questions. The data processing algorithm consists of the following steps:

(1) Data cleaning - check for missing values and handle them appropriately, standardize text on key columns (e.g., capitalization, space trimming), check for missing data, and remove duplicate entries.
(2) Descriptive analysis summary (gender distribution, satisfaction distribution, usefulness distribution).
(3) Data is analyzed to identify trends - common themes or repeated keywords are identified, similar responses are grouped (for example, recommendations related to improving images or usability), key trends or frequent suggestions are highlighted.

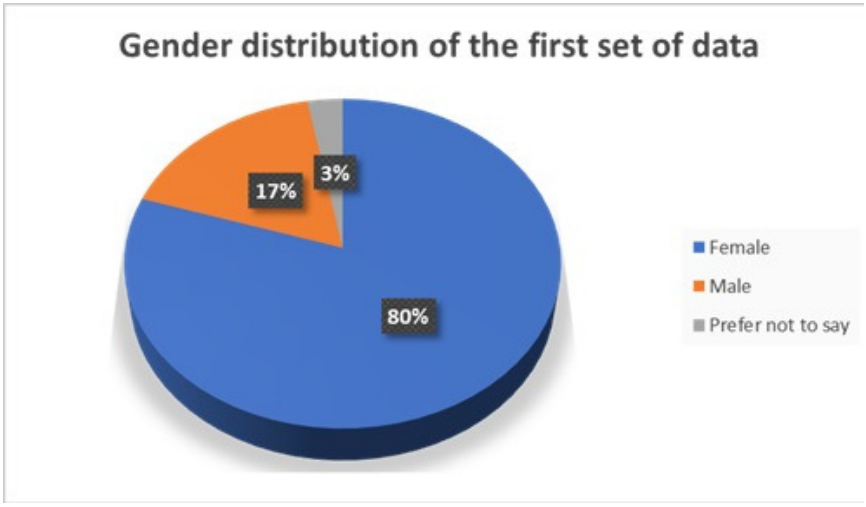

Figure 3. Gender distribution of the first set of data

(4) To determine the correlation between different data, the Chi-square test will be applied which is used to check if there is a relationship between two categorical variables or if an observed distribution differs significantly from an expected distribution.

2.1. For the first set of data

Descriptive analysis for the first data set consists of gender distribution (see Figure 3) of them, satisfaction level, and usefulness rating of users (see Figure 4).

In order to determine the correlation between gender and user satisfaction level, the chi-square test will be applied. Chi-square test results:

- Chi-square statistics (X^2): 121.31
- P-value: $6.27e-09$ (≈ 0.00000000627)

The extremely low p-value (< 0.05) suggests that there is a significant relationship between gender and satisfaction level. This indicates that the distribution of satisfaction levels is not uniform across genders and that there may be a distinct pattern.

The Chi-square test indicated a significant relationship between gender and level of satisfaction ($p < 0.05$). Women had a majority turnout, which may influence the overall distribution. Specific issues which were mentioned by the users were of limited compatibility, large app size, and limited interactivity. Several recommendations were made, such as ensuring compatibility of applications with multiple platforms (multiple devices

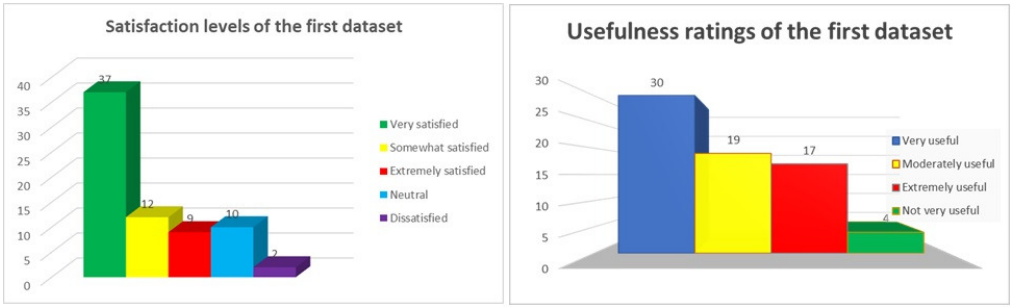

Figure 4. Satisfaction and usefulness for the first dataset

and operating systems), the possibility of using multiple languages, adding additional interactive features such as animations and sounds, especially for younger users, improving accessibility, reducing the size of the application for easier installation.

The relationship between utility and satisfaction was analyzed in order to identify whether the perception of utility influences the level of satisfaction.

Chi-square test results:

- Chi-square statistics (X^2): 253.33
- P-value: $5.10e-22$

The extremely small p-value indicates a significant relationship between perceived usefulness and the level of satisfaction. The distributions suggest that perceived usefulness directly influences user satisfaction. Users who find the app extremely useful or very useful report higher levels of satisfaction. To the question of what they did not like about the application, the most respondents answer with ”Nothing”, indicating a general level of satisfaction. Dissatisfactions identified include limited compatibility, app size, and interactivity.

2.2. For the second set of data

The descriptive analysis for the second data set includes the gender distribution (see Figure 5), user satisfaction levels, and usefulness ratings provided by users (see Figure 6).

Chi-square test results for utility vs. satisfaction:

- Chi-square statistics (X^2): 27.92
- P-value: 0.063

There is no significant relationship at the 5% level ($p > 0.05$), but there is a notable trend. The distribution indicates that perceived usefulness can influence satisfaction.

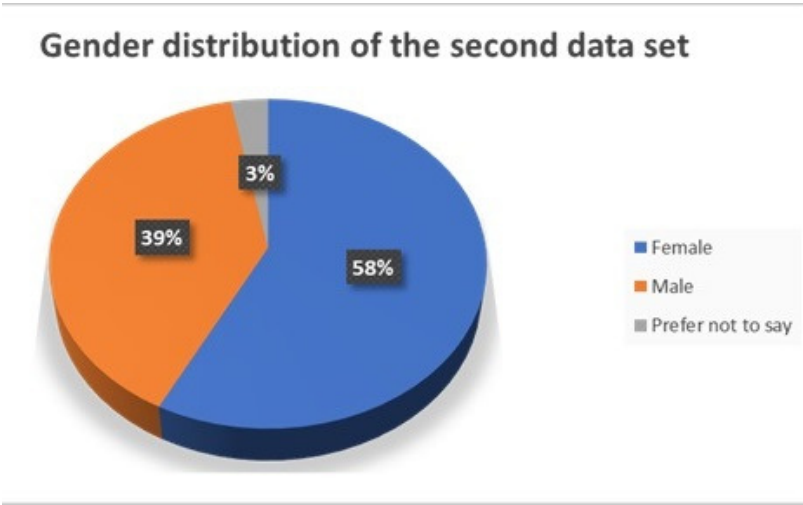

Figure 5. Gender distribution of the second set of data

Chi-square test results for clarity vs. satisfaction:

- Chi-square statistics (X^2): 17.29
- P-value: 0.836

The relationship between task clarity and satisfaction is not significant ($p > 0.05$). The distributions are more uniform, suggesting that satisfaction does not depend directly on perceived clarity.

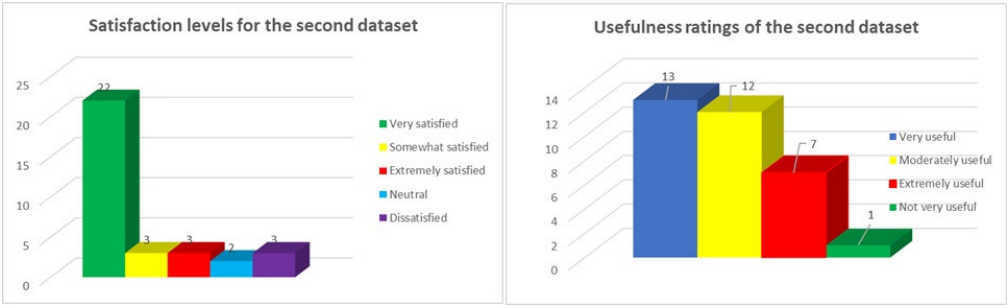

Figure 6. Satisfaction and usefulness for the second dataset

Participants who consider the app extremely useful or very useful tend to report higher levels of satisfaction. In contrast, perceptions of moderate usefulness are associated with varying levels of satisfaction, suggesting a partial correlation between perceived usefulness and overall satisfaction. Task clarity does not significantly influence overall satisfaction. The responses are evenly distributed for very clear or extremely clear scenarios, regardless of satisfaction. Increasing perceived usefulness of the apps may contribute

to greater satisfaction. Task clarity is well rated but does not appear to be a determinant of satisfaction.

Recommendations: adding interactive functionality (e.g., animations, visual tutorials), developing more applicative scenarios that increase the practical value of the application, keeping current standards, given that participants already perceive them to be very clear, creating a continuous feedback mechanism to better understand user needs, and developing custom functionality for different levels of satisfaction. Cards and scenarios are the main elements that users found attractive. Feedback suggests requirements for more content, but also observations about what works well.

3. SWOT Analysis

Integrating augmented reality (AR) into education involves challenges such as infrastructure limitations, content creation complexity, teacher training, and ensuring equitable access for students. To overcome these obstacles and fully leverage AR's potential, conducting a SWOT analysis of user satisfaction survey data is essential. This analysis helps identify strengths, weaknesses of developed applications, opportunities for improvement, and highlight threats, providing a solid foundation for optimizing applications and creating a more effective educational experience.

- **Strengths**:

  Most respondents consider the tasks and scenarios very clear or extremely clear, and a significant number express high satisfaction with the applications. Many find these applications useful or very useful, particularly in educational fields such as mathematics, computer science, and biology. "Cards" and "Scenarios" are highly appreciated, especially those featuring metaphors and animations, while users also value interactive examples and 3D animations.
- **Weaknesses**:

  In some cases applications face technical issues, such as incompatibility with iOS or long loading times, while criticism has been directed at the text size on cards and the overall interface design. Additionally, the lack of clear navigation menus and the absence of integration into a single platform are noted as limitations.
- **Opportunities**:

  There is a desire to diversify scenarios, such as those related to geometry, robotics, physics, and biology, while also adapting applications to work seamlessly on all devices, including iOS. Personalization is another key focus, with the aim

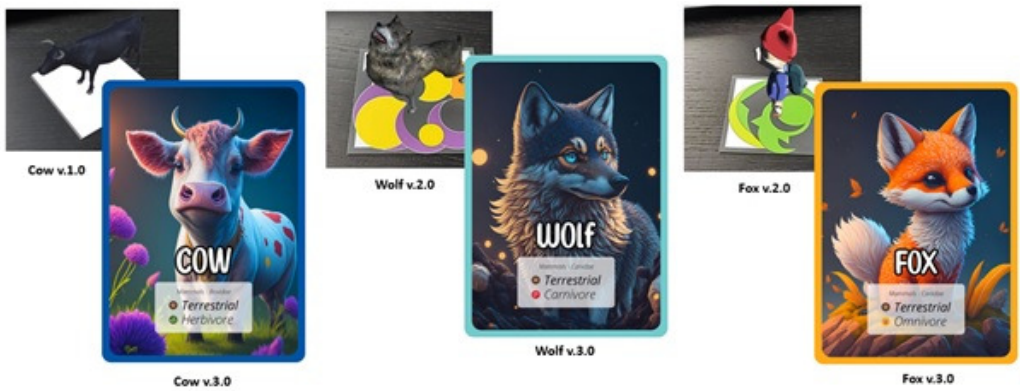

Figure 7. Marker designs improvements

of creating tailored scenarios based on user feedback, incorporating more animations with sounds and interactions. In addition, leveraging augmented reality is seen as a valuable opportunity to enhance lessons across multiple domains.

- **Threats**:

  The developed augmented reality applications do not collect personal data from students, making them relatively secure in terms of data privacy. However, several potential threats could arise. One is that users with limited engagement may find it difficult to provide detailed or meaningful feedback, which could hinder developers' efforts to enhance and adapt the platform based on user needs. Another challenge could stem from competition, as other AR learning platforms offering a wider range of features or personalized experiences might attract users, impacting the application's growth and user retention. In addition, compatibility and design issues present technical limitations that could negatively affect the overall perception of the applications.

4. Application improvements as a result of the data analysis from the questionnaire

After the presentation at Gimnaziul Nr. 42, where four of the developed applications were demonstrated to students for testing, they provided feedback on usability, functionality, and engagement, identified bugs, and suggested improvements to help refine the user experience. Although they preferred the card designs, they suggested that the markers feature more relevant and specific imagery. For instance, they would prefer to see real animals related to the cards rather than abstract designs.

Although they acknowledged that designing markers for math exercises can be challenging in terms of clarity and aesthetics, they felt that there is more flexibility for animal-themed applications. Based on this feedback, we have made several iterations to improve the marker designs (see Figure 7) for the animal app to better align with their preferences.

5. Conlusions

The integration of Augmented Reality (AR) into educational applications offers immense potential to enhance learning experiences. Through the development and testing of augmented flashcards, we have demonstrated that interactive and multimedia-rich tools can significantly increase engagement and effectiveness in deep learning.

Feedback from various user groups highlights both the strengths and challenges of AR-based educational applications. While most users expressed high satisfaction with the clarity and utility of the applications, issues such as technical compatibility, app size, and limited interactivity underline the need for ongoing improvements. The SWOT analysis further emphasizes opportunities for expanding the range of scenarios, improving accessibility, and incorporating personalized features to cater to diverse learning needs. Testing showed that the application was well-received, particularly in subjects like language learning, mathematics, and biology, although technical issues and interface design needed improvement. Feedback from users led to design improvements for animal-themed markers, aligning them with preferences for more relevant imagery. Continuous refinement based on user feedback is essential to maximize the application's educational value and accessibility.

Acknowledgments. Institutional Project 011301, Information systems based on Artificial Intelligence has supported part of the research for this paper.

References

[1] Kesim, M., Ozarslan, Y., Augmented Reality in Education: Current Technologies and the Potential for Education, *Procedia - Social and Behavioral Sciences*, 2012, vol. 810, no. 47, 297–302.

[2] Bacca, J., Baldiris, S., Graf, S., et al. Augmented reality trends in education: A systematic review of research and applications. *Educational Technology & Society*, 2014, vol. 14, no. 4, 133–149.

[3] Titchiev, I., Caftanatov, O., Talambuta, D., Iamandi, V., Caganovschi, D. An approach to augmented reality classification and an example of its usage for application development with VAK learning styles Markers. *Computer Science Journal of Moldova*, 2023, no. 2, 248–271.

[4] Titchiev, I., Caftanatov, O., Talambuta, D. Challenges associated with using AR technology in education. *Computer Science Journal of Moldova*, 2023, vol. 13, no. 3, 367–380.

[5] Titchiev, I., Caftanatov, O., Talambuta, D. Discovering the mysteries of Pi number using AR technologies. *Acta et Commentationes. Exact and Natural Sciences*, 2023, Vol. 16, no. 2, 118–127.

[6] Caftanatov, O., Malahov, L., Titchiev, I., Talambuta, D., Caganovschi, D., Mincu, E. Metaphor Mastery: Augmented Reality Dictionary Flashcards for E-Learning. *The 18th International Conference on Linguistic Resources and Tools for Natural Language Processing*, December 11-14, 2023, Braşov, România. Proceedings of ConsILR-2023, 63–72.

Received: October 19, 2024 *Accepted: December 28, 2024*

(Inga Titchiev, Olesea Caftanatov) "Vladimir Andrunachievici" Institute of Mathematics and Computer Sciences, Moldova State University, 5 Academiei St., Chişinău, Republic of Moldova
E-mail address: inga.titchiev@gmail.com, inga.titchiev@math.usm.md
E-mail address: olesea.caftanatov@math.usm.md