Multimodal Technologies and Interaction

MDPI

Article

Exploring the Role of User Experience and Interface Design Communication in Augmented Reality for Education

Matina Kiourexidou [1,*], Andreas Kanavos [2], Maria Klouvidaki [3] and Nikos Antonopoulos [4,*]

[1] Department of Digital Media and Communication, Ionian University, 28100 Argostoli, Greece
[2] Department of Informatics, Ionian University, 49100 Corfu, Greece
[3] Department of Production Engineering and Management, Technical University of Crete, 73100 Chania, Greece
[4] Department of Digital Media and Communication, NeMeCULAB, Ionian University, 28100 Argostoli, Greece
* Correspondence: kiourexidou@ionio.gr (M.K.); nikos@antonopoulos.info (N.A.)

Abstract: Augmented Reality (AR) enhances learning by integrating interactive and immersive elements that bring content to life, thus increasing motivation and improving retention. AR also supports personalized learning, allowing learners to interact with content at their own pace and according to their preferred learning styles. This adaptability not only promotes self-directed learning but also empowers learners to take charge of their educational journey. Effective interface design is crucial for these AR applications, requiring careful integration of user interactions and visual cues to blend AR elements seamlessly with reality. This paper explores the impact of AR on user experience within educational settings, examining engagement, motivation, and learning outcomes to determine how AR can enhance the educational experience. Additionally, it addresses design considerations and challenges in developing AR user interfaces, drawing on current research and best practices to propose effective and adaptable solutions for educational AR applications. As AR technology evolves, its potential to transform educational experiences continues to grow, promising significant advancements in how users interact with, personalize, and immerse themselves in learning content.

Keywords: augmented reality; user experience design; educational technology; AR interface design; interactive learning

Citation: Kiourexidou, M.; Kanavos, A.; Klouvidaki, M.; Antonopoulos, N. Exploring the Role of User Experience and Interface Design Communication in Augmented Reality for Education. *Multimodal Technol. Interact.* **2024**, *8*, 43. https://doi.org/10.3390/mti8060043

Academic Editor: Deborah Richards

Received: 28 April 2024
Revised: 16 May 2024
Accepted: 18 May 2024
Published: 22 May 2024

1. Introduction

Augmented Reality (AR) technology has significantly influenced both the fields of education and technology in recent years, presenting notable developments and expanding opportunities for interactive learning [1]. As one of the most innovative and engaging fields today [2], AR enhances educational experiences by seamlessly integrating virtual elements with real-world environments, thus making abstract concepts tangible and interactive [3]. The increased appeal of AR, driven by technological advances and the growing accessibility of AR devices, is particularly notable within education, where it is rapidly becoming a central tool for enhancing learning [4,5].

The extensive application of AR in educational settings is well documented, as evidenced by the proliferation of research with approximately 18,000 articles indexed by Google Scholar in 2023 alone, using the search term 'augmented reality education'. These studies collectively explore how AR can enhance learning environments by fostering greater engagement, personalization, and diverse educational experiences [3,6]. They highlight AR's capacity to support varied learning styles and needs, offering a more adaptive and responsive educational toolset.

AR has been used in education with a positive impact for over twenty-five years [7]. Recent advancements in AR technology have not only improved the fidelity and usability of AR applications but have also spurred further discussions on critical design considerations. These discussions encompass key aspects such as tracking accuracy, advanced display technologies, and user-friendly interaction techniques, which are vital for developing effective and immersive educational tools [8,9]. Moreover, these technological enhancements have enabled AR to facilitate a more collaborative and interactive learning atmosphere, where students can engage in shared educational activities and projects in a virtual space that mimics real-world interactions.

This study aims to delve deeper into the impact of AR on user experiences in educational settings, focusing specifically on motivational factors and learning outcomes. It also seeks to explore the intricacies of user interface design for AR applications, which is pivotal in creating intuitive and effective educational tools. By scrutinizing existing research and identifying best practices, this research endeavors to uncover insights for the development of effective and user-centric AR interfaces tailored for educational purposes. Ultimately, leveraging rigorous user experience (UX) and measurement standards, this study aims to align AR applications with user needs, thereby enhancing the overall educational experience and setting new benchmarks in educational technology.

The rest of the paper is organized as follows: Section 2 details the mixed-methods approach employed in our study, including descriptions of the sample, survey instruments, and data analysis techniques used to explore the impact of augmented reality on user experience. Section 3 presents the findings from the survey, highlighting key correlations and insights into the usability and application of AR in various contexts. In Section 4, we interpret these findings, discussing the implications for both the design of AR interfaces and their practical applications in education and daily life. We examine how factors such as ease of use and educational utility influence user perceptions and engagement. Section 5 summarizes the major contributions of our research, addresses its limitations, and suggests directions for future research to further understand and enhance the integration of AR technologies in user-centric applications.

2. Materials and Methods

This study employed a mixed-methods approach, integrating both qualitative and quantitative research methods, to investigate the impact of augmented reality (AR) on user experience and interface design in educational applications. Specifically, the quantitative component consisted of surveys and usability testing, while the qualitative aspect involved detailed analysis of open-ended survey responses and usability feedback. All statistical analyses were conducted using SPSS version 23 (IBM Corp., Armonk, NY, USA).

2.1. Selection of Technological Tools

The choice of the "Google Arts & Culture" app for this study was driven by several factors that align with our research objectives [10]. First, the app's broad accessibility and robust AR features make it an ideal platform for studying the integration of AR into educational settings. Additionally, the "Art Projector" feature uniquely allows for interactive learning experiences that are pivotal in studying the impacts of UX/UI design on user engagement and educational outcomes. This app also represents a readily available AR technology that can be generalized across different educational and cultural contexts, thereby providing insights that are applicable beyond the specific confines of traditional educational technologies. Utilization of this app enables a comprehensive examination of how AR can enhance educational experiences and outcomes through improved user interaction and interface design.

2.2. Research Tools and Rationale

The research was conducted using the "Google Arts & Culture" application, focusing on the "Art Projector" feature. This feature was selected due to its innovative use of AR to project digital images of artworks into physical spaces, making it a relevant tool for exploring AR's educational capabilities. The Art Projector allows users to envision how artworks, such as Van Gogh's "Irises," might appear on their own walls, providing a unique blend of art appreciation and interactive learning.

2.3. Sample Description

The study sample comprised 93 participants, including students and university or college graduates from a diverse range of educational institutions. These participants were selected to provide a broad perspective on the usability and educational value of AR in diverse learning environments. Informed consent was obtained from all participants, with assurances of confidentiality and anonymity rigorously maintained.

2.4. Survey Design and Data Collection

A structured questionnaire was developed to gather quantitative data on user perceptions, engagement, and learning outcomes related to AR in education. The research started on 1 December 2023 and lasted for seven days. Additionally, the link for the questionnaire was posted on a Facebook profile. The survey featured a variety of question types, including Likert-scale, Guttman-scale, and open-ended items. The inclusion of demographic questions at the beginning of the questionnaire helped contextualize the findings. The questionnaire was designed based on established research, and was pilot tested to ensure reliability and validity. Each question was crafted to link directly to the research objectives, with the aim of elucidating specific aspects of AR's impact on learning and user interaction.

2.5. Example Survey Questions with Justifications

Familiarity with AR: "Are you familiar with the term 'augmented reality'?" This evaluates awareness of AR, which is crucial for understanding its adoption and implications [11].

Daily Use of AR: "Do you use augmented reality every day?" This question assesses the integration of AR into daily routines, as discussed in Azuma (1997), highlighting its widespread applicability [12].

AR in Education: "Do you use augmented reality for educational purposes?" Inspired by Klopfer (2019), this question explores AR's role in enhancing educational processes and outcomes [13].

Usage of AR applications: "Have you used applications or devices that support augmented reality?" This assesses the prevalence of AR technologies in various sectors [9].

AR's Educational Utility: "Do you think augmented reality is useful for education?" This examines AR's potential to improve educational experiences based on findings from Dunleavy (2009) [14].

AR in Daily Life: "Do you think augmented reality is useful for everyday life?" This investigates AR's broader societal impact, as described by Billinghurst and Duenser (2012) [15].

Ease of Use: "Do you find augmented reality easy to use?" This question addresses usability improvements in AR interfaces [15].

Engagement: "Do you find augmented reality engaging?" This focuses on AR's immersive capabilities, which are fundamental for user engagement [12].

Creativity Enhancement: "Do you think augmented reality can enhance creativity?" This explores AR's potential to foster creative expression [11].

Social Interaction: "Do you think augmented reality can enhance interactions with others?" This assesses AR's ability to create new social dynamics and shared experiences [14].

2.6. Ethical Considerations

This study does not contain person-related data acquisition, and was conducted only with adult participants with their permission. All procedures performed were in accordance with ethical standards of the academic community.

2.7. Usability Testing

This subsection outlines the usability testing process [16] conducted to assess the effectiveness and user-friendliness of the AR user interface within the "Google Arts & Culture" app, specifically focusing on the "Art Projector" feature.

2.7.1. Testing Setup and Participant Demographics

Usability testing was conducted in a controlled environment, using the "Art Projector" feature of the "Google Arts & Culture" app to assess interface navigability and user interaction efficiency. Nineteen participants, including five professors and fourteen students from a university, were involved. These participants were selected due to their varying degrees of familiarity with AR technology, with students aged between 18 and 24, and professors aged between 35 and 40, providing a diverse range of perspectives.

2.7.2. Task Design and Implementation

Participants were asked to perform a series of tasks designed to assess various aspects of the AR interface, such as navigation, interaction with virtual objects, and accessing educational content. Each task was aligned with specific usability goals to evaluate the effectiveness of the "Art Projector". Tasks were explained in detail, and participants were guided on how to interact with the AR interface and perform the assigned tasks.

2.7.3. Application of Theoretical Frameworks

'Shneiderman's Eight Golden Rules of Interface Design' served as foundational guidelines for evaluating the usability of the AR interface [17]. These rules were methodically applied to each task to ensure that the interface design adhered to principles that promote clarity, efficiency, and user-friendliness. For example, the first task assessed the consistency of interaction patterns across different AR experiences to see if the interface met Shneiderman's criteria for consistency.

2.7.4. Participant Interaction and Feedback

Detailed observations were made of participants' interactions with the AR interface, noting ease of use, challenges encountered, and intuitive design aspects. Feedback was gathered through both structured and spontaneous responses, using the think-aloud protocol to capture real-time insights. This method provided immediate information that could be used for iterative improvements of the interface [18].

2.7.5. Evaluation of Specific Tasks

Each task was directly linked to a specific principle of Shneiderman's rules [17]:

Task 1-Consistency: participants explored various AR artworks to observe interaction patterns, gestures, and controls across different AR experiences.

Task 2-Shortcuts: this enabled frequent users to identify shortcuts that facilitate efficient navigation and interaction.

Task 3-Informative Feedback: participants paid attention to the feedback provided by the app during interactions.

Task 4-Closure: this involved engaging with an AR artwork to observe if the interaction exhibited clear beginning, middle, and end phases.

Task 5-Error Prevention: this involved attempting to access the text description of a painting and noting any error messages.

Task 6-Reversal of Actions: upon selecting a painting, participants attempted to undo the action.

Task 7-Control: this involved exploring and manipulating AR artworks to assess if they felt a sense of control over the AR experience.

Task 8-Memory Load: this involved engaging with multiple AR artworks, noting if the app provided clear cues to minimize reliance on short-term memory.

Upon completing the usability tests, participants were debriefed, and their qualitative feedback was recorded. Open-ended questions were posed to gather their thoughts, opinions, and suggestions for improvement. This feedback will be used to inform future iterations of the AR interface, ensuring it better meets users' needs and enhances their learning experience.

3. Results

3.1. Sample Demographics

This study involved a diverse group of 93 participants selected to evaluate the impact of augmented reality (AR) technologies in educational settings. The participant pool consisted of 54 students (58.7%) and 38 university or college graduates (41.3%), reflecting a robust cross-section of the current educational landscape. It is noteworthy that there was one non-response concerning educational level, leading to a total of 92 responses being processed for demographic analysis.

Table 1 provides a detailed breakdown of the demographic characteristics:

- Gender Distribution: the sample included 43 males (46.2%) and 50 females (53.8%), showcasing a slight female predominance.
- Educational Background: A significant portion of the participants were students (58.7%), with university or college graduates making up the remaining 41.3%. This distribution underscores the study's relevance to ongoing learners and educational professionals alike.
- Age Range: The majority of respondents (55.9%) were between 18–25 years old, capturing a predominantly youthful demographic. Additionally, 21.5% were aged 26–35 years, and 22.6% were older than 36 years. This age diversity highlights the broad appeal and applicability of AR technologies across different age groups.

This demographic overview, detailed in Table 1, ensures a comprehensive understanding of the study's participant base, which is critical for contextualizing the findings within real-world educational environments.

Table 1. Sample demographics.

Gender				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Male	43	46.2	46.2	46.2
Female	50	53.8	53.8	100.0
Total	93	100.0	100.0	
Educational level				
	Frequency	Percent	Valid Percent	Cumulative Percent
Student	54	58.1	58.7	58.7
University/College	38	40.9	41.3	100.0
Total	92	98.9	100,0	
No answers	1	1.1		
Total	93	100.0		

Age				
Frequency		Percent	Valid Percent	Cumulative Percent
18–25	52	55.9	55.9	55.9
26–35	20	21.5	21.5	77.4
36+	21	22.6	22.6	100.0
Total	93	100.0	100.0	

The demographic data presented in Table 1 are crucial for understanding the context in which the AR technology was used. The youthful nature of the sample is indicative of a group likely to be familiar with and receptive to new technologies, which is essential for studies involving innovative tools like AR.

3.2. Descriptive Statistics

This subsection presents descriptive statistics that summarize the responses regarding internet usage, daily use of augmented reality (AR), and attitudes toward AR's application in education and daily life.

3.2.1. Internet Usage

The distribution of internet usage among the respondents is depicted in Figure 1. A majority, 74.2%, reported using the internet 1–3 h per day, highlighting moderate engagement with web activities. In contrast, 11.8% use the internet for 4–6 h, and 14% for more than 7 h daily, indicating a smaller segment with high web usage.

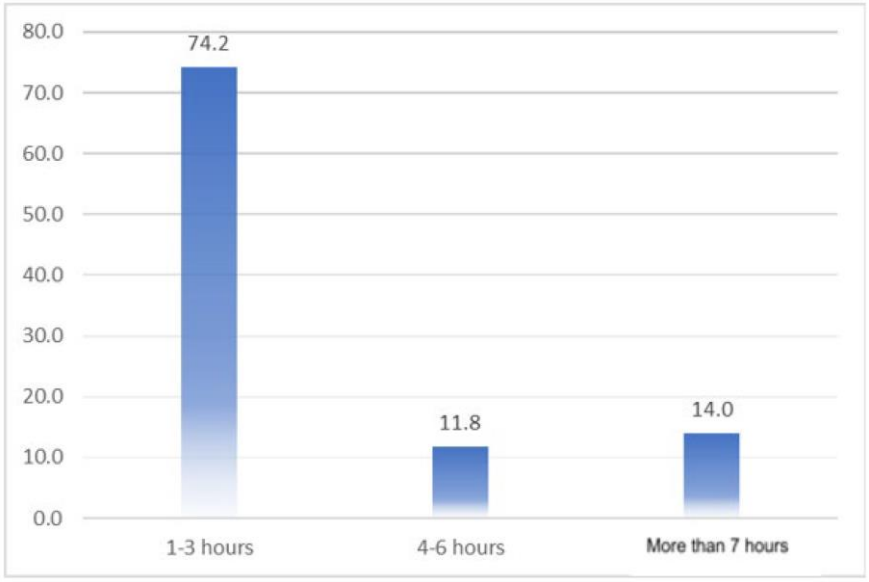

Figure 1. Internet usage (in hours). (Responses in %).

3.2.2. Daily Use of Augmented Reality

Figure 2 illustrates that 66.7% of the participants use augmented reality daily, demonstrating significant adoption of AR technology among the sample. Conversely, 33.3% of the participants do not use AR daily.

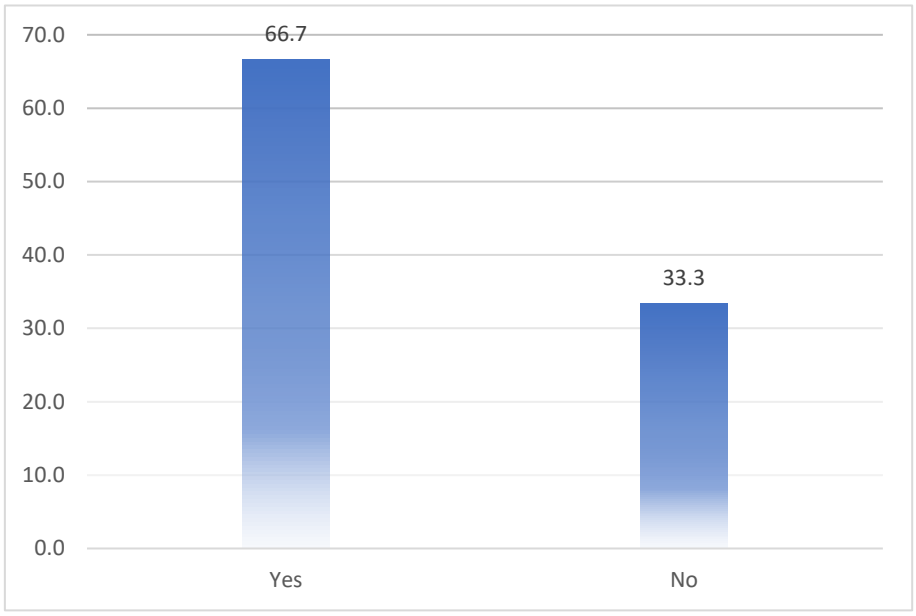

Figure 2. Do you use augmented reality daily? (Responses in %).

3.2.3. Augmented Reality for Educational Purposes

The usage of AR for educational purposes shows even more intense activity among respondents, as shown in Figure 3. This suggests a strong potential for AR applications within educational settings.

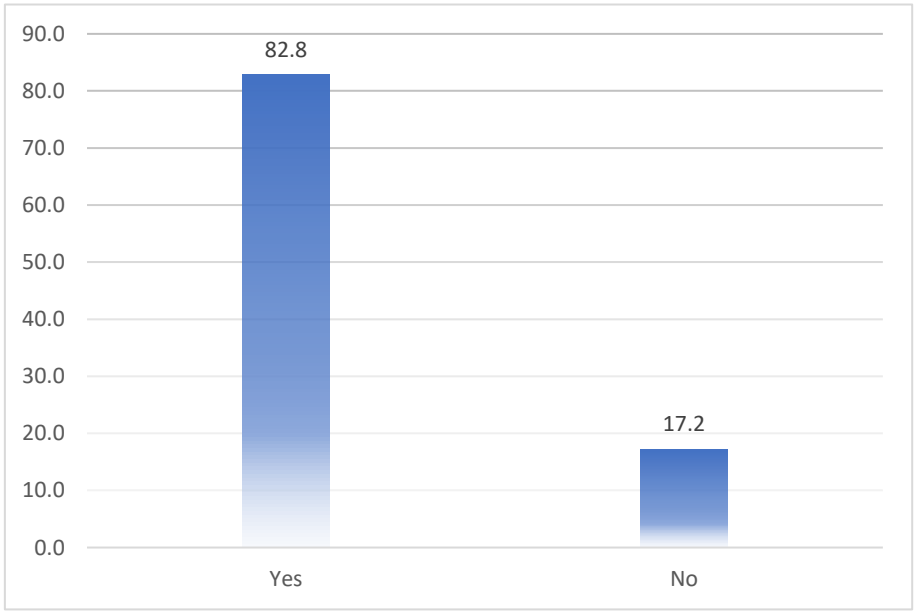

Figure 3. Do you use augmented reality for educational purposes? (Responses in %).

3.2.4. Attitudes towards Augmented Reality

The respondents generally exhibited positive attitudes towards AR, particularly valuing its application in education and everyday life. The descriptive statistics presented in Table 2 and Figure 4 reveal high mean scores for AR's usefulness, ease of use, and interest level, which align with strong acceptance and a positive perception of AR technology.

Table 2. Descriptive statistics.

	Mean	Std. Deviation
Are you familiar with the term "augmented reality"?	**4.2473**	1.08002
Do you think augmented reality is useful in education?	**4.7097**	0.54335
Do you think augmented reality is useful in everyday life?	**4.6452**	0.60154
Do you think augmented reality is easy to use?	**4.5484**	0.69963
Do you think augmented reality is interesting?	**4.8817**	0.43861

(1 = strongly disagree, 5 = strongly agree.).

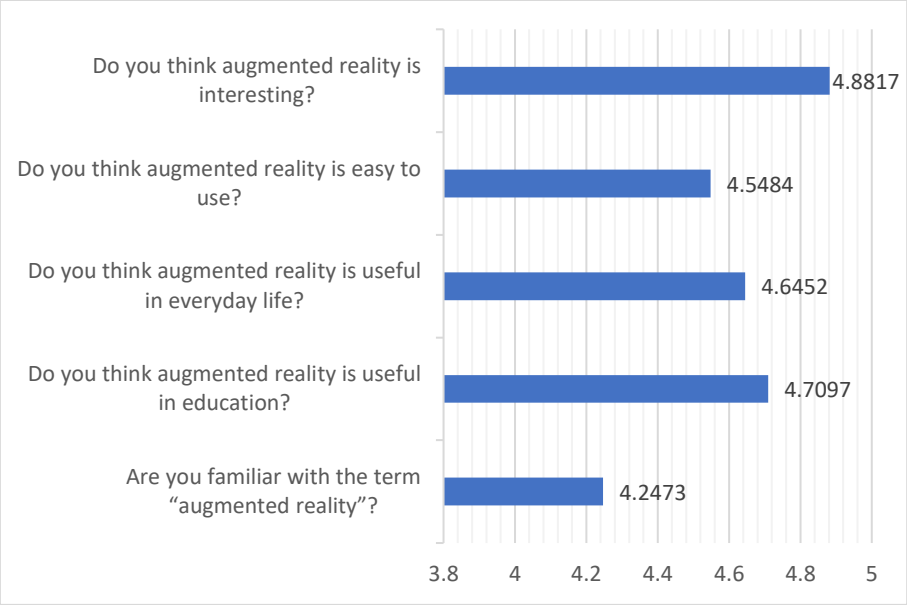

Figure 4. Distribution of agreement levels regarding the usefulness of AR (1 = strongly disagree, 5 = strongly agree).

These results underscore a broad endorsement of AR's potential, indicating that participants not only find AR technologies accessible and engaging but also of significant utility in both educational contexts and everyday applications.

3.3. Parametric Tests

3.3.1. Normality Tests

Prior to conducting the *t*-tests, we assessed the normality of the age distribution among our study participants to ensure the appropriateness of using parametric tests. The normality was evaluated using graphical methods: Histograms and Q–Q plots were generated for the age data. The histogram displayed a bell-shaped curve, while the Q–Q plot indicated that the data points closely followed the theoretical normal line, suggesting a normal distribution.

These tests confirmed that the assumptions of normality required for the application of *t*-tests were met, supporting the subsequent statistical analyses presented in this study.

3.3.2. Independent t-Tests (Gender)

Independent *t*-tests were used to evaluate whether responses towards augmented reality (AR) differ significantly between genders, as depicted in Table 3. These tests are crucial for understanding if gender influences perceptions of AR's utility, which can guide targeted strategies in AR development and application [19].

The null hypotheses tested were as follows:

- H0 (Education): there is no difference in mean scores between males and females regarding their perceptions of the usefulness of AR in education.
- H0 (Everyday Life): there is no difference in mean scores between males and females regarding their perceptions of the usefulness of AR in everyday life.

Significant differences were found in perceptions of AR's usefulness in education (p = 0.001) and everyday life (p = 0.001), with males reporting higher agreement levels than females. These findings suggest that men are more positively disposed towards the benefits of AR. Understanding these gender differences is crucial for stakeholders aiming to develop, market, and utilize AR technology more effectively.

To provide a more comprehensive understanding of these differences, 95% confidence intervals for the mean differences were calculated. These intervals offer insights into the magnitude and precision of the differences observed:

- Usefulness in Education: the mean difference was 0.36698 with a 95% confidence interval of [0.15460; 0.57935].
- Usefulness in Everyday life: the mean difference was 0.40047 with a 95% confidence interval of [0.16492; 0.63601].

Table 3. Independent *t*-test results by gender.

	Gender	N	Mean	Sig.
Are you familiar with the term "augmented reality"?	Male	43	4.3488	0.403
	Female	50	4.1600	
Do you think augmented reality is useful in education?	Male	43	4.9070	0.001
	Female	50	4.5400	
Do you think augmented reality is useful in everyday life?	Male	43	4.8605	0.001
	Female	50	4.4600	
Do you think augmented reality is easy to use?	Male	43	4.6047	0.475
	Female	50	4.5000	
Do you think augmented reality is interesting?	Male	43	4.9535	0.144
	Female	50	4.8200	

These results support the need for gender-tailored strategies in the development and implementation of AR technologies, as they clearly indicate different levels of acceptance and perceived utility between males and females.

3.3.3. Independent t-Tests (Educational Level)

The influence of educational level on attitudes towards AR was also examined, comparing responses between students and university/college graduates as presented in Table 4.

Educational level showed significant differences in perceptions of AR's usefulness, ease of use, and interest. Students reported higher levels of agreement across these aspects than university/college graduates, indicating that younger, currently enrolled students may be more receptive to AR technologies. This could be due to greater exposure to innovative educational tools and technologies during their studies.

Table 4. Independent *t*-test results by educational level.

	Educational Level	N	Mean	Sig.
Are you familiar with the term "augmented reality"?	Student	54	4.4259	0.064
	University/College	38	4.0000	
Do you think augmented reality is useful in education?	Student	54	4.9259	0.000
	University/College	38	4.3947	
Do you think augmented reality is useful in everyday life?	Student	54	4.8889	0.000

	University/College	38	4.3158	
Do you think augmented reality is easy to use?	Student	54	4.7593	0.000
	University/College	38	4.2368	
Do you think augmented reality is interesting?	Student	54	5.0000	0.002
	University/College	38	4.7105	

3.3.4. One-Way ANOVA (Age)

A one-way ANOVA was conducted to investigate if age groups differ in their responses toward AR. This analysis, presented in Table 5, is critical for identifying which age group is more inclined towards adopting AR technologies.

The one-way ANOVA results indicate that younger participants (18–25 years) exhibit significantly higher levels of agreement that AR is useful, easy to use, and interesting compared to older age groups. This pattern suggests that younger users are more positively inclined towards AR, likely due to greater technological engagement and openness to new experiences.

Table 5. One-way ANOVA results by age.

		N	Mean	Sig.	Tukey Post Hoc Evaluation
Are you familiar with the term "augmented reality"?	18–25	52	4.5000	0.000	18–25 > than other categories
	26–35	20	3.3500		
	36+	21	4.4762		
	Total	93	4.2473		
Do you think augmented reality is useful in education?	18–25	52	4.9231	0.000	18–25 > than other categories
	26–35	20	4.4000		
	36+	21	4.4762		
	Total	93	4.7097		
Do you think augmented reality is useful in everyday life?	18–25	52	4.9231	0.000	18–25 > than other categories
	26–35	20	4.2500		
	36+	21	4.3333		
	Total	93	4.6452		
Do you think augmented reality is easy to use?	18–25	52	4.7500	0.000	18–25 > than other categories
	26–35	20	4.0500		
	36+	21	4.5238		
	Total	93	4.5484		
Do you think augmented reality is interesting?	18–25	52	5.0000	0.011	18–25 > than other categories
	26–35	20	4.7000		
	36+	21	4.7619		
	Total	93	4.8817		

3.4. Correlations

Pearson correlation analysis was used to assess the relationships between various perceptions of augmented reality (AR). This statistical method helps quantify the strength and direction of linear relationships between pairs of continuous variables, providing insights into how different aspects of AR perception are interrelated [20].

A very strong positive correlation ($r = 0.845$, $p < 0.01$) between the perceptions of AR's usefulness in education and its usefulness in everyday life was identified, as introduced in Table 6. This suggests that individuals who recognize AR's benefits for educational purposes are likely to perceive similar benefits in their daily activities. This finding indicates a broad appreciation of AR's utility, extending beyond educational settings.

Table 6. Correlations between usefulness in education and everyday life.

		Do You Think Augmented Reality Is Useful in Education?	Do You Think Augmented Reality Is Useful in Everyday Life?
Do you think augmented reality is useful in education?	Pearson Correlation	1	0.845 **
	Sig. (two-tailed)		0.000
	N	93	93

**. Correlation is significant at the 0.01 level (two-tailed).

There is a moderate positive correlation (r = 0.285, $p < 0.01$) between the ease of use of AR and interest in AR (Table 7). This relationship highlights the importance of intuitive and user-friendly design in fostering interest and engagement with AR technology. Enhancing ease of use may, therefore, be a critical factor in increasing AR's appeal and adoption.

Table 7. Correlations between ease of use and interest.

		Do You Think Augmented Reality Is Easy to Use?	Do You Think Augmented Reality Is Interesting?
Do you think augmented reality is easy to use?	Pearson Correlation	1	0.285 **
	Sig. (two-tailed)		0.006
	N	93	93

**. Correlation is significant at the 0.01 level (two-tailed).

Significant positive correlations were found between the ease of use of AR and its perceived usefulness both in education (r = 0.423, $p < 0.01$) and in everyday life (r = 0.442, $p < 0.01$), as presented in Table 8. These findings suggest that the more user-friendly an AR system is, the more useful it is considered, reinforcing the necessity for developers to prioritize ease of use in AR design.

Table 8. Correlations between ease of use and perceived usefulness.

		Do you Think Augmented Reality Is Useful in Education?	Do You Think Augmented Reality Is Useful in Everyday Life?
Do you think augmented reality is easy to use?	Pearson Correlation	0.423 **	0.442 **
	Sig. (two-tailed)	0.000	0.000
	N	93	93

**. Correlation is significant at the 0.01 level (two-tailed).

Strong positive correlations exist between interest in AR and its perceived usefulness in both educational (r = 0.721, $p < 0.01$) and everyday contexts (r = 0.704, $p < 0.01$), as introduced in Table 9. This indicates that interest in AR is closely linked with perceptions of its utility. The more individuals find AR interesting, the more likely they are to consider it useful, which could drive higher adoption rates and more innovative applications of AR technology.

Table 9. Correlations between interest and perceived usefulness.

		Do You Think Augmented Reality Is Useful in Education?	Do You Think Augmented Reality Is Useful in Everyday Life?
Do you think augmented reality is interesting?	Pearson Correlation	0.721 **	0.704 **
	Sig. (two-tailed)	0.000	0.000
	N	93	93

**. Correlation is significant at the 0.01 level (two-tailed).

3.5. Usability Test

The usability test was meticulously designed to evaluate user experience with the "Google Arts & Culture" app, particularly focusing on the "Art Projector" tool. The tasks were specifically tailored to assess the intuitiveness of the app's navigation, the effectiveness of its interaction design, and overall user engagement with AR features (Table 10).

Table 10. Tasks of think-aloud usability test (negative answers).

Task No.	Task Description	Negative Answers (%)
1	Explore different artworks using the AR interface	47.3%
2	Identify shortcuts for quickly changing artworks	100%
3	Observe the clarity and helpfulness of in-app messages	0%
4	Manipulate and interact with the artwork displayed	36.8%
5	Access and interact with the text description of paintings	0%
6	Test the undo functionality in app navigation	0%
7	Assess ease of manipulating AR artworks	26.3%
8	Evaluate the display of multiple artworks for comparative analysis	0%

Downloading and Initial Access (Figure 5): All participants successfully downloaded and launched the app without any issues, indicating a smooth, user-friendly initial setup. This ease of entry is critical for first-time users and sets a positive tone for the app's usability.

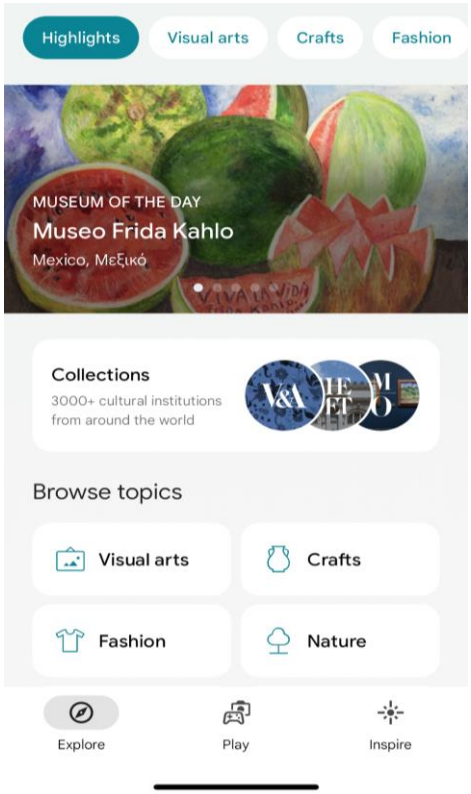

Figure 5. First page of the application Google Arts & Culture [10].

Locating the Art Projector Tool (Figure 6): Of all the users, 26.3% initially struggled to find the Art Projector tool, suggesting that the app could benefit from more prominent placement or clearer directions for accessing this feature. Improving discoverability could enhance user experience and reduce initial frustration.

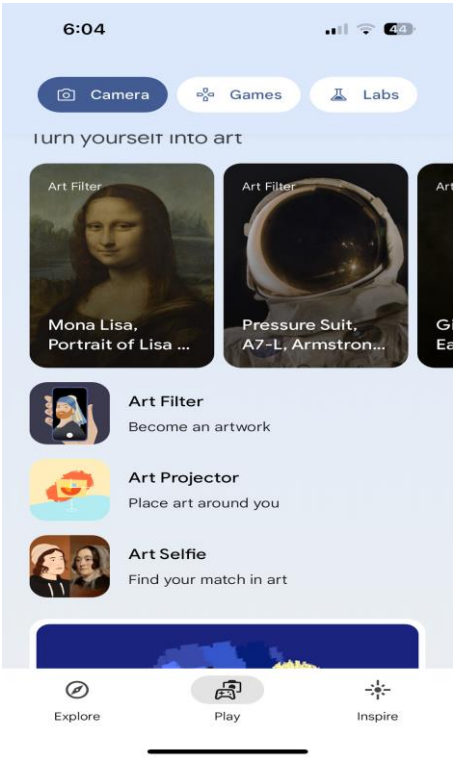

Figure 6. The "Play" screen where users can select the Art Projector [10].

Detailed Task Insights:

Task 1 (Figure 7): Nearly half of the participants (47.3%) had difficulty initially finding the option to switch artworks. This challenge highlights a need for more intuitive navigation cues. Clearer interface guidance could help users understand how to navigate between different artworks more seamlessly.

Figure 7. Art Projector first screen [10].

Task 2: Although all participants successfully used the navigation arrow to change artworks, the feedback indicated that this arrow did not align with users' expectations of a "shortcut." This suggests that while functional, the navigation could be enhanced by incorporating more conventional shortcut elements that users might expect.

Task 3 (Figure 8): The context-sensitive messages displayed by the app were well received, with all participants understanding the instructions without confusion. This success points to effective communication within the app, aiding user interaction by providing clear, actionable information at the right moments.

Figure 8. A message in the application [10].

Task 4: The difficulties experienced by 36.8% of participants in manipulating the paintings, especially with zoom controls, indicate that the gestures or controls might not be intuitive or are insufficiently explained. Enhancing gesture recognition or providing clearer instructions could improve user interaction with the AR features.

Task 5 (Figure 9): The inability of participants to interact with text descriptions significantly restricts access to detailed information about the artworks. Issues with the display of long titles, which were truncated, further hindered the educational value of the app. This suggests a critical area for improvement in content layout and interactive elements to ensure all text is accessible and fully visible.

Figure 9. Text of the painting [10].

Task 6: The absence of a specific undo button highlights a gap in the navigation design. Although participants used the navigation arrow to backtrack, a dedicated undo feature could enhance user control and improve the navigation experience.

Task 7: Initial difficulties in understanding how to manipulate AR artworks indicate a steep learning curve for users unfamiliar with AR interfaces. Offering initial guidance or tutorials could mitigate these challenges and enhance the user's ability to engage with the technology.

Task 8: The limitation of viewing one painting at a time was noted as a significant drawback for users who wished to engage in comparative analysis or broader exploration of artworks. This feedback suggests a need for interface adjustments to allow simultaneous viewing of multiple artworks or easier toggling between them.

Comments ranged from technical issues like app stability to subjective experiences comparing AR to physical artworks. Positive feedback highlighted the educational value

of the app, especially its provision of cultural information at no cost. However, technical problems and navigational challenges detracted from the user experience.

The usability test revealed several key areas where the "Google Arts & Culture" app could improve, particularly in enhancing the intuitiveness of navigation and interaction within the Art Projector tool. Addressing these issues could significantly improve user satisfaction and broaden the app's appeal, making it not only a tool for viewing art but also an effective educational resource.

By analyzing user interactions and feedback in detail, developers can better understand how to refine the app to meet user needs and preferences, ultimately leading to a more engaging and user-friendly experience.

4. Discussion

4.1. Overview of Attitudes towards AR

Overall, the responses were highly positive towards augmented reality (AR), with particular enthusiasm about its applications in education and everyday life. This sentiment is consistent across various studies, emphasizing AR's potential to significantly enhance user engagement and learning experiences.

4.2. Influence of Demographic Variables

While our findings indicate gender-specific preferences towards AR, it is essential to consider underlying factors such as societal roles and exposure to technology, which may shape these perceptions differently across genders. Such insights could guide more customized AR development that considers gender-specific user experience preferences.

Gender Differences: The study found men generally more receptive to AR than women, suggesting gender-specific approaches might be needed in AR application development and deployment. This finding aligns with some previous research indicating gender differences in technology adoption [21]. However, it contrasts with Amores-Valencia (2023), who reported no significant gender differences in attitudes towards AR, suggesting that such differences may vary by context or over time [22].

Educational Level: Responses also varied significantly with educational level. Students showed more positivity towards AR compared to university/college graduates, possibly due to the different contexts in which these groups encounter and use technology. This finding supports Silva's (2023) assertion that AR can improve academic performance and foster engagement, particularly among younger, more tech-savvy learners [21].

Age: Age was another determinant factor, with younger respondents more favorable towards AR. This trend underscores the generational shift in technology use and comfort, which can influence the adoption and advocacy of new technologies like AR.

4.3. Utility and Ease of Use

The significant correlation between ease of use and perceived utility highlights a virtuous cycle where user-friendly designs enhance user satisfaction and perceived effectiveness of AR tools. This relationship suggests that focusing on improving the user interface could not only enhance immediate user engagement but also long-term adoption and advocacy for AR technologies in educational settings.

Respondents noted AR's utility in both educational settings and daily life, praising its ease of use. This observation aligns with Dunleavy et al. (2009), who highlighted that user-friendly technologies are more likely to be adopted and positively rated [14]. The study also corroborated findings from Sumadio and Rambli (2010), who observed widespread acceptance of AR's educational benefits [6].

Correlations of Usefulness and Ease of Use: Ease of use significantly influenced perceptions of AR's usefulness. Participants who found AR interfaces intuitive also perceived the technology as more beneficial, a relationship that underscores the importance of ergonomic and accessible design in educational technology.

In addition to our findings, the importance of user interface design in AR applications has been underscored in [23]. This study highlights how refinements in the user interface can significantly enhance usability and educational effectiveness in primary education settings. This aligns with our results, which suggest that intuitive and user-friendly interfaces are critical for the successful implementation of AR in educational contexts. By focusing on interface design, developers can improve user engagement and learning outcomes, as demonstrated in both the current study and contemporary literature.

4.4. Educational Implications

Our results suggest a strong endorsement of AR's potential in educational contexts, particularly in enhancing engagement and learning outcomes. Educators and developers might consider these findings when designing curriculum and technological interventions, ensuring that AR tools are integrated in a way that is pedagogically sound and enhances the educational experience.

Enthusiasm for AR's potential to enhance educational processes suggests a growing recognition of its value in pedagogical contexts. This is particularly pronounced in how students perceive AR's ability to enhance learning, correlating with increased academic performance as noted by Silva (2023) [21] and Dunleavy et al. (2009) [14].

Advanced Content Learning: Participants who engaged with more complex AR content reported better learning outcomes, supporting Radu's (2023) findings [24]. This suggests that AR's impact is most pronounced when used for teaching complex or abstract subjects that benefit from visual and interactive aids.

4.5. Technological Integration and Future Directions

The challenges noted in navigating and interacting with the AR interface reflect broader issues in technology adoption where user interface complexities can hinder the full utilization of innovative technologies. It is crucial for developers to prioritize user-centric design principles that simplify navigation and interaction, thus reducing barriers to adoption and enhancing the overall user experience.

Despite the positive feedback, usability issues were highlighted, particularly in the Google Arts & Culture app's Art Projector feature. Participants faced challenges in navigating and interacting with the AR interface, echoing Wu's (2013) concerns about the need for improved usability in AR applications [25].

Further Research Needs: Moving forward, it will be essential to conduct longitudinal studies to explore the sustained impact of AR in educational settings across diverse demographic groups. This will help determine the broader applicability and scalability of AR technologies in global educational strategies.

This discussion integrates extensive research references and user feedback to provide a comprehensive overview of current perceptions of AR. The positive attitudes, influenced by demographic factors and enhanced by the technology's ease of use, highlight AR's potential as a transformative tool in education and beyond. Future improvements in interface design and functionality, informed by ongoing research and user experience data, are crucial for realizing the full potential of AR technologies.

5. Conclusions and Future Work

This research has underscored the significant impact of augmented reality (AR) on user engagement within mobile applications, particularly through an in-depth evaluation of the Art Projector feature in the Google Arts & Culture app. The findings align with existing theories and research, stressing the critical importance of user-centric interface design in AR applications.

5.1. Key Findings and Implications

User Engagement: The study highlighted how well-designed AR features could substantially enhance user engagement and interactivity, particularly in educational contexts. By leveraging AR, educators can create immersive and interactive learning environments that not only capture the interest of learners but also facilitate deeper knowledge acquisition and retention.

Daily Interactions with AR: Interestingly, the research also pointed out that many users interact with AR technology in their daily activities without full awareness, such as through features like filters in apps like Viber. This subtle integration of AR into everyday applications suggests a growing penetration of AR technologies into daily life, emphasizing the need for intuitive and seamless design.

Role of UI/UX in AR Development: Placing user experience (UX) and interface design (UI) at the forefront of AR application development is paramount. This approach ensures that AR technologies are not only effective but also accessible and enjoyable for all users. By prioritizing these aspects, developers can enhance the overall utility and appeal of AR applications.

Our research confirms that the utility and ease of use of AR are pivotal for its adoption in educational settings. Consistent with [23], we advocate for ongoing refinement of AR interfaces to enhance their educational value. This approach is crucial for ensuring that AR technologies meet the diverse needs of learners and educators, facilitating more effective learning experiences through improved interaction design.

5.2. Limitations and Future Research

Study Constraints: While the findings are compelling, it is important to acknowledge the limitations of this study, including its relatively small sample size and the narrow focus on a specific application. These factors may affect the generalizability of the results.

Expanding Research Scope: Future research should look to address these limitations by exploring the impacts of AR across a broader range of applications and with larger, more diverse populations. Investigating the long-term effects of AR in educational settings and its efficacy across different subject areas or demographic groups would provide deeper insights into its educational potential.

Evaluation of AR Applications: The study prompts further reflection on the evaluation processes for AR applications, particularly whether they adequately consider UI and UX principles. As AR technology continues to evolve and proliferate, maintaining rigorous standards for user interface design and interaction quality is essential to ensure they meet user needs and preferences.

5.3. Recommendations for Future Work

Researchers are encouraged to delve into the long-term educational impacts of AR, examining how various design features influence learning outcomes and user satisfaction.

There is a need for comprehensive evaluations of AR applications across various fields to ensure they adhere to high standards of usability and effectiveness, informed by robust UI and UX guidelines.

In summary, this research not only confirms the pivotal role of AR in enhancing user engagement and educational experiences but also highlights the necessity for thoughtful, user-oriented design in AR applications. The insights garnered from the Art Projector feature of the Google Arts & Culture app demonstrate the profound potential of AR to transform educational methodologies and enrich daily user interactions. Moving forward, embracing these insights will be crucial for the continued advancement and integration of AR technologies in various domains.

Author Contributions: Conceptualization, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; methodology, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; software, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; validation,

M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; formal analysis, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; investigation, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; resources, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; data curation, M.K. (Maria Klouvidaki),; writing—original draft preparation, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; writing—review and editing, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; visualization, M.K. (Matina Kiourexidou), A.K., M.K. (Maria Klouvidaki) and N.A.; supervision, N.A.; project administration, N.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All of the data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Abdullah, N.; Hanafi, H. The rights of persons with disabilities in Malaysia: The underlying reasons for ineffectiveness of persons with disabilities Act 2008. *Int. J. Stud. Child. Women Elder. Disabl.* **2017**, *1*, 127–134.
2. Iqbal, M.Z.; Mangina, E.; Campbell, A.G. Current Challenges and Future Research Directions in Augmented Reality for Education. *Multimodal Technol. Interact.* **2022**, *6*, 75. https://doi.org/10.3390/mti6090075.
3. Billinghurst, M.; Clark, A.; Lee, G. A survey of augmented reality. Foundations and Trends®® in Human–Computer Interaction. **2012**, 8, 73–272.
4. Boboc, R.G.; Băutu, E.; Gîrbacia, F.; Popovici, N.; Popovici, D.M. Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications. *Appl. Sci.* **2022**, *12*, 9859. https://doi.org/10.3390/app12199859.
5. Kapetanaki, A.; Krouska, A.; Troussas, C.; Sgouropoulou, C. Exploiting Augmented Reality Technology in Special Education: A Systematic Review. *Computers* **2022**, *11*, 143. https://doi.org/10.3390/computers11100143.
6. Sumadio, D.D.; Rambli, D.R. Preliminary evaluation on user acceptance of the augmented reality use for education. InComputer Engineering and Applications (ICCEA), *Second. Int. Conf. Comput. Eng. Appl.* **2010**, *2*, 461–465.
7. Ventoulis, E.; Xinogalos, S. AR The Gods of Olympus: Design and Pilot Evaluation of an Augmented Reality Educational Game for Greek Mythology. *Multimodal Technol. Interact.* **2023**, *7*, 2. https://doi.org/10.3390/mti7010002.
8. Azuma, R.; Baillot, Y.; Behringer, R.; Feiner, S.; Julier, S.; MacIntyre, B. Recent advances in augmented reality. *IEEE Comput. Graph. Appl.* **2001**, 21, 34–47.
9. Arifin, Y.; Sastria, T.; Barlian, E.User Experience metric for augmented reality application: A review. *Procedia Comput. Sci.* **2018**, *135*, 648–656. https://doi.org/10.1016/j.procs.2018.08.221.
10. Google Arts & Culture. 2024. Available online: https://apps.apple.com/gr/app/google-arts-culture/id1050970557?l=el (accessed on 20 November 2023).
11. Milgram, P.; Kishino, F. A taxonomy of mixed reality visual displays. *IEICE Trans. Inf. Syst.* **1994**, 77, 1321–1329.
12. Azuma, R.T. A survey of augmented reality. *Presence Teleoperators Virtual Environ.* **1997**, *6*, 355–385.
13. Klopfer, E.; Osterweil, S.; Salen, K. Moving learning games forward. Education Arcade, Boston, MA: Education Arcade. 2009. Available online: http://education.mit.edu/papers/MovingLearningGamesForward_EdArcade.pdf (accessed on 20 November 2023).
14. Dunleavy, M.; Dede, C.; Mitchell, R. Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *J. Sci. Educ. Technol.* **2009**, *18*, 7–22. https://doi.org/10.1007/s10956-008-9119-1.
15. Billinghurst, M.; Duenser, A. Augmented reality in the classroom. *Computer*. 2012, 45, 56–63. https://doi.org/10.1109/MC.2012.111.
16. Kiourexidou, M.; Antonopoulos, N.; Kiourexidou, E.; Piagkou, M.; Kotsakis, R.; Natsis, K. Websites with Multimedia Content: A Heuristic Evaluation of the Medical/Anatomical Museums. *Multimodal Technol. Interact*. **2019**, *3*, 42. https://doi.org/10.3390/mti3020042.
17. Aottiwerch, N.; Kokaew, U. Design computer-assisted learning in an online Augmented Reality environment based on Shneiderman's eight Golden Rules. Proceedings of the 14th International Joint Conference on Computer Science and Software Engineering (JCSSE). IEEE: Nakhon Si Thammarat, Thailand, 12–14 June 2017, 1–5, doi: 10.1109/JCSSE.2017.8025926.
18. Doi, T. Usability Textual Data Analysis: A Formulaic Coding Think-Aloud Protocol Method for Usability Evaluation. *Appl. Sci.* **2021**, *11*, 7047. https://doi.org/10.3390/app11157047.
19. Saunders, M.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*; Pearson: Harlow, UK, 2016.
20. Malhotra, N.; Birks, D. *Marketing Research: An Applied Approach*, 3rd ed.; Pearson Education: Harlow, UK, 2006.

21. Silva, M.; Bermúdez, K.; Caro, K. Effect of an augmented reality app on academic achievement, motivation, and technology acceptance of university students of a chemistry course. *Comput. Educ. X Real.* **2023**, *2*, 100022. https://doi.org/10.1016/j.cexr.2023.100022.
22. Amores-Valencia, A.; Burgos, D.; Branch-Bedoya, J.W. The Impact of Augmented Reality (AR) on the Academic Performance of High School Students. *Electronics* **2023**, *12*, 2173. https://doi.org/10.3390/electronics12102173.
23. Volioti, C.; Orovas, C.; Sapounidis, T.; Trachanas, G.; Keramopoulos, E. Augmented reality in primary education: An active learning approach in mathematics. *Computers* **2023**, *12*, 207.
24. Radu, I.; Huang, X.; Kestin, G.; Schneider, B. How augmented reality influences student learning and inquiry styles: A study of 1-1 physics remote AR tutoring. *Comput. Educ. X Real.* **2023**, *2*, 100011. https://doi.org/10.1016/j.cexr.2023.100011.
25. Wu, H.K.; Lee, S.W.Y.; Chang, H.Y.; Liang, J.C. Current status, opportunities and challenges of augmented reality in education. *Comput. Educ.* **2013**, *62*, 41–49.