Interdisciplinary Journal of Virtual Learning in Medical Sciences

Review Article

Designing for Differences: A Systematic Literature Review of User Interface and User Experience Features in Autism Educational Applications

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ABSTRACT

Background: Autism Spectrum Disorder (ASD) is among the most common neurodevelopmental conditions and is characterized by difficulties in social interaction, communication, and patterns of behavior. Addressing the varied needs of children with ASD requires careful attention to User Interface (UI) and User Experience (UX) design, as these elements are essential to the effectiveness of educational applications. This study aimed to review and synthesize evidence on UI and UX design features that improve accessibility, engagement, and usability in educational applications for children with ASD.

Methods: A systematic literature search was conducted across PubMed, Web of Science, ScienceDirect, IEEE Xplore, and ProQuest to identify studies published between 2015 and 2025. The review process was reported in accordance with the PRISMA (2020) guidelines. The primary search terms included User Interface, User Experience, Autism Spectrum Disorder, and Educational Application. Studies were considered eligible if they examined UI/UX characteristics within educational or therapeutic applications designed for children with ASD. Following the removal of duplicate records and the application of predefined inclusion and exclusion criteria, 11 studies met the eligibility requirements. The screening was performed independently by the reviewers, and the Mixed Methods Appraisal Tool (MMAT) was used to ensure both relevance and methodological rigor. The findings were synthesized using a qualitative approach.

Results: The synthesis identified seven main categories of design principles: Simplicity and Clarity of UI (6 studies), Visual Design (7 studies), Feedback and Support (7 studies), Engagement and Interaction (8 studies), Accessibility (7 studies), User-centered and Dedicated Design for ASD (8 studies), and Technology and System Stability (2 studies). The selected studies included qualitative, quantitative, and mixed-methods designs, with most emphasizing the significance of visual simplicity, user adaptability, and sensory appropriateness.

Conclusion: Evidence supports that adherence to these seven UI/UX design principles can improve usability and engagement for children with ASD. However, heterogeneity in methods, small sample sizes, and limited experimental validation restrict generalizability. Further research is recommended to develop evidence-based, adaptive, and user-centered digital learning environments.

Keywords: Autism Spectrum Disorder, Educational Technology, Patient Satisfaction, User-Computer Interface, User Experience

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Please cite this paper as:
Khouban M, Abedi R. Designing for Differences: A Systematic Literature Review of User Interface and User Experience Features in Autism Educational Applications. Interdiscip J Virtual Learn Med Sci. 2026;17(1):22-43.doi:10.30476/ijvlms.2026.108916.1357.

Received: 27-09-2025
Revised: 08-01-2026
Accepted: 24-01-2026

Introduction

Autism Spectrum Disorder (ASD) is among the most prevalent neurodevelopmental conditions and is marked by difficulties in social interaction, communication, and patterns of behavior. According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), children affected by this condition need specialized educational support that not only aids them in acquiring cognitive and academic skills but also enhances their social and emotional competencies (1).

Traditional education often fails to meet the diverse needs of children with ASD, highlighting the increasing importance of modern technologies as complementary educational tools. These technologies including virtual environments, robots, language tools, and educational games have shown potential in enhancing learning experiences and supporting skill development. Children with ASD demonstrate a strong inclination to use digital devices like tablets and smartphones, drawn to the multimedia environments and visual appeal these tools offer (2, 3).

However, while a wide range of technologies has been employed in ASD education such as tablet-based learning applications, humanoid and social robots, Augmented Reality (AR) and Virtual Reality (VR) environments, computer-assisted instruction systems, and eye-tracking or sensor-based interactive platforms existing evidence regarding which specific User Interface (UI) and User Experience (UX) design elements most effectively support learning remains fragmented (4-7). This gap presents a valuable opportunity for educators and technology designers to create tailored educational applications that streamline learning and empowerment pathways for these children (4, 8). Digital technologies can serve as assistive tools, facilitating independent learning, improving communication, and providing structured environments (9). Additional studies are needed to determine which design features most effectively enhance the performance and impact of these applications (4, 8, 9).

UI refers to the visual and interactive elements of software, including layout, colors, icons, and touch capabilities. UX involves the overall feelings, perceptions, and satisfaction a user derives from interacting with the software (5, 10-13).

For children with ASD, effective UI and UX design are crucial due to their unique cognitive and sensory characteristics (8). High-quality design can enhance usability and engagement, while poor design may diminish the software's effectiveness and lead to stress or rejection by the child (5, 14-16). Therefore, attention to these design dimensions is essential to ensure that digital tools effectively support the educational needs of children with ASD.

Research background indicates that many studies have focused on the development or evaluation of educational applications for children with autism (17-19). Some studies have investigated how game-based applications can improve social skills (5, 15), whereas others have focused on teaching communication or academic abilities (4, 8, 20). Research has also emphasized that interactive and multimedia technologies can enhance the motivation of children with autism (19–21). However, our focus is on the importance of well-designed UI and UX in educational applications for children with autism, a topic that several studies have recognized as significant (14, 19–21).

In the context of creating accessible and engaging digital experiences for individuals with autism, recent evidence highlights the importance of carefully structured UX features. One study emphasizes that color-based design particularly the use of calming, aesthetically balanced tones can enhance engagement and cognition while reducing cognitive load and anxiety, thereby contributing both to user comfort and overall design coherence (16). This body of work indicates that visual simplicity and sensory-friendly design are foundational to accessibility, although further empirical

testing is required to identify which specific visual features most effectively alleviate anxiety in autistic users.

Further studies emphasize the importance of directly involving autistic individuals in the evaluation of UX. Findings indicate that participatory design approaches yield unique behavioral and perceptual insights that support the development of more adaptive and inclusive interfaces (17). Expanding on user-centered design concepts, another investigation introduces a structured framework for developing digital games aimed at enhancing life skills among individuals with intellectual disabilities and autism (21). Complementary findings draw attention to accessibility-focused tools—such as simplified reading supports and comprehension aids—that utilize tailored visual and textual cues to enhance usability for autistic users (20).

Collectively, these framework-driven and tool-based strategies reflect an increasing effort to formalize inclusive design practices for people with autism, yet they reveal a significant research gap in evaluating the long-term usability and adaptability of such tools across different levels of the autism spectrum. While these studies illustrate the critical need for thoughtful and inclusive design that prioritizes the unique experiences of individuals with autism, there remains a lack of synthesis in translating these insights into cohesive design principles. This inconsistency hinders the consistent development of effective digital tools for this population. Therefore, further research is essential to establish a unified framework that integrates these diverse findings, addressing the complexities and variances in current design approaches to ensure that digital environments are genuinely supportive and beneficial for individuals across the autism spectrum.

Despite increasing attention to UI and UX in autism-focused applications, existing research remains fragmented, with most studies emphasizing educational outcomes rather than design processes (5, 8, 18, 22). Besides, no systematic review has yet comprehensively synthesized evidence on which UI and UX elements, such as color and image selection, interaction level, environmental simplicity or complexity, customization, and sensory considerations are most critical for optimizing accessibility, personalization, and therapeutic effectiveness for individuals with ASD.

Accordingly, this review aimed to identify and examine the key and influential components of UI and UX design in educational applications developed specifically for children with ASD through reviewing of previous research. The objective was to integrate existing evidence and propose a structured framework for more effective design, thereby addressing the existing gap in the scientific literature. The primary research question guiding this study is: Which UI and UX elements require particular consideration when creating educational applications for children with ASD? Addressing this question can offer valuable direction to researchers, instructional designers, and software developers in implementing a user-centered approach that aligns with the distinct needs of children with ASD in future educational technologies.

Methods

Study Design

This study employed a systematic literature review approach, and all stages of the review process, including searching, screening, data extraction, and synthesis, followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to enhance methodological rigor and transparency. The main objective was to identify, evaluate, and synthesize existing evidence related to UI and UX design principles in educational applications and games developed for individuals with ASD.

Search Strategy

A systematic literature search was conducted in December 2024 and updated in July 2025, covering publications from

January 2015 to June 2025. This timeframe was chosen to capture recent advances in digital design practices relevant to ASD education and technology. The search was conducted across PubMed, IEEE Xplore, Web of Science, ScienceDirect, and ProQuest, and was limited to publications in English and Persian. Additionally, manual searches were performed by reviewing reference lists of relevant articles to ensure comprehensiveness. The primary (general) search query was structured as follows:

("User Interface" OR "UI") AND ("User Experience" OR "UX") AND ("Autism Spectrum Disorder" OR "ASD" OR "Autism") AND ("Educational application" OR "Educational Games" OR "Serious Games" OR "Mobile games")

Since the databases varied in their search functionalities and indexing structures, minor modifications were made to optimize retrieval in each. For instance, one of the exact queries used in PubMed was:

("User Interface"[All Fields] OR "UI"[All Fields] OR "User Experience"[All Fields] OR "UX"[All Fields]) AND ("Autism Spectrum Disorder"[MeSH Terms] OR "Autism Spectrum Disorder"[All Fields] OR "ASD"[All Fields] OR "Autism"[All Fields])

The search was filtered for the period January 2015–June 2025, and the final search was completed on July 28, 2025. Duplicate records were identified and removed using EndNote software.

Selection Criteria

Systematic reviews represent the highest level of evidence in the research hierarchy and provide a comprehensive synthesis of existing literature on specific topics through precise and predefined methods (20). This approach allowed us to systematically and scientifically analyze and evaluate appropriate UI and UX for individuals with ASD, applying the obtained results to improve educational applications and mobile games for this target group.

The eligibility criteria for study selection were defined a priori to ensure a focused and methodologically rigorous review. Studies were included if they addressed UI or UX design principles specifically in educational applications for children with ASD, presented original empirical data (qualitative, quantitative, or mixed-methods), were published in peer-reviewed sources such as journal articles, conference papers, dissertations, or books, and were published from 2015 onward to reflect recent technological and design advancements. Conversely, studies were excluded if the full text was unavailable, if the paper was not written in English (or Persian for local databases), or if the record was a duplicate. Although the review primarily focused on peer-reviewed literature, relevant grey literature, such as doctoral dissertations and master's theses, was considered if it met the same quality and methodological standards as peer-reviewed studies.

Data Extraction

A standardized data extraction form was created in Microsoft Word to maintain consistency across the 11 included studies. This form documented essential study characteristics, including the author(s), publication year, country of origin, research design, sample size, participants' age range (children with ASD), and key outcomes specifically related to UI and UX design features. Full-text articles were examined manually, and pertinent information was retrieved from the methods, results, and discussion sections.

Data extraction was conducted independently by the reviewers. Any discrepancies such as differences in interpreting outcomes or categorizing study designs were resolved through discussion until consensus was reached. Given the high level of agreement, no statistical measures of inter-rater reliability were deemed necessary. The finalized dataset served as the basis for the qualitative synthesis by providing a structured and comparable set of extracted variables across heterogeneous study types.

Quality Assessment

A structured methodological appraisal was conducted to evaluate the rigor of all included studies. Given the presence of varied research designs, the Mixed Methods Appraisal Tool (MMAT, 2018) was employed for all studies to which it was applicable, including qualitative research, quantitative descriptive studies, quantitative non-randomized studies, and mixed-methods investigations (23). The criteria were scored as "Yes," "No," or "Cannot tell," and overall quality was expressed as the number of "Yes" responses out of five. Studies receiving fewer than three affirmative ratings were excluded from the review.

To enhance reliability, two reviewers independently conducted the appraisal. This procedure is consistent with established recommendations for transparent quality assessment in systematic reviews that incorporate heterogeneous study designs. The detailed appraisal outcomes for all included studies are provided in Table 1, as evaluated using the MMAT.

Table 1: Quality assessment scores for included studies

	Author(s)	Study Design	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Quality Score	Quality Classification
1	Silva and colleagues, 2015 (24)	Experimental study	2.1 Yes	2.2 Yes	2.3 Yes	2.4 Yes	2.5 Yes	5.0	High
2	Stauffer A, 2015 (25)	Case study	1.1 Yes	1.2 Yes	1.3 Yes	1.4 Cannot tell	1.5 Cannot tell	3.0	Moderate
3	Xinogalos and colleagues, 2019 (26)	Survey research	4.1 Yes	4.2 No	4.3 Cannot tell	4.4 Yes	4.5 Yes	3.0	Moderate
4	Ghanouni and colleagues, 2020 (27)	Qualitative study (uasability)	1.1 Yes	1.2 Yes	1.3 Yes	1.4 Yes	1.5 Cannot tell	4.0	High
5	Rezae and colleagues, 2020 (28)	Qualitative study (METUIGA)	1.1 Yes	1.2 Yes	1.3 Yes	1.4 Cannot tell	1.5 Yes	4.0	High
6	Groba and colleagues, 2021 (29)	Qualitative, longitudinal, multicenter study	1.1 Yes	1.2 Cannot tell	1.3 Yes	1.4 Yes	1.5 Yes	4.0	High
7	Penev and colleagues, 2021 (30)	Mixed methods (Clinical study design)	5.1 Yes	5.2 Yes	5.3 Yes	5.4 Cannot tell	5.5 Yes	4.0	High
8	Aguiar and colleagues, 2021 (31)	Exploratory study	5.1 Yes	5.2 Yes	5.3 NO	5.4 Cannot tell	5.5 Yes	3.0	Moderate
9	Valencia and colleagues, 2021 (32)	Qualitative research (with a focus on UX evaluation)	1.1 Yes	1.2 Yes	1.3 Yes	1.4 Yes	1.5 Yes	5.0	High
10	Somerton M, 2022 (33)	Mixed methods	5.1 Yes	5.2 Yes	5.3 Yes	5.4 Cannot tell	5.5 Yes	4.0	High
11	Ashar and colleagues, 2022 (34)	Qualitative research (Human-centered design)	1.1 Yes	1.2 Yes	1.3 No	1.4 No	1.5 Yes	3.0	Moderate

Data Synthesis and Analysis

A qualitative synthesis method was employed to analyze and integrate the findings of the 11 selected studies using ATLAS.ti software. After performing initial open coding, related codes were systematically clustered and refined through iterative comparison to identify overarching conceptual relationships. Two researchers independently conducted the coding and theme development, ensuring analytical consistency through continuous discussion and consensus. Although axial coding was considered, the resulting seven major categories provided a sufficient conceptual framework, making further condensation unnecessary. The final synthesis emphasized conceptual significance over frequency of occurrence, reflecting patterns most relevant to the design of digital learning environments for children with ASD. The analysis yielded seven overarching themes capturing key principles of effective user interface design: simplicity and clarity, visual design, feedback and support, engagement and interaction, accessibility, user-centric and ASD-specific adaptation, and technology and system stability. These themes collectively illustrate the multi-dimensional nature of inclusive and therapeutic interface design for ASD-focused applications.

Results

Characteristics of Included Studies

A total of 821 records were identified across all databases and manual searches. After removing 73 duplicate references using EndNote, 748 records remained for screening. Title screening resulted in the exclusion of 302 records due to irrelevance, followed by the removal of 204 records at the abstract screening stage for lacking key terms related to user interface, user experience, or autism. As a result, 242 records were considered for retrieval.

Of these, 12 records could not be retrieved, and 230 full-texts were assessed for eligibility. Following full-text evaluation, 174 articles were excluded due to lack of relevance, and a further 45 were removed after detailed review because they did not sufficiently align with the study objectives. Ultimately, 11 studies met all inclusion criteria and were included in the final synthesis. The study selection process is illustrated in Figure 1. Screening was performed independently by two reviewers, and any disagreements were resolved through discussion to enhance reliability and minimize potential bias.

Thematic Synthesis of Results

This systematic review identified seven major themes related to UI and UX design principles in educational applications for children with ASD: Simplicity and Clarity, Visual Design, Feedback and Support, Engagement and Interaction, Accessibility, User-Centric Design, and Technology and System Sustainability. Each theme reflects a convergent set of evidence regarding how specific design features influence usability, learning engagement, and emotional comfort for users with ASD.

1. Simplicity and clarity: Some studies highlighted that simple, uncluttered interfaces reduce cognitive load and improve comprehension. The regular use of recognizable icons, consistent layouts, and limited text was identified as essential for improving usability (28, 29).

2. Visual design: A visually coherent environment characterized by soft colors, adequate contrast, and predictable spatial structure has been shown to enhance comfort and attention across several studies (24, 28, 29, 31, 32). Low-saturation, cartoon-based imagery was also reported to sustain motivation more effectively than realistic photos or dense textual content (24).

3. Feedback and support: Effective feedback, whether visual, auditory, or multimodal, consistently improved engagement and motivation (24, 25, 33). Immediate, positive, and predictable responses (e.g., voice activation, subtle animations, visual rewards) helped users understand task outcomes more clearly and maintain focus.

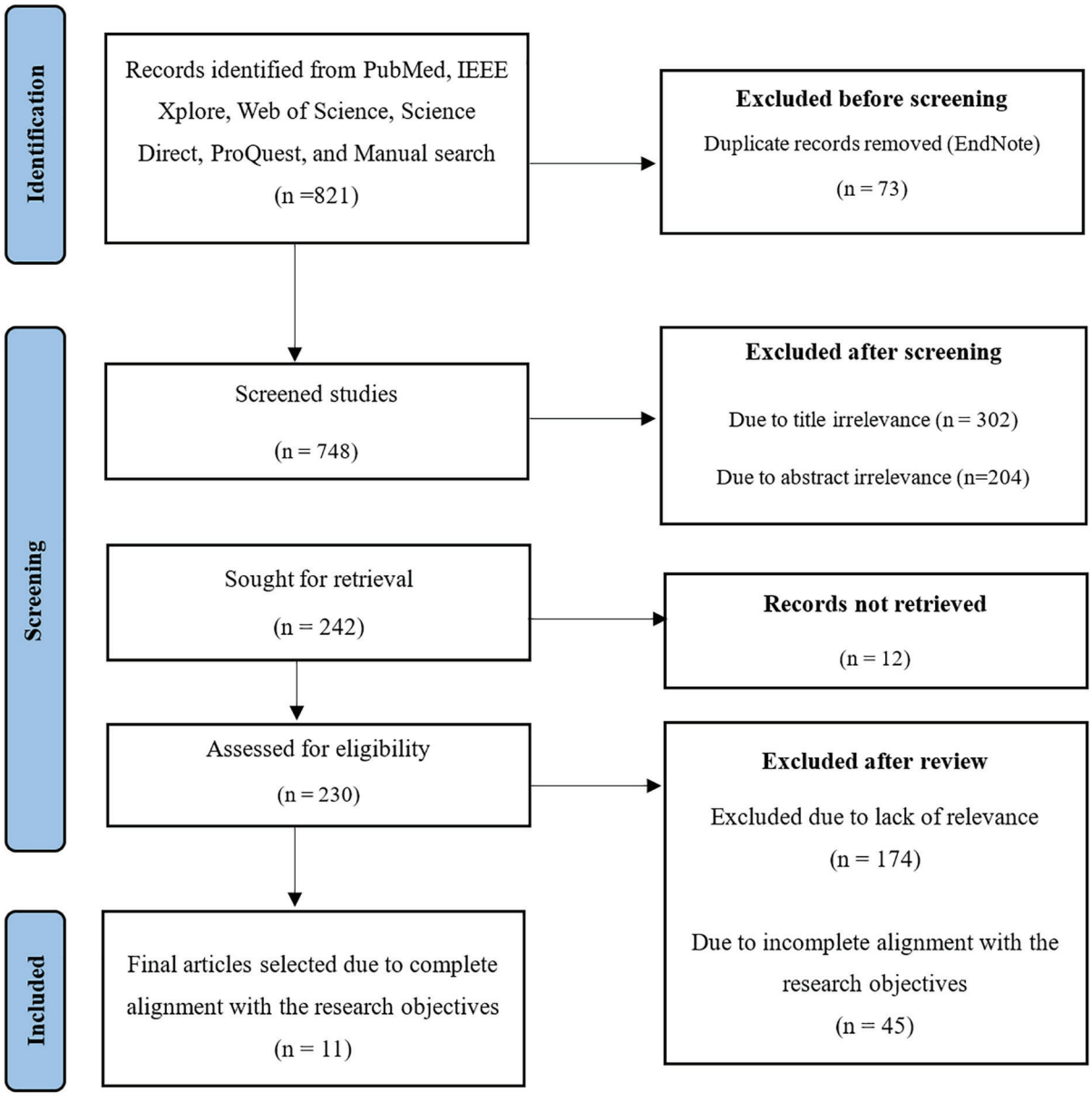

Figure 1: PRISMA 2020 flow diagram for study selection

4. Engagement and interaction: Interactive and play-based elements such as gamification, imitation tasks, and turn-taking significantly improved attention and learning outcomes (26, 30). Applications that incorporated visual prompts, haptic feedback, and responsive cues also maintained motivation and reduced task dropout (25, 26, 30).

5. Accessibility: Accessibility was conceptualized as flexibility and sensory-aware design. Evidence indicates that customizable settings such as adjustable volume, color schemes, speed, and navigation along with clear visual cues, increased comfort and usability (24, 31).

6. User-centric and tailored design: Research grounded in Human-Centered Design (HCD) approaches demonstrated that actively integrating input from children with ASD, along with parents and educators, led to greater task completion rates and enhanced user satisfaction (30, 33, 34). These findings reinforce the importance of iterative, user-informed development.

7. Technology and System Sustainability: Stability, reliability, and predictability of the system were identified as essential

components of UX (24, 32). The findings indicated that technical failures, lag, or abrupt visual changes caused frustration and disengagement, whereas stable and smoothly functioning systems supported emotional regulation and promoted user trust. Comprehensive information about these studies is provided in Table 2.

Table 2: Overview of the included studies

Title	Author	Year	Country	Study Design	Sample Size	Age range of participants	Outcomes
Motivational approach and avoidance in autism spectrum disorder: A comparison between real photographs and cartoons	Silva and colleagues (24)	2015	France	Experimental study	50 participants (25 ASD, 25 typically developing)	11–21 years (ASD group M = 13.96, SD = 2.57)	ASD participants showed atypical motivational responses: avoidance of positive real photos, preference for positive cartoons. Findings support need for simplified, cartoon-based stimuli in learning apps.
User Interface Adaptability within an Augmentative Communication App for Children with ASD Spectrum Disorder	Stauffer A, (25)	2015	Canada	Case study	3 participants (case studies)	3-6 years	Examined usability of AAC app (*Proloquo2Go*); button and array size had minimal influence for most participants; highlighted need for individualized UI design based on behavioral.
Designing Serious Games for People with Special Needs: Implications from a Survey	Xinogalos and colleagues (26)	2019	Greece	Survey research	93 special education professionals and teachers	Adult professionals (exact range not specified).	Survey on serious games for ASD/ID education showed positive evaluations of usefulness, usability, and effectiveness; provided implications for future SG design.
An interactive serious game to Target perspective taking skills among children with ASD: A usability testing	Ghanouni and colleagues, (27)	2020	Canada	Qualitative study (usability)	20 participants (children/youth with high-functioning ASD and parents)	Children and youth with ASD; approximately 8–18 years	Improved usability and user-friendliness of a motion gaming program for perspective-taking; incorporated stakeholder (child + parent) feedback on design, engagement, and feedback mechanisms.

The evaluation of a mobile user interface for people on the autism spectrum: An eye movement study	Rezae and colleagues (28)	2020	Australia	Qualitative study (METUI-GA)	39 participants (21 autistic, 18 neurotypical controls)	Age range: 17–25 years (M ≈ 20)	Eye-tracking analyses showed different interaction patterns between autistic and non-autistic users. Autistic participants preferred icons over text, with better comprehension when both were used together. The *OrienTrip* app enhanced navigation confidence and reduced anxiety for autistic individuals using public transport.
Stakeholder Perspectives to Support Graphical User Interface Design for Children with ASD Spectrum Disorder: A Qualitative Study	Groba and colleagues (29)	2021	Spain	Qualitative, longitudinal, multicenter study	39 participants (20 ASD professionals, 13 tech professionals, 3 parents, 3 children with ASD)	Children aged 10–13 years (ASD group)	Identified graphical UI design recommendations based on stakeholder input; emphasized simplicity, clarity, and personalization for children with ASD. Generated user-centered design guide.
A Mobile Game Platform for Improving Social Communication in Children with ASD: A Feasibility Study	Penev and colleagues (30)	2021	USA	Mixed methods (Clinical study design)	72 children with ASD (75% male)	3–12 years	Mobile game "*GuessWhat*" improved SRS-2 and VABS-II socialization scores; demonstrated feasibility of home-based digital therapy for social communication improvement.
Teaching Emotions in Children with ASD Spectrum Disorder Through a Computer Program with Tangible Interfaces	Aguiar and colleagues (31)	2021	Mexico	Exploratory study	Not specified (preliminary exploratory phase with expert usability evaluation)	Children with ASD (age not reported)	Developed a tangible user interface and gamified application for emotion understanding; preliminary heuristic evaluation showed positive usability results.

User Experience Factors for People with Autism Spectrum Disorder	Valencia and colleagues (32)	2021	Not Reported	Qualitative research (with a focus on UX evaluation)	Not applicable (conceptual and review study)	Not applicable	Proposed nine UX factors specifically adapted for people with ASD, addressing their cognitive, sensory, and interaction needs. Provided a theoretical foundation for developing ASD-specific UX evaluation models and design guidelines.
Developing an educational app for students with autism	Somerton M, (33)	2022	Australia	Mixed methods	2 participants (AB case study design)	8–11 years (middle primary school readers)	Developed and pilot-tested "*Blinded*," an interactive reading comprehension app embedding evidence-based strategies. Immediate feedback and scaffolded learning improved vocabulary, comprehension, and reading behaviors. Highlighted culturally relevant content and adaptive difficulty as critical UX elements for ASD learners.
User Interface and User Experience Design in Digital Learning Applications for Autistic Users with the Human-Centered Design Method	Ashar and colleagues (34)	2022	Indonesia	Qualitative research (Human-centered design)	Not reported (design-based study with user observation and prototype testing)	School-aged children with autism	A web-based learning application for autistic children was developed using a Human-Centered Design approach, focusing on user needs, iterative evaluation, and autism-adapted UI/UX for improved usability and experience.

ASD: Autism Spectrum Disorder; UI: User Interface: UX: User Experience.

Table 2 presents an overview of the 11 included studies, outlining the authors, publication year, country, study design types and outcomes. These studies were published between 2015 and 2025, covering a range of educational contexts such as mobile learning environments, serious games, and interactive platforms tailored for ASD learners.

Table 3 provides a more detailed analysis of 78 subcategories organized into seven principal categories that shape UI and UX design for children with ASD. These categories comprise simplicity and clarity of UI, visual design, feedback and support, interaction and engagement, accessibility, user-centric design, and design tailored for ASD. Each of these factors can contribute significantly to enhancing the learning experience and increasing motivation among children with ASD.

The identified main categories for effective app design in supporting individuals with ASD were variably endorsed across the included studies. Specifically, simplicity and

Table 3: Classification of main categories and subcategories

Main category	Subcategories	Supported Studies
Simplicity and clarity of the user interface	Easy user interface, use of common and familiar symbols, simple, clear, and minimal user interface, elimination of unnecessary elements, low number of elements on a page, uniform layout, iconic and clear buttons, clear and descriptive page titles, avoidance of metaphors and specific phrases, avoidance of overly bright colors, avoidance of flashing content, avoidance of multimedia interfaces, no use of complex shapes and terminology, reduction of textual content.	(26, 28, 29 32-34)
Visual design	Use of understandable icons, use of text alongside symbols, use of pictograms, use of simple images with minimal details, use of soft colors, use of three-dimensional cartoons, use of colors as visual cues, use of simple colors on main pages, appropriate background color, suitable font color, appropriate font, high-contrast font, suitable image and font size, large-sized text, increased use of images, realism of shapes and objects, clear and cartoonish graphics, quality animation design.	(24, 25, 27-30)
Feedback and support	Providing audio feedback, providing instant feedback, providing feedback to the development team, providing qualitative feedback instead of quantitative and scoring feedback, precise and visual feedback, easy and quick information delivery, providing support appropriate to the user's cognitive level and growth, using audio guides, providing clear guidance and instructions, visual support, ability to view one's own performance	(24-27, 30, 32, 33)
Engagement & interaction	Use of interactive speaking avatars, creating useful interactive systems, creating immersion, using visual and auditory elements, using attractive buttons and images, simple mechanics, use of reward mechanics, balance in challenge levels, age targeting, user action repeatability.	(25, 27, 30-34)
Accessibility	Large button sizes, sufficient time for interaction with the system, clear and high-quality sound, flexibility of the user interface, single-button navigation, quick and consistent navigation, personalization capability, reduction of cognitive load, reduction of sensory stimuli.	(24, 25, 27-29, 31, 32)
User-centric and dedicated design for ASD	Design tailored to the challenges of children with ASD, design aligned with clinical characteristics, avoidance of loud and harsh sounds, error-free learning environment, use of familiar and favorite elements for the child, ability to transfer skills to real life, providing concrete examples for understanding abstraction and generalization, use of human-centered design methods, co-designing with users.	(26-30, 32-34)
Technology and system stability	Timely updates of the program, iterative design and evaluation, quick response to user requests, use of artificial intelligence-based systems, authentic and useful content, predictable content.	(24, 32)

clarity of user interface was supported by 6 studies, emphasizing intuitive navigation to reduce cognitive overload. Visual design was backed by seven studies, highlighting the role of appealing and non-overstimulating aesthetics. Feedback and support appeared in seven studies, focusing on timely guidance to enhance learning. Engagement and interaction were the most frequently cited, with eight studies underscoring interactive elements to maintain user interest. Accessibility was noted in seven studies, stressing inclusive features for diverse needs. User-centered and dedicated design for ASD was supported by eight studies, advocating tailored approaches based on stakeholder input. Finally, Technology and system stability was mentioned in only two studies, indicating a need for reliable performance.

Discussion

To address the main research question, this study employed a qualitative synthesis approach consistent with the principles of qualitative synthesis (35). The analysis systematically synthesized qualitative and quantitative findings extracted from the 11 included studies. All relevant textual and conceptual data related to UI and UX design in educational applications for children with ASD were coded and organized into meaningful categories. During this process, overlapping codes were merged, and conceptually similar dimensions were integrated to form broader themes.

Through this structured synthesis, seven major dimensions emerged: simplicity and clarity of user interface, visual design, feedback and support, interaction and engagement, accessibility, user-centric design and design tailored for ASD, and technology and system sustainability. These dimensions collectively represent the core principles influencing usability and learning effectiveness for children with ASD across the reviewed literature.

The interrelations among these dimensions can be understood through the lens of the UX Honeycomb framework (36), which emphasizes that effective digital experiences must be usable, accessible, desirable, valuable, and credible. In the context of ASD education, the identified dimensions align with these principles where simplicity and accessibility enhance usability and visual design and feedback contribute to desirability and engagement and user-centered, sustainable systems ensure long-term value and credibility (36). This conceptual linkage demonstrates that the seven dimensions are not isolated design factors but mutually reinforcing components that together optimize UX and learning outcomes for children with ASD.

In this section, we aimed to examine and explain the seven key categories that hold special importance in the context of the subject matter. These categories serve as the main axes of our research and assist in a deeper analysis of various aspects of the issue. By addressing each of these categories, we will strive to clarify the different dimensions of the topic and identify the existing connections among them. This analysis allows us to gain a more comprehensive understanding of the subject and reach well-documented and meaningful conclusion.

Simplicity and clarity of user interface: Simplicity and clarity in the UI refer to eliminating unnecessary complexities and presenting graphical and textual elements in a clear and comprehensible manner. This principle is particularly essential for children with ASD, who often experience difficulties in processing multiple stimuli simultaneously (7, 37). This category includes avoiding metaphors and specific phrases, steering clear of overly bright colors, refraining from flashing content, avoiding complex shapes and terminology, reducing textual content by using familiar icons, and preventing sudden changes in design (28, 29, 37). The reviewed studies consistently emphasized that reducing visual and cognitive load enhances comprehension and engagement for these users. For instance, a recent study demonstrated through eye-tracking analysis that autistic users rely more heavily on visual cues than text and that excessive or mismatched visual–textual

information increases confusion and fixation duration (28). Consistent with this, another study reported that children with ASD benefit from large, clearly organized visual elements and minimal textual content, underscoring the importance of predictable, uncluttered interfaces (29). The same study further showed, based on stakeholder interviews, that background colors and familiar pictograms that the use of background colors and familiar pictograms—such as those from the Aragonese Center of Augmentative and Alternative Communication (ARASAAC)—help children in organizing information more efficiently and sustaining their attention (26).

Additional research identified "Ease of Use," "Understandability," and "Appearance" as core usability factors in autism-focused applications, reinforcing that simplicity and clarity are fundamental to efficiency and user satisfaction (37). Collectively, these findings support that avoiding metaphors, bright or flashing colors, and complex terminology, while reducing textual density and relying on consistent, recognizable icons, can make applications more intuitive and less overwhelming for users with ASD. However, a notable limitation of prior reviews is their focus on broad usability principles without adequately addressing how the distinct perceptual and cognitive traits of individuals with ASD—such as differences in visual processing, heightened sensitivity to environmental stimuli, and a preference for structure and predictability—inform specific user interface requirements. This synthesis extends this work by systematically integrating empirical findings that directly link user interface simplicity to reduced cognitive load and improved task performance.

Across the included studies, a clear and simple UI consistently emerged as a primary usability determinant for ASD-oriented educational applications (26, 32, 33, 38-41). This theme highlights the need for designers to balance functional richness with perceptual simplicity, ensuring that applications remain accessible and comprehensible to diverse users on the autism spectrum.

Visual design: Visual design in UI is particularly significant for individuals with cognitive and developmental disorders such as ASD. This design dimension determines how colors, symbols, images, and the arrangement of graphical elements influence usability and emotional comfort. For users on the autism spectrum, visual simplicity, balanced colors, and predictable image layouts are critical for maintaining attention and minimizing sensory overload. Prior analyses have consistently shown that autistic users prefer well-structured, visually simple layouts and rely heavily on consistent color schemes and familiar pictograms to support comprehension and focus (28, 29). Complementary findings also emphasized "appearance" and "understandability" as central usability determinants, indicating that coherent, minimalistic visuals directly contribute to satisfaction and ease of use (37).

Across the included studies, several principles consistently emerged: reducing textual content, using icons alongside short text labels, maintaining contrast between background and foreground, and selecting soft, non-distracting colors. A recent systematic review (38), highlighted that gamification and virtual-reality features may enhance engagement when combined with accessible, visually coherent design. Likewise, another review (39), synthesized 69 design recommendations, emphasizing visual consistency, appropriate typography, and balanced interface layout as essential requirements for ASD-friendly applications. These findings collectively confirm that a visually predictable environment supported by simple icons, adequate spacing, and readable fonts helps users process information efficiently and engage comfortably with digital interfaces.

The current synthesis extends prior understanding by showing that specific visual strategies, such as avoiding high-saturation colors, ensuring spatial predictability, and pairing text with visuals are empirically supported for ASD contexts. These strategies reduce anxiety and enhance learning outcomes

by aligning the sensory environment with users' perceptual preferences (42).

The reviewed evidence demonstrates that achieving harmony between simplicity, attractiveness, and functional clarity enhances accessibility and supports sustained engagement (24, 25, 27-30, 37-39). Designing with these principles ensures that users can navigate, comprehend, and interact with the interface without distraction or sensory strain (41).

Feedback and support: Feedback and support refer to providing quick and understandable responses to user actions. For children with ASD, clarity and predictability are essential so that they understand the consequences of each interaction. Therefore, displaying simple, consistent, and predictable visual or auditory messages after an activity plays a crucial role (25, 26, 30, 33). This category includes immediate information, step-by-step guidance, and the use of positive feedback to enhance motivation. Without clear and consistent feedback, children may become confused or discouraged, while appropriate support fosters a sense of achievement and motivation.

Findings from the included studies reinforce the significance of this element. An empirical work assessing an Augmentative and Alternative Communication (AAC) application demonstrated that responsive feedback such as immediate voice output following correct selections enhanced engagement and reduced maladaptive behaviors (25). Related experimental findings (24), showed that children with ASD display greater motivational responses to cartoon-based, simplified stimuli compared with real photographs, suggesting that animated visual feedback can sustain attention and enhance satisfaction. These findings align with those of other included studies emphasizing the importance of accessible, motivating, and adaptive feedback (24, 33, 37).

Participants in multiple studies, including parents and children, emphasized that feedback should be not only immediate but also varied and understandable for children with different performance levels. Parents favored "specific" and visual feedback (37), while most children preferred qualitative reinforcement (e.g., excellent, very good) over quantitative scores. Moreover, the studies highlighted that continuous and accurate system responses encourage user interaction and learning. Incorporating motivational elements such as rewards, game-like structures, and appealing visual or auditory components further enhances engagement and persistence in task performance (32, 40, 41).

In contrast to earlier reviews that broadly addressed usability and satisfaction, the current synthesis delineates feedback as an explicit design dimension. Prior reviews acknowledged the value of usability in general but did not examine feedback mechanisms as a separate, functionally distinct component (37). By contrast, this review highlights feedback as a distinct, evidence-based component supported across empirical studies involving different feedback formats (visual, auditory, and combined).

Engagement and interaction: Engagement and interaction play a crucial role in the effectiveness of educational applications—especially serious games—by sustaining user immersion, boosting intrinsic motivation, and encouraging active involvement in the learning process (32). For children with ASD, engagement is not only about entertainment but also about structured participation through touch, selection, or response mechanisms. This observation aligns with previous work showing that children's engagement with touch-based AAC systems depends heavily on the simplicity of the interface and the predictability of user interactions (25). Complex designs or irregular feedback patterns reduced motivation and disrupted task persistence (32, 34, 41).

The analysis of the included studies further revealed that interactive and play-based features significantly contribute to maintaining attention and motivation. Additional evidence demonstrated that a mobile social-skills game improved social responsiveness and adaptive behavior

among children with ASD, largely due to its structured turn-taking, imitation-based interactions, and immediate reward cycle (30). Another study reported that interfaces incorporating haptic feedback, eye-tracking cues, and simple visual layouts improved attention and reduced disengagement (28).

Although educational games for ASD learners were perceived as highly useful for developing conceptual and social skills, their adoption remained limited due to insufficient customization and limited adaptivity (26). The findings of the current review synthesize these insights, suggesting that active interaction should not be limited to touch-based activities but extended to personalized, feedback-rich experiences that adapt to individual learners' performance levels.

The reviewed evidence thus establishes a clear relationship between user interaction quality and engagement outcomes; children with ASD demonstrate higher levels of motivation and persistence when feedback mechanisms are immediate, interfaces are visually clear, and control is shared between user and system. This pattern is consistent with experimental findings showing that positive and understandable feedback enhances users' sense of achievement and emotional involvement (24). Across all included studies, interaction and engagement consistently emerged as interdependent dimensions directly shaping the educational effectiveness of ASD-oriented applications. By integrating evidence from empirical evaluations (25, 26, 30) and expert-based investigations (30), the synthesis demonstrates that sustained engagement depends simultaneously on interface design quality and the presence of continuous, motivating feedback loops. Future research should therefore focus on adaptive engagement models that integrate user analytics to personalize the learning experience for children with ASD (25, 26, 30).

Accessibility: Accessibility refers to the design of digital learning environments that can be easily used by all children, regardless of their cognitive or sensory abilities. For children with ASD, accessibility includes customizable features such as volume and color controls, captioning for audio content, adequate interaction time, clear sound quality, flexible and personalized user interfaces, and simplified navigation paths (24, 25, 27, 37). These elements ensure that the environment aligns with users' sensory and cognitive characteristics, avoids overload, and facilitates smoother learning experiences.

Evidence from several reviewed studies reinforces the importance of accessible and sensory-appropriate design. One usability investigation involving an interactive motor-skills application highlighted that clear auditory quality, expressive animation, and natural visual cues were essential for sustaining engagement among children and adolescents with ASD (27). Participants also reported discomfort when exposed to excessive sensory stimulation, underscoring the need for controlled input and customizable interface elements. Similarly, another design study employing a user-centered methodology removed unnecessary auditory stimuli and incorporated subtle color schemes, tactile components, and gamified features to support emotion-recognition tasks, demonstrating how carefully adjusted sensory cues can enhance usability and learning (25). These adaptations enabled smoother interaction and reduced the sensory overload commonly experienced by children with ASD (43). In addition, other studies included in this review (24, 25, 27-29, 31, 37, 39, 40) consistently emphasized that simple and consistent navigation, sufficient time to complete the task, and the option for instructors to adjust the difficulty of the content were critical to promote usability. Systems that failed to accommodate slower response times or used inconsistent transitions tended to disrupt attention and reduce learning outcomes. When combining these findings, a clear pattern emerges that accessibility in ASD-focused educational tools should be both sensory-aware and flexible. Visual and auditory customization, predictable navigation, and personalization options significantly improve usability, emotional comfort, and learning

engagement for children with ASD.

Compared with some earlier works that broadly examined usability in digital environments for ASD (26, 30), the present synthesis provides more detailed insight into how accessibility mechanisms such as sensory load regulation and customizable interface features directly influence user comfort, sustained attention, and overall engagement. The present review identified these elements as essential dimensions of accessibility for ASD-based applications, thereby expanding the existing literature by explicitly linking sensory customization, user control, and cognitive adaptability within the same design framework.

In the reviewed studies, accessibility is not a static design feature but rather a dynamic interplay between sensory simplicity, user flexibility, and adaptive scheduling. Designing applications that consider these factors ensures equitable participation, minimizes sensory overload, and enhances usability and the learning experience for children with ASD (24, 25, 27-29, 31).

User-centric design and tailored design for ASD: In the development of educational applications for individuals with ASD, user-centric and tailored design principles are essential. This approach emphasizes designing based on the actual characteristics and needs of children with ASD rather than applying general design principles. Such designs require understanding individual differences in information processing, interests, and sensory sensitivities (27-29).

Data from the selected studies confirms the importance of user-centered processes. Additional evidence supports the role of user participation and structured pedagogical design in improving learning outcomes. One study integrating pedagogical principles directly into the design process reported improved reading comprehension among autistic learners, although challenges persisted in tailoring content across age groups (33). Further support comes from research applying a Human-Centered Design (HCD) framework to a web-based learning platform, where iterative testing with autistic students and educators yielded high task-completion rates and strong satisfaction, confirming that involving end users in design decisions leads to more effective interactions (34). A separate analysis of user feedback across multiple ASD-related mobile applications revealed that many adult users emphasized the need for simple interfaces, clear navigation, and stable performance findings that align with the broader theme of user-centricity and the importance of iterative refinement based on real-world experience (40).

Across the included studies, the user-centric design process often involved collaboration with key stakeholder's parents, teachers, therapists, and in some cases, the users themselves during ideation, testing, and refinement stages (26, 30, 38). While direct participation of children with ASD in the design process can be challenging due to communication barriers, several studies suggested that proxy feedback from caregivers and educators can effectively inform design decisions and maintain user relevance. Even when direct participation from children is limited due to communication barriers, insights from close stakeholders and systematic feedback can guide meaningful design adaptation (33, 40).

Designs should therefore incorporate tangible examples, provide clear feedback, and support augmentative and alternative communication for individuals with verbal challenges (25, 26, 38).

When compared with prior assessments of assistive and educational technologies for ASD (32), the present synthesis extends earlier conclusions by demonstrating that effective design depends not only on sensory and visual adjustments but also on the systematic integration of user feedback as a mechanism for evidence-based improvement.

Technology and system sustainability: Technology and sustainability refer to the reliability of both software and hardware infrastructures, which must operate smoothly without interruptions or errors. Children with ASD are often highly sensitive to

sudden changes or disruptions in digital environments, making system stability a critical design factor. Ensuring sustainability therefore involves maintaining stable connections, reliable functionality, and predictable system behavior (24, 27, 38). The importance of this is that instability in the system can cause anxiety and distrust in the child, while stable and reliable technology provides a positive and continuous learning experience (44).

Findings from the included studies confirm the importance of stable and well-structured digital systems. Multiple studies underscored the significance of predictability and consistency as fundamental UX requirements for autistic users, noting that stable interaction patterns support a sense of safety and confidence when navigating digital tools (32). Additional research on smartphone-based applications emphasized that smooth interactions, visual clarity, and the absence of system instability are critical, as unpredictable behavior or visual overload can lead to confusion and disengagement (41). These findings align with our category emphasizing stable technological performance, secure data storage, and seamless updates.

To ensure the continuity of use and minimize anxiety, applications should update automatically and maintain fast loading speeds, while preventing crashes or data loss (24-33, 37). Earlier work also highlighted that frustration-free interaction through effective error management and avoidance of abrupt, unexpected changes supports emotional regulation for individuals with ASD (32). Building upon these findings, the present synthesis broadens the perspective from general UX stability to long-term system sustainability, emphasizing the importance of reliable software performance, regular maintenance, and overall technological robustness as key contributors to continued usability and user trust. Previous reviews primarily examined short-term usability and interface engagement, while the current analysis highlights sustainability as a determinant of trust and consistent learning engagement over time.

Iterative design and continuous evaluation are essential for understanding user needs and refining design requirements. Various tools such as questionnaires, interviews, focus groups, and observations are commonly used to collect feedback and identify usability issues. While involving individuals with ASD directly in such processes would be ideal, challenges in communication and interaction often make full participation difficult (30, 33, 38, 39). Therefore, many studies emphasize the importance of involving therapists, caregivers, and educators as proxies to ensure the appropriateness of design decisions. Moreover, the accuracy and completeness of tasks within the application should be verified so that the UI can present reliable outcomes aligned with users' expectations. Content must be original, purposeful, and responsive to users' specific educational or therapeutic needs. Likewise, system predictability and non-stressful interaction are critical to building a sense of safety and trust in users. These observations are also consistent with insights reported in external studies not included in the final review (6), as well as other included research (32, 38).

A key finding emerging from the reviewed studies is that UI and UX design for educational applications targeting children with ASD should not follow a uniform or generalized model. Instead, designs must be adapted to the learning objectives and content focus of each application. For instance, applications designed to teach social or emotional skills should prioritize interactive elements, social feedback, and familiar visual representations, whereas those focusing on cognitive or language skills should emphasize simplicity, reduced cognitive load, and clear visual cues to aid comprehension (45). This highlights that topic-oriented and intelligent design approaches can significantly enhance user engagement and learning outcomes. Consequently, future research should move toward more customized, flexible, and context-sensitive design frameworks.

Limitations and Suggestions

Several limitations should be noted regarding both the included evidence and the review process. Some of the studies analyzed had small sample sizes, lacked control groups, or relied primarily on qualitative assessments, thus limiting the generalizability of their findings. At the review level, constraints also existed. The search was limited to English and Persian publications, which may have introduced language and publication bias. Although grey literature such as theses and dissertations was included to capture emerging ideas in this interdisciplinary field, methodological variability across these sources may have influenced the overall consistency of evidence.

In contrast to previous reviews that mainly focused on educational outcomes or therapeutic effectiveness of ASD technologies, this study offers a distinct design-centered synthesis emphasizing UI and UX principles. This contribution complements prior works by identifying design features that shape usability and engagement rather than solely learning outcomes. Nevertheless, heterogeneity in study designs and the lack of standardized evaluation frameworks remain key challenges for evidence synthesis in this domain.

From a practical standpoint, several recommendations can be drawn for designers, developers, and educators. Designers should employ participatory and user-centered approaches, involve therapists and caregivers during iterative testing, and ensure simplicity, consistency, and accessibility in design. Developers are encouraged to integrate adaptive and AI-driven personalization features to align with individual sensory and cognitive profiles. For educators and practitioners, awareness of UX principles can facilitate the selection or customization of digital tools suited to learners with ASD. Future studies should employ larger and more diverse samples, combine quantitative and qualitative methods, and explore long-term user engagement. Additionally, expanding future reviews to include non-English databases and systematically mapping grey literature can improve the comprehensiveness and reduce bias in subsequent syntheses.

Conclusion

Evidence from the reviewed studies suggests a potential association between thoughtful UI/UX design and improved learning experiences for children with ASD. Nonetheless, the strength of this evidence remains limited, and further rigorous research is required before firm conclusions can be drawn. Through synthesizing evidence from 11 studies, seven overarching design principles were identified: simplicity and clarity of the UI, visual design, feedback and support, interaction and engagement, accessibility, user-centered and ASD-oriented design, and technology and system stability. These principles collectively provide a conceptual framework that can inform the development of more inclusive and supportive educational applications.

Beyond summarizing existing knowledge, this synthesis highlights key gaps in the literature. The current body of evidence remains limited by small sample sizes, heterogeneous methodologies, and the absence of standardized evaluation frameworks. Consequently, while the evidence indicates promising directions, further high-quality empirical studies are needed to validate and refine these design principles in real-world contexts.

In practical terms, adopting these principles may help developers, designers, and educators create digital tools that are simpler, clearer, and better aligned with the sensory and cognitive profiles of children with ASD. Theoretically, this review contributes to building a more structured understanding of design-based interventions in special education technology, encouraging future research toward evidence-based, adaptive, and user-centered design frameworks.

Abbreviations

AAC: Augmentative and Alternative Communication

ASD: Autism Spectrum Disorder
MMAT: Mixed Methods Appraisal Tool
UI: User Interface
UX: User Experience

Acknowledgments

The authors used ChatGPT to assist with English translation, language polishing, and improving the overall coherence and readability of the manuscript. The AI tool was not involved in data analysis, interpretation of findings, or drawing conclusions. All outputs generated by the AI were carefully reviewed, verified, and revised by the authors to ensure accuracy and academic integrity.

Authors' Contribution

The conception and design of the study were developed by MKH and RA. The database search, data extraction, and qualitative synthesis were conducted by MKH. Supervision, validation, and critical revision of the manuscript were carried out by RA. Both authors contributed to drafting and revising the manuscript and approved the final version.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical Considerations

In light of the nature of the research, no ethical issues were identified that necessitated consideration.

Funding/Support

Not applicable.

Availability of Data and Materials

The data that support the findings of this study are available within the article. All analyzed data were derived from publicly available studies retrieved from public databases including PubMed, Web of Science, ScienceDirect, IEEE Xplore, and ProQuest. No new data were generated or collected in this study.

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