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Digital Pedagogical Resources as Supportive Aids for Children with Autism Spectrum Disorder

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Abstract: Autism Spectrum Disorder (ASD) presents diverse educational challenges stemming from its core characteristics in social communication, interaction, and repetitive behaviors. This article explores the efficacy of digital pedagogical resources as assistive technologies for children with ASD. Through a qualitative review of existing literature and an examination of a specific case study (Squizzy application), it investigates various forms of educational software, including mobile applications, augmented reality (AR) tools, and AI-powered robotics, and their applications in enhancing social skills, communication, and academic outcomes. The findings highlight the significant benefits of these technologies in providing individualized, visually-driven, and engaging learning experiences that can supplement traditional therapeutic approaches. The discussion also addresses critical considerations such as the quality and suitability of available software, the complex issue of generalizing learned skills to real-world contexts, prevailing issues of access and equity, and the indispensable role of human intervention and supervision. The article concludes that while these digital tools hold immense potential to foster development and inclusion for children with ASD, their effective and responsible implementation requires careful selection, thoughtful integration into broader intervention strategies, and ongoing research to maximize their long-term impact and address current limitations.

Keywords: Autism Spectrum Disorder, ASD, Assistive Technology, Educational Software, Digital Pedagogical Resources, Mobile Applications, Augmented Reality,

Robotics, AI, Special Education, Communication, Social Skills.

Introduction: The term "autism," derived from the Greek word "autos" meaning "self," was initially introduced to describe a self-centered pattern of thinking observed in individuals with schizophrenia [1]. Over time, the understanding of this complex neurological condition has evolved, leading to the current diagnostic framework of Autism Spectrum Disorder (ASD). ASD is recognized as a childhood-onset developmental disorder primarily affecting the immature brain, leading to significant impairments in social communication and interaction. These core deficits are often accompanied by persistent restricted, repetitive patterns of behavior, interests, or activities [1, 3]. The categorization of ASD under neurodevelopmental disorders in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) underscores its neurological basis and the wide range of symptoms and severities observed across individuals [3]. This spectrum nature means that while individuals with ASD share common diagnostic criteria, their specific manifestations, strengths, and challenges vary considerably [1, 4].

Globally, the prevalence of ASD has become a subject of intense focus, with estimates indicating that approximately one in 160 children worldwide are affected [4]. This growing awareness is critical for public health initiatives and resource allocation. However, in many developing countries, including Indonesia, official and comprehensive surveys regarding ASD prevalence are scarce [5]. Despite this lack of precise data, reports from various sources suggest a significant number of cases. For instance, Dr. Rudy Sutadi reported an incidence of two new cases per 1,000 population per year in Indonesia, with a cumulative prevalence of 10 cases per 1,000 population since 1997 [6]. Considering Indonesia's substantial population of 237.5 million in 2010 and a growth rate of 1.14% [7], these figures imply a significant population of children with ASD, estimated to be around 2.4 million, with an additional 500 new cases annually. This highlights a pressing need for effective support systems and interventions within the country [5, 6, 7, 8, 9, 10].

Children with ASD face unique and often profound educational hurdles that stem directly from their diagnostic characteristics. These challenges can manifest as difficulties in comprehending abstract concepts, a tendency towards literal interpretation of language, heightened sensory sensitivities that can lead to overload, and significant struggles in generalizing skills learned in one context to new and varied environments [1, 15]. Traditional educational paradigms, often designed for neurotypical development, may not adequately accommodate these diverse learning profiles. This frequently results in a suboptimal learning experience for children with ASD, emphasizing the urgent demand for tailored, flexible, and effective pedagogical approaches [15].

In response to these educational disparities, Assistive Technology (AT) has emerged as a profoundly promising solution. Broadly defined by the World Health Organization (WHO) and the International Standards Organization (ISO), AT encompasses "any device or system that allows individuals to perform tasks they would otherwise be unable to do or increases the ease and safety with which tasks can be performed" [11]. More comprehensively, ISO 9999:2016 defines assistive products for persons with disability as "Any product (including devices, equipment, instruments and software), especially produced or generally available, used by or for persons with disability for participation to protect, support, train, measure or substitute for body functions structures and activities, or to prevent impairments, activity limitations or participation restrictions" [12]. For children with ASD, assistive technologies can act as powerful enablers, offering structured, predictable, and engaging avenues for learning, communication, and social interaction [13].

Within the vast landscape of assistive technologies, educational software—encompassing a range from simple mobile applications to complex immersive digital environments—holds particular promise [15, 22, 23]. These digital tools can leverage the visual strengths often observed in individuals with ASD, providing a systematic and less anxiety-provoking approach to learning compared to traditional face-to-face interactions [13, 14]. The past decade has witnessed a clear surge in research addressing technologies specifically designed for children with autism, highlighting the growing recognition of their potential [15]. This article aims to comprehensively explore how digital pedagogical resources can serve as effective supportive aids for children with Autism Spectrum Disorder. It will delve into their diverse applications, examine their documented benefits, and critically discuss the inherent challenges and limitations that must be addressed for their optimal implementation. The insights presented herein are drawn from a synthesis of current literature, including a case study of a specific educational software designed for children with ASD in Indonesia.

Methods

This article employs a qualitative review methodology

to explore the application, development, and effectiveness of digital pedagogical resources as assistive technologies for children with Autism Spectrum Disorder. The approach involves a structured synthesis of insights derived from published research articles, academic reports, and conceptual papers. The focus is specifically on the intersection of educational software, assistive technology principles, and the unique learning characteristics of individuals with ASD. The selection of references, as provided by the user, was meticulously guided by their direct relevance to this defined scope, ensuring that the review encompasses a broad spectrum of digital tools and their reported impacts on key developmental areas pertinent to children with ASD.

The review primarily focuses on several interconnected aspects:

- Types of Educational Software and Technologies: Identification and categorization of various digital platforms and applications that have been developed or adapted for learners with ASD. This includes a detailed examination of mobile applications (specifically tablet-based, such as iPad apps), emerging technologies like augmented reality (AR) and virtual reality (VR) tools, and the innovative integration of robotics and artificial intelligence (AI) in therapeutic and educational contexts [16, 17, 18, 19, 20, 21, 24, 25, 26]. The methodology involves analyzing how these technologies are designed to cater to the sensory and cognitive profiles of children with ASD.
- Targeted Skills and Learning Outcomes: Investigation into the specific skills and educational outcomes that these technologies aim to enhance. This includes an assessment of their efficacy in improving social communication skills, fostering emotional recognition, supporting academic learning (such as reading comprehension and vocabulary development), aiding in the acquisition of daily living skills, and assisting in behavior management strategies [13, 14, 16, 29, 30]. The review evaluates the mechanisms through which these tools facilitate skill acquisition and generalization.
- Reported Benefits and Limitations: A comprehensive analysis of the documented advantages and disadvantages associated with integrating educational software into the learning and therapeutic environments of children with ASD. This involves considering factors such as the degree of user engagement, the potential for individualization and personalization of learning content, issues related to accessibility and usability, and the crucial challenge of ensuring the generalizability of skills learned within a digital environment to real-world social and educational settings [15, 27].

The overarching methodology adopted for this review is descriptive and analytical. Conclusions are drawn based on the collective evidence presented in the extensive list of cited works. Given the inherent heterogeneity of ASD manifestations and the diverse nature of digital educational software, the review aims to provide a robust and comprehensive overview of the current landscape rather than a specific meta-analysis of narrowly defined intervention outcomes. The synthesis of information is designed to highlight recurring patterns, identify successful applications, and underscore persistent challenges within the field. By drawing directly from the provided reference list, all claims and observations are meticulously supported, ensuring the academic rigor and foundational basis of the discussion. The ultimate intention of this structured review is to provide valuable insights for educators, parents, therapists, and software developers, guiding them in understanding and leveraging the profound potential of these digital tools in supporting children with ASD. Furthermore, the methods section will incorporate details from the PDF regarding the development methodology and evaluation of "Squizzy," a specific educational software for children with ASD.

2.1. Research and Development Methodology: A Case Study of Squizzy

The development of "Squizzy," an assistive technology application specifically designed as educational software for children with ASD, serves as a pertinent case study within this review. Squizzy targets children between the ages of 5 and 15 years old, recognizing the diverse developmental stages within this age range. The design philosophy for Squizzy was fundamentally rooted in a user-centered design approach, acknowledging that assistive technology for children with special needs requires continuous attention throughout its entire lifecycle—from initial configuration and ongoing maintenance to future upgrades and eventual replacement. It was recognized that developing applications for children with ASD cannot be approached in the same manner as designing typical applications, given their unique cognitive and sensory profiles. This necessitates extra effort in understanding and gathering input from all individuals involved in the child's care, including therapists and parents, each of whom brings specific targets and expectations for assistive technology.

The research method for developing Squizzy followed a structured approach, typically encompassing:

1. Requirement Gathering: This crucial initial phase involved extensive interviews to understand the specific needs and challenges faced by children with

ASD and their caregivers.

2. Literature Review: A thorough examination of existing research and applications in the field of assistive technologies for ASD to inform design decisions and identify best practices.

3. System Analysis: Detailed analysis of the gathered requirements and literature to define the functional and non-functional specifications of the application.

4. Application Development: The iterative process of building the software based on the defined specifications.

5. Evaluation: Rigorous testing and feedback collection to assess the effectiveness and usability of the developed application.

2.1.1. Requirement Gathering Process for Squizzy

For the requirement gathering phase of Squizzy, interviews were conducted with key stakeholders from Yayasan Cinta Harapan Indonesia (YCHI) Autism Center [28]. YCHI is a non-profit organization that provides support to children with special needs, including ASD, from underprivileged families without charge, making it an ideal environment for understanding real-world needs. The interviewees included two psychologists, five therapists, and five parents of children with ASD from YCHI. This multi-perspective approach was critical to capturing a comprehensive understanding of the challenges and requirements from both professional and familial standpoints.

The evaluation matrix for guiding requirements was informed by research conducted by Melissa Dawe [27]. Dawe's research highlighted that parents and teachers consistently favor assistive technology that is as simple as possible. This insight became a guiding principle for Squizzy's development: to create an application that is simple in design yet highly functional in purpose. Consequently, three key factors were identified as paramount for Squizzy's design and functionality:

1. Portability: The application needed to be easily transportable and usable in various settings.

2. Ease of Use: The interface had to be intuitive, with a low learning curve for both children and caregivers.

3. Usefulness: The application needed to directly address and support existing therapeutic activities and learning goals.

These three factors formed the bedrock of Squizzy's design and development, ensuring it was practical, accessible, and therapeutically relevant.

2.1.2. The Imperative of Portability

The need for portability was strongly articulated by the therapists at YCHI. Each therapist typically manages a caseload of two to five children, a number often considered less than optimal given the intensive nature of ASD therapy. Therapists traditionally rely on various physical therapeutic tools, which necessitate significant preparation time and are cumbersome to transport, especially when sessions are conducted at the children's homes rather than exclusively at the clinic. The therapists expressed a strong desire for digital alternatives to some of these activities, believing that a software-based solution could significantly reduce preparation time and logistical inconvenience. Parents echoed this sentiment, seeing the potential for an application to enable them to conduct therapy sessions with their children even in the absence of a professional therapist. This dual benefit—reducing therapist workload and increasing accessibility for home-based therapy—underscored the importance of portability.

In light of these requirements, the decision was made to develop Squizzy as a tablet application. Tablets are highly favored for their portability, combined with a screen size that is sufficiently large for interactive learning activities, unlike smaller mobile phone screens. While acknowledging that technology can become outdated or break, the design of Squizzy specifically aimed to not require the very latest tablet technology, ensuring a wider accessibility range for families. Specifically, Squizzy was developed for the iPad platform, requiring a minimum operating system of iOS 10. This choice was further supported by existing research demonstrating the successful use of iPads as effective learning devices for children with ASD [29, 30], lending empirical validation to the platform selection.

2.1.3. Prioritizing Ease of Use

Ease of use emerged as a paramount concern, particularly from the perspective of parents. They emphasized the critical need for an extremely simple interface with a minimal learning curve. The reasoning was straightforward: if an application proved difficult or frustrating to use in the initial interactions, children with ASD were highly unlikely to return to it. While many contemporary applications prioritize interactive multimedia elements (text, images, audio, video, animation), the design for children with ASD demands that every interaction serves a clear, meaningful purpose. This is due to the common challenge faced by children with ASD in maintaining focus on completing specific tasks, often being easily distracted. Therapists at YCHI provided invaluable feedback, advising that the application should rigorously avoid excessive "distractors," such as overly illustrated images or unnecessary animations. Even the slightest visually "eye-catching" event could easily derail a child's concentration. Furthermore, a crucial insight was that

children with ASD often process and understand real pictures more effectively than abstract or stylized illustrations, guiding a key design decision.

Consequently, Squizzy was designed to utilize only real photographs instead of illustrations, and these images were used judiciously to prevent overstimulation. Another significant consideration was language. Recognizing that many of the children at YCHI primarily understood Indonesian, the development team made a deliberate choice to build Squizzy exclusively in Indonesian. This decision was also driven by the observation that, at the time of development, there was a noticeable scarcity of educational software specifically designed for children with special needs in the Indonesian language. This commitment to a real-picture, Indonesian-language interface directly addressed the expressed needs for a highly intuitive, focused, and culturally appropriate learning tool.

2.1.4. Ensuring Usefulness and Therapeutic Relevance

The usefulness of Squizzy was defined by its ability to replicate and enhance existing, proven therapy activities. During interviews, therapists detailed typical therapy sessions that included:

1. Inserting wooden blocks with various shapes and sizes into corresponding containers: This activity targets fine motor skills, shape recognition, and problem-solving.

2. Matching and re-ordering cards displaying pictures of day-to-day activities: This focuses on sequencing, understanding routines, and cognitive organization.

3. Matching text and images: This supports early literacy, vocabulary development, and visual-verbal association.

4. Arranging simple puzzles: This promotes spatial reasoning, visual discrimination, and problem-solving.

Squizzy was designed to faithfully replicate these types of activities within a tablet environment, leveraging the digital platform's capabilities for interactivity and tracking.

Each activity within Squizzy was structured with three distinct levels of difficulty: mudah (easy), sedang (medium), and sulit (hard). This tiered approach allows therapists to adjust the challenge based on the child's individual condition and progress. For each set of activity, there are five questions that must be answered. A key pedagogical design choice was that the current question must be answered correctly before the child can proceed to the next, reinforcing correct responses.

- The easy level is primarily designed as an introduction, ensuring a high probability of success to build confidence. In this mode, only the correct answer choice is presented.
- The medium level incrementally increases the challenge by providing two answer choices, requiring the child to discriminate between options.
- The hard level offers the most significant challenge, presenting three answer choices, demanding greater cognitive effort and focus.

Beyond task completion, the application also incorporates a basic scoring system, recording the child's performance and the time taken to complete each activity. This scoring system is not intended for comparative evaluation but rather as a record to track the child's individual progress over time, providing valuable data for therapists and parents. Upon successfully completing an activity, children are provided with positive reinforcement in the form of verbal praise or a celebratory confetti animation, aimed at maintaining motivation and engagement.

In addition to the core therapeutic activities, Squizzy includes two crucial supporting features:

- Perpustakaan (Library): This feature is designed to help children learn about new objects and their shapes, expanding their vocabulary and general knowledge.
- Laporan (Report): This feature is essential for caregivers, allowing therapists and parents to monitor their child's daily therapy session progress comprehensively.

2.1.5. Implementation and Evaluation Methodology

The development of Squizzy implemented the Scrum methodology, an agile framework known for its iterative and incremental approach, which is well-suited for projects requiring flexibility and continuous feedback—especially relevant when designing for users with specific needs like children with ASD.

For the evaluation phase, Squizzy was formally delivered to ten children with ASD from YCHI, who were actively accompanied by their therapists or parents during the trial. A key aspect of the evaluation involved assessing the application's portability in practice. Therapists found that during sessions, particularly when conducted at the children's homes, they were no longer required to carry a full suite of physical therapeutic tools, as a significant portion of the activities could be seamlessly conducted using Squizzy on the tablet. Furthermore, some parents had Squizzy installed on their personal tablets, enabling them to independently engage their children in therapeutic activities at home. Following several therapy sessions, detailed interviews were conducted with both the therapists and parents to

gather comprehensive feedback on Squizzy's usability, effectiveness, and overall impact on the therapy process. This direct user feedback loop was critical for validating the design choices and identifying areas for future improvement.

RESULTS

The evaluation of Squizzy, alongside insights from broader literature on digital pedagogical resources, reveals significant findings regarding their utility as assistive technologies for children with Autism Spectrum Disorder. The synthesis highlights how various digital tools effectively address a wide range of developmental and educational needs.

3.1. Mobile Applications and Tablets: The Foundation of Accessibility

Mobile devices, particularly tablets such as the iPad, have rapidly become indispensable tools in educational and therapeutic interventions for children with ASD [24]. Their inherent characteristics—intuitive touch interfaces, portability, and the vast ecosystem of applications—make them highly accessible and adaptable learning platforms [25]. The evaluation of Squizzy specifically demonstrated these advantages. The therapists who participated in the study reported being significantly aided by Squizzy's portability, as it drastically reduced the logistical burden of transporting traditional therapeutic tools. This convenience extended to parents as well, who could easily install Squizzy on their tablets and conduct activities with their children at home, fostering continuity in learning beyond formal therapy sessions.

Research consistently indicates that iPad-based interventions can lead to significant improvements across various domains. These include enhancing communication skills [25, 30], fostering social interaction, and boosting academic learning, particularly in foundational areas such as reading [29]. For example, applications specifically designed for picture and word matching have demonstrated considerable efficacy in teaching literacy skills to students with severe communication impairments [30]. The visual-centric nature of these applications often aligns seamlessly with the processing strengths of many individuals with ASD, providing predictable, structured, and visually engaging environments that facilitate skill acquisition [17]. Furthermore, the inherent ability of these digital platforms to allow for extensive customization and personalization of content, coupled with built-in progress tracking features, offers substantial advantages for creating highly individualized learning pathways [26]. Squizzy's design, with its real pictures and clear interface, directly reflects these best practices observed in successful iPad interventions.

3.2. Augmented Reality (AR) and Virtual Reality (VR) Tools: Bridging the Real and Digital

Beyond traditional mobile applications, Augmented Reality (AR) and Virtual Reality (VR) technologies are emerging as powerful modalities in ASD interventions. AR applications overlay digital information onto the real-world environment, creating interactive and immersive learning experiences. For children with ASD, AR offers a unique advantage: it can create simulated social scenarios or highly interactive learning environments that significantly reduce the sensory overload often experienced in complex, real-world situations. This controlled exposure facilitates the practice of crucial skills in a less intimidating context [18, 19]. Examples from the literature include augmented reality games that have been shown to effectively help children practice complex social skills [16] and even daily living routines, such as learning the steps for daily prayers [20]. By providing a safe, controlled, yet highly interactive environment, AR allows for repetitive practice of skills, helping to bridge the gap between abstract concepts and concrete understanding [18]. This immersive, multi-sensory approach can capture the attention of children with ASD in ways that traditional methods might not, fostering deeper engagement and more effective learning.

3.3. Robotics and AI-Powered Interventions: Consistent and Personalized Support

The frontier of assistive technology for ASD is expanding rapidly into the realm of social robotics and AI-powered interventions. Social robots, equipped with sophisticated artificial intelligence, are increasingly being explored for their potential to facilitate social and emotional learning in children with ASD [21]. These robots offer a unique advantage: they can provide consistent and predictable social cues and responses, which for some children with ASD can be less overwhelming and more manageable than the complexities of human interaction [21]. The predictability of robot behavior can help reduce anxiety and create a more comfortable environment for learning social rules and emotional expressions.

AI-powered systems further enhance this potential by enabling personalized interventions. These systems can adapt dynamically to a child's individual responses and learning pace, offering tailored feedback and support for developing skills like emotional recognition and engagement [21]. While still an evolving field, early research indicates that robots can be highly effective in capturing children's attention and maintaining engagement in therapeutic settings, particularly for promoting crucial developmental milestones such as

joint attention and imitation [21]. The ability of AI to analyze a child's behavior and provide real-time, adaptive feedback opens new avenues for highly customized and effective therapeutic pathways.

3.4. Communication and Social Skill Supports: Directing Core Deficits

Educational software explicitly targets the core deficits in social communication often observed in ASD [13]. A variety of digital tools are designed to facilitate communication and social interaction:

- Text-to-speech applications: These can serve as expressive assistive technologies, aiding individuals with autism spectrum conditions in translating their thoughts into spoken language, thereby reducing communication barriers [14].
- Mobile assistive tools like "MOSOCO": These applications are specifically designed to support children in practicing social skills within simulated or real-life situations. They offer visual prompts, feedback, and structured scenarios to help children navigate complex social interactions [16]. MOSOCO, for instance, engages students in activities that promote eye contact, appropriate spatial boundaries, conversational turn-taking, sharing interests, and disengaging appropriately from interactions.
- Interactive visual supports applications: Tools such as "Mocotos" (a mobile visual augmentative communication aid) and "vSked" (a multi-device interactive visual schedule system) leverage the visual strengths of individuals with ASD. Instead of relying solely on oral conversation, children can use the application interface to express their needs, make choices by pointing to pictures, or follow visual schedules, providing structure and reducing anxiety associated with unpredictable social interactions [17].

The systematic presentation of information, coupled with repeated opportunities for practice offered by these software tools, is invaluable for developing these crucial social and communication skills [15]. By externalizing social cues and breaking down interactions into manageable steps, digital tools provide a scaffold that supports learning and application.

3.5. Academic and Cognitive Skill Development: Enhancing Learning Capabilities

Beyond addressing social and communication challenges, educational software also plays a significant role in aiding academic learning and cognitive development in children with ASD. As previously noted, iPad applications have been rigorously evaluated for their efficacy in enhancing both communication skills [25] and reading instruction [29]. These digital platforms are adept at presenting academic content in highly engaging and multi-modal formats, often integrating gamification elements that significantly boost and sustain interest and motivation among learners. The gamified approach transforms potentially challenging academic tasks into interactive play, encouraging repeated engagement.

A key advantage of educational software is its capacity to break down complex academic tasks into smaller, more manageable, and sequential steps. This incremental approach, combined with immediate feedback mechanisms, makes these tools exceptionally powerful for supporting cognitive development and fostering academic achievement in children with ASD [15]. Whether it's through interactive quizzes, visual learning modules, or adaptive practice exercises, software can provide a structured yet flexible environment that caters to the individual learning pace and style, facilitating a deeper understanding and retention of academic concepts. Squizzy, with its tiered difficulty levels and structured activities like "Image Matching" and "Simple Questions," embodies this principle, aiming to build cognitive skills systematically.

3.6. Detailed Description of Squizzy Features

Squizzy features a user-friendly interface designed with the specific needs of children with ASD in mind. It comprises six main features, four dedicated to core therapy activities and two serving as additional supporting functions.

3.6.1. Introduction and User Login

Upon launching Squizzy, users are greeted with an introduction screen (as illustrated in Figure 2 of the original PDF). This screen briefly highlights Squizzy's core benefits: helping children understand that devices are not solely for play, aiding focus during therapy sessions, and emphasizing that it is a free application requiring no additional equipment.

Before accessing the main features, the application prompts the user to enter the child's name (Figure 3a of the original PDF). This step is crucial as it ensures that each child's progress can be tracked and stored separately, allowing for personalized monitoring and reporting. After entering the name, the user is directed to the main menu (Figure 3b of the original PDF), which serves as the central navigation hub to all other features.

3.6.2. Core Therapy Activities

Squizzy incorporates four main therapy activities, each designed to address specific cognitive and learning skills:

1. Cocokkan Gambar (Image Matching):
   - Purpose: This activity aims to enhance visual

discrimination, pattern recognition, and matching skills.

- Workflow: The child is presented with a target picture and must match it with an identical picture from a set of choices (Figure 4a-4d of the original PDF).
- Difficulty Levels:
  - Mudah (Easy): Presents the target picture and only one correct matching option, ensuring immediate success and building confidence (Figure 4b).
  - Sedang (Medium): Introduces a slightly higher challenge by presenting two answer choices, requiring the child to differentiate (Figure 4c).
  - Sulit (Hard): Offers the highest challenge with three answer choices, demanding more focused visual processing and selection (Figure 4d).

2. Lawan Kata (Opposite Words):

- Purpose: This activity focuses on developing vocabulary, understanding abstract concepts (opposites), and verbal reasoning.
- Workflow: The child is given a word or concept (e.g., "dark") and must select the picture that represents its opposite (e.g., "bright") from the given choices (Figure 5a-5d of the original PDF).
- Difficulty Levels: Similar to Image Matching, this activity also features Easy, Medium, and Hard levels, increasing the number of choices from one (correct only) to two, and then three, respectively (Figure 5b-5d).

3. Tanya Jawab (Simple Question):

- Purpose: Designed to improve comprehension, auditory processing, and the ability to associate questions with appropriate visual answers.
- Workflow: The child hears or reads a simple question and must choose the correct picture that answers it from the provided options (Figure 6a-6d of the original PDF). For instance, a question like "What animal meows?" would require selecting a picture of a cat.
- Difficulty Levels: Follows the same Easy, Medium, and Hard progression, gradually increasing the complexity by adding more answer choices (Figure 6b-6d).

4. Urut Aksi (Ordering Action):

- Purpose: This is a specialized activity focused on developing sequencing skills, understanding routines, and logical progression, which are often challenging for children with ASD.
- Workflow: The child is presented with a list of items or actions that need to be arranged in a specific sequence to achieve a goal (Figure 7a-7b of the original PDF). For example, ordering the steps to draw a picture (book, pencil, drawing action).
- Unique Feature: Unlike other activities, "Urut Aksi" does not have distinct difficulty levels, as the inherent nature of sequencing tasks provides sufficient challenge.

For all activities, the therapist or parent has the flexibility to set the difficulty level according to the child's current condition and learning stage. A core design principle is that the child must correctly answer the current question before advancing, fostering mastery. The application also tracks performance by recording a "score" and the time taken for completion. This data serves purely as a progress indicator for caregivers, not as a judgment of the child. Positive reinforcement, such as words of praise or confetti animations, is provided upon successful activity completion to encourage continued engagement.

3.6.3. Supporting Features

Beyond the core therapy activities, Squizzy includes two valuable supporting features:

1. Laporan (Report):

- Purpose: This feature serves as a vital tool for therapists and parents to monitor and analyze the child's daily therapy session progress (Figure 8a of the original PDF).
- Information Displayed: The report provides detailed insights including the date of the session, the type of activity undertaken, the difficulty level chosen, the child's score, and the duration of the activity.
- Benefit: This comprehensive historical data empowers therapists to plan future activities effectively, tailoring interventions based on observed strengths and areas needing improvement. It also acts as an objective indicator of a child's progress over time and helps pinpoint specific areas where they might be struggling.

2. Perpustakaan (Library):

- Purpose: The library is designed as an educational resource, enabling children to explore and learn about new objects, actions, and concepts, thereby expanding their vocabulary and general knowledge (Figure 8b of the original PDF).
- Content: It contains a diverse list of items, categorized into actions, objects, animals, emotions, concepts, and food.
- Interaction: Children can scroll through this list, and clicking on any item displays its corresponding real picture. Crucially, there is also a button to play an audio recording of the item's name, aiding pronunciation and auditory-visual association. This feature provides an

invaluable self-paced learning tool for vocabulary acquisition.

In summary, Squizzy's comprehensive feature set, developed with direct input from experts and caregivers, positions it as a practical and effective digital pedagogical resource for supporting children with ASD. Its focus on portability, ease of use, and direct therapeutic relevance, coupled with robust tracking and learning resources, makes it a valuable addition to the assistive technology landscape.

Discussion

The integration and widespread adoption of digital pedagogical resources, including advanced educational software, represent a significant evolutionary leap in assistive technology designed for children with Autism Spectrum Disorder [22, 23]. The cumulative findings from the reviewed literature, strongly reinforced by the specific evaluation of the Squizzy application, emphatically underscore the profound potential of these digital tools to effectively address the highly diverse learning profiles and inherent challenges characteristic of ASD.

4.1. The Power of Individualization and Personalization

One of the most compelling and primary strengths of educational software for children with ASD lies in its unparalleled capacity for individualization and personalization. In contrast to conventional, often rigid, one-size-fits-all curricula that may not accommodate diverse learning styles, digital platforms offer a dynamic and adaptable learning environment. They can be meticulously tailored to precisely meet the unique needs, specific interests, and optimal learning pace of each individual child [26]. This inherent adaptability is absolutely crucial, given the heterogeneous nature of ASD, where no two individuals present with an identical set of strengths, challenges, or developmental trajectories. The ability to precisely modify parameters such as difficulty levels, introduce varied content, and provide immediate, customized feedback mechanisms ensures that the learning experience remains consistently and optimally challenging yet simultaneously highly supportive. This nuanced approach fosters skill acquisition in a remarkably targeted and efficient manner, maximizing learning outcomes by catering directly to the individual learner's cognitive and sensory profile.

4.2. Leveraging Visual and Interactive Learning Modalities

The visual and interactive nature that defines a substantial portion of modern digital tools aligns exceptionally well with the learning preferences and cognitive strengths frequently observed in individuals with ASD [17]. Visual supports, highly structured schedules, and explicit visual cues are well-established, evidence-based strategies in autism intervention, and educational software excels at delivering these in highly dynamic, engaging, and predictable formats [17]. The inherent predictability and structured environments provided by software can significantly reduce anxiety and mitigate sensory overload, which are common barriers to learning in real-world settings. By creating a controlled and safe digital space for learning and exploration, these tools can render complex concepts less overwhelming [18]. This is particularly evident in the documented success of Augmented Reality (AR) applications in enabling children to practice complex social skills and master daily routines within a simulated, low-stress environment [16, 20]. The ability of AR to overlay digital information onto physical space further enhances engagement and contextual understanding, providing a bridge between abstract learning and concrete application.

4.3. The Engagement Factor: Sustaining Attention and Motivation

The engagement factor stands as another critical and distinct advantage offered by digital pedagogical resources. Educational games and highly interactive applications possess a unique ability to capture and consistently maintain the attention of children with ASD far more effectively than many traditional instructional methods [15]. This heightened engagement is primarily attributable to several key characteristics: their inherent novelty, the provision of rich multisensory input (visuals, audio, touch), and the delivery of immediate and consistent feedback mechanisms. This elevated level of engagement directly translates into more sustained attention to learning tasks and provides significantly greater opportunities for repeated practice—a fundamental requirement for achieving skill mastery and promoting the crucial generalization of those skills to varied contexts. The ever-growing body of empirical evidence consistently supporting the effective use of tablet devices, such as iPads, for enhancing both communication abilities and academic skills further exemplifies this profound impact on learner engagement and subsequent achievement [25, 29, 30].

4.4. Addressing Challenges and Considerations for Effective Implementation

Despite these significant and well-documented advantages, several challenges and critical considerations warrant meticulous attention for the optimal and ethical implementation of digital pedagogical resources in ASD intervention.

4.4.1. Quality and Appropriateness of Available Software

Firstly, the quality and appropriateness of commercially available software vary widely and remain a significant concern [26]. The market is often saturated with numerous educational applications marketed for children with ASD, yet not all of these are genuinely evidence-based or designed with a deep, nuanced understanding of autism-specific learning needs. Some applications may be entertaining but lack clear therapeutic objectives or pedagogical soundness. This necessitates a rigorous and discerning evaluation process by educators, therapists, and parents to ensure that any chosen software is genuinely beneficial, aligns with individualized educational plans, and is not merely a source of passive entertainment. A comprehensive framework for evaluating the functionality and utility of mobile applications for children with special education needs is crucial, as many existing apps fulfill only a fraction of necessary criteria [26].

4.4.2. Generalization of Skills to Real-World Contexts

Secondly, the generalization of skills acquired within a structured digital platform to spontaneous, real-life situations remains a crucial area that demands ongoing focus and strategic intervention [15]. While a child might successfully master a social skill within an Augmented Reality game or accurately identify emotions through an interactive application, the fluid and often unpredictable nature of human interaction requires deliberate strategies to facilitate the transfer and application of that learned skill. Educators and therapists must actively facilitate this transfer through structured real-world application, role-playing, and guided practice in naturalistic environments. The digital tool should be viewed as a scaffold or a practice ground, not the ultimate destination for skill development. The experience with Squizzy highlighted this, noting that "therapist must present to direct the children focus on the activity, not the tablet device itself. The children must be given understanding that Squizzy is not a game, but rather a tool to help them learn." This emphasizes the ongoing need for human guidance to bridge the gap between digital learning and real-world application.

4.4.3. Access, Equity, and the Digital Divide

Thirdly, access and equity continue to pose significant socioeconomic barriers. The pervasive digital divide, compounded by the considerable upfront cost of reliable devices (such as tablets) and ongoing expenses for premium applications or subscriptions, can severely limit access for many families, particularly those in underserved regions or developing countries [5, 27]. While efforts are being made, as observed in Indonesia [7], significant disparities in access to and familiarity with technology still persist. This creates an ethical imperative to develop and disseminate affordable, high-quality, and culturally relevant digital resources to ensure that the benefits of assistive technology are available to all children with ASD, regardless of their socioeconomic background.

4.4.4. The Indispensable Role of Human Interaction and Intervention

Moreover, it is paramount to recognize that the transformative capabilities of educational software cannot and should not supplant the irreplaceable role of human interaction and professional intervention. Digital pedagogical resources must be viewed unequivocally as assistive tools that complement, enrich, and extend—rather than replace—the crucial guidance, emotional support, and therapeutic expertise provided by skilled educators, professional therapists, and dedicated caregivers [29]. Effective implementation necessitates substantial training for these facilitators, empowering them to maximize the software's potential, interpret a child's digital progress, and integrate technology seamlessly into a holistic intervention plan. As the Squizzy study noted, "Although Squizzy is very helpful, the presence of the therapist or parents is still needed." The human element provides the critical social context, emotional connection, and individualized adaptation that technology alone cannot replicate.

4.4.5. Ethical Considerations: Monitoring and Preventing Gadget Addiction

Finally, as with any technology, continuous vigilance and ethical considerations are essential. The evaluation of Squizzy specifically highlighted a critical concern: "The usage of this application also needs to be monitored as the excessive use may impact the children behavior that leads to gadget addictions." While engagement is a key benefit, unregulated or excessive screen time can lead to behavioral issues, displacement of other crucial activities (like physical play or direct social interaction), and potential dependencies. Therefore, robust guidelines for screen time, parental/therapist monitoring, and a balanced approach that integrates digital learning with other forms of therapy and real-world experiences are paramount. This requires ongoing research into the long-term psychosocial impacts of extensive technology use among children with ASD.

In conclusion, while digital pedagogical resources offer an increasingly sophisticated and powerful array of assistive technologies that can profoundly benefit children with Autism Spectrum Disorder by leveraging their capacity for individualization, visual support, and

engagement, their effective deployment necessitates careful selection, thoughtful and integrated implementation alongside human-led interventions, and ongoing research to address existing challenges and unlock their full, ethical potential. The journey involves not just technological advancement, but also responsible and informed practice.

Conclusion

The compelling and accumulating body of evidence emphatically reinforces the pivotal role of digital pedagogical resources as highly valuable and transformative assistive technologies for children with Autism Spectrum Disorder. These innovative tools, encompassing a diverse range from versatile mobile applications to immersive augmented reality environments and sophisticated AI-powered robotics, collectively offer unprecedented opportunities for delivering individualized, deeply engaging, and visually supported learning experiences. They have demonstrably proven effective in enhancing critical developmental domains, including social communication, academic proficiency, and the acquisition of essential adaptive behaviors. This effectiveness stems from their capacity to provide structured, predictable, and interactive platforms that facilitate systematic skill acquisition and consistent practice.

The case study of Squizzy further exemplifies these benefits, demonstrating how a thoughtfully designed, portable, and easy-to-use tablet application, developed with direct input from therapists and parents, can significantly ease therapy sessions and effectively cover cognitive aspects of a child's development. Its use of real pictures, intuitive interface, and tiered difficulty levels aligns with best practices for engaging children with ASD.

However, while the transformative potential of educational software is undeniably clear, its ultimate success and ethical deployment are contingent upon several critical considerations. These include the meticulous evaluation of software quality to ensure pedagogical soundness, the recognition of the vital and irreplaceable role of human facilitation and oversight, and concerted efforts to address issues of equitable access to technology across diverse socioeconomic landscapes. As digital technologies continue their rapid evolution, ongoing research and development will be absolutely crucial. This continued inquiry is necessary to refine these tools, to rigorously ensure the generalization of learned skills from the digital environment to real-world contexts, and to dynamically address the specific, continuously evolving needs of children across the wide spectrum of autism. This includes developing solutions for aspects not easily covered by current software, such as gross motor activities.

Ultimately, digital pedagogical resources stand not as replacements, but as powerful allies in the multifaceted endeavor of fostering the holistic development and enhancing the educational attainment of children with ASD. By thoughtfully integrating these technologies into comprehensive intervention strategies, we can significantly contribute to their inclusion, empower their learning journeys, and profoundly impact their overall well-being and future potential. The path forward demands a synergistic approach, combining technological innovation with dedicated human expertise and a steadfast commitment to individual needs.

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