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Review Article

Effectiveness of Using Augmented Reality-Based Picture Exchange Communication System (PECS) in Improving Communication Skills of Autistic Students in Indonesian Language Subjects: Bibliometric Analysis

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ABSTRACT

This research aims to evaluate the effectiveness of employing an augmented reality-based Picture Exchange Communication System (PECS) to enhance the communication skills of autistic students in Indonesian language subjects. A systematic literature review collected and analyzed various studies integrating PECS with augmented reality technology in educational settings. The study comprised three stages: determining keywords, searching for article data, and determining inclusion criteria. The findings from this review indicate that augmented reality-based PECS significantly enhances verbal and nonverbal communication abilities among autistic students. Key advantages of this approach include increased interactivity, enhanced visualization, and heightened student motivation. However, challenges such as requiring specialized equipment and sufficient teacher training were identified. Additionally, the review revealed fluctuations in the number of publications on PECS use across different years. This research aims to contribute to communication training for autistic children, particularly in the context of learning the Indonesian language. This study aims to inform educational practices and stimulate further research in this area by highlighting the benefits and challenges of AR-based PECS integration.

Keywords: Augmented Reality, autism spectrum disorder (ASD), communication, Indonesian, picture exchange communication system (PECS)

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INTRODUCTION

Autism Spectrum Disorder (ASD) is a group of neurobiological developmental disorders that present significant challenges in social interaction, communication, and repetitive

behaviors (Parisi et al., 2015). Symptoms of ASD generally appear before a child is three years old (Johnson, 2008). ASD is characterized by varying degrees of difficulty in social interaction and communication. Other characteristics include atypical patterns of activity and behavior, such as difficulty transitioning from one activity to another, a strong focus on details, and unusual reactions to sensory experiences (Kaufmann et al., 2004; Wetherby, 2006).

Children with ASD often experience difficulties understanding and using language, a key aspect of everyday communication skills (Wetherby, 2006; Tager-Flusberg et al., 2005). In Indonesia, as awareness of ASD increases, innovative therapeutic approaches are being introduced to improve the communication skills of these children in formal educational contexts, including Indonesian language learning.

The Picture Exchange Communication System (PECS) is a widely used alternative communication method for children with ASD. PECS utilizes pictures to help children express desires, ask for help, or communicate their needs (Frost, 2002). The PECS method is often combined with augmented reality (AR) technology. For example, Taryadi and Kurniawan (2018) researched using an augmented reality-based multimedia PECS method as a learning alternative to training communication skills in autistic children.

Augmented reality (AR) technology offers new potential in education, especially for children with special needs such as ASD. AR allows integration between the real world and virtual elements, providing a more immersive and engaging learning experience (Billinghurst et al., 2015). In the context of PECS, the use of AR can enhance the interest and involvement of children with ASD in the language learning process.

Previous studies have shown that using AR technology in the education of children with ASD can facilitate learning, improve social skills, and reduce anxiety (Ramdoss et al., 2011). However, little research has focused on the integration of PECS with AR, especially in the context of teaching Indonesian language subjects. Therefore, in-depth research on the effectiveness of using AR-based PECS to improve Indonesian language communication skills in students with ASD is both relevant and important to carry out.

This research aims to explore the extent to which AR-based PECS can improve the verbal and nonverbal communication skills of autistic students in the context of Indonesian language teaching. By utilizing this approach, it is hoped that empirical evidence will be found to support the use of AR technology as an effective tool for increasing the participation and academic achievement of students with ASD in learning the Indonesian language.

STUDY LITERATURE

Review of Picture Exchange Communication System (PECS)

The PECS is an alternative communication method that enables individuals with limited or no communication skills to communicate using pictures (Bondy & Frost, 1994). PECS

involves several phases designed to teach users to recognize, select, and exchange images corresponding to specific situations or needs.

The PECS process starts with an initial phase where individuals learn to exchange images for desired objects. For instance, a child who desires a drink receives a drink card and gives it to an adult to get the drink. Through repetition, children grasp that exchanging pictures elicits desired responses. Subsequent phases in PECS focus on advancing communication skills, including basic sentence structure and comprehension of verbal language (Bondy & Frost, 2001).

Howlin et al. (2007) investigated the effectiveness of PECS in enhancing communication skills among children with autism. The study involved 84 autistic children aged 4 to 10 years, divided into two groups: one received a PECS intervention, while the other received a non-PECS communication intervention as a control. Results indicated significant improvements in communication initiation and use of picture symbols among children in the PECS group compared to the control group. For instance, Danny, a participant who previously relied on non-verbal behavior, successfully used PECS to request food and toys within three months of intensive training. This research underscores PECS as an effective tool for enhancing communication skills in children with autism.

Review of Augmented Reality (AR)

AR technology integrates digital elements interactively and in real-time with the real world (Dargan et al., 2023). AR technology enables users to perceive and interact with virtual objects overlaid in their real-world environment using devices such as smartphones, tablets, or specialized AR glasses (Azuma, 1997). It captures real-world images through a device's camera and augments them with digital information or objects through software processing (Billinghurst et al., 2015).

For instance, educational applications utilizing AR can project 3D models of human body organs when a smartphone camera is aimed at relevant images or text in textbooks (Figure 1). Users can interact with these models, rotate them, and access additional information by tapping on specific parts (Billinghurst & Duenser, 2012). Another application of AR is technical training, where technicians can view step-by-step guides overlaid on the equipment they are repairing, aiding in easier and more efficient instruction-following (Tang et al., 2003).

Review on Autism Spectrum Disorder (ASD)

ASD comprises a range of neurobiological developmental disorders that present significant challenges in social interaction, communication, and consistent behavior (Parisi et al., 2015). Individuals with ASD commonly experience difficulties in various areas, including language comprehension, appropriate social interactions, and cognitive flexibility. The

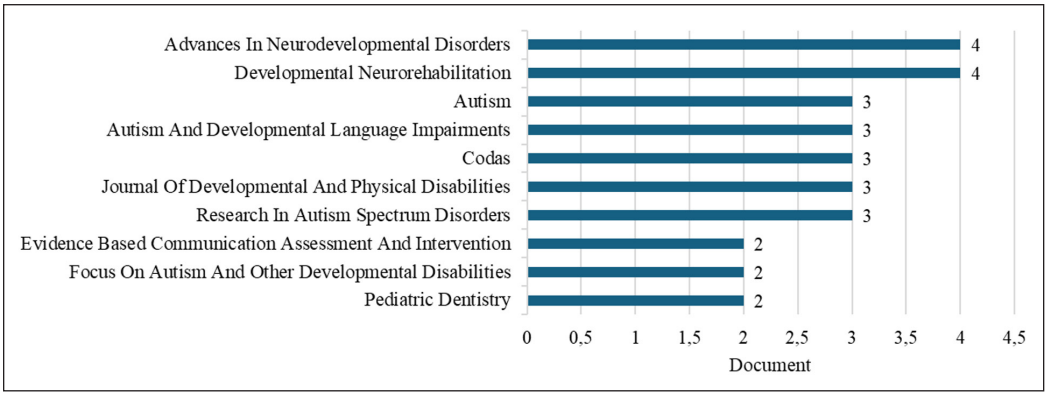

Figure 1. Top 10 publications: Article counts

disorder can manifest across a spectrum of symptoms and severity levels, from mild to severe. Symptoms typically emerge early in life, often before age 3, although diagnosis can occur at any age (Johnson, 2008). Diagnostic criteria for ASD encompass restricted and repetitive behavioral patterns, difficulties in social interaction, and challenges in using and understanding verbal and nonverbal language.

ASD affects approximately 1 in 160 children worldwide, with prevalence showing an upward trend in recent decades (Baio et al., 2020). While the exact causes of ASD remain unclear, research suggests that genetic and environmental factors contribute to its development (Geschwind, 2009). Diagnosis typically involves behavioral observation and standardized diagnostic criteria such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) or the International Classification of Diseases (ICD-11), necessitating a comprehensive evaluation by a multidisciplinary team of medical doctors and psychologists.

The management of ASD typically involves an interdisciplinary approach encompassing behavioral therapy, speech therapy, specialized educational interventions, and robust family support (Matson & Kozlowski, 2011). While ASD is a lifelong condition, early intervention and targeted interventions can markedly enhance the quality of life for individuals affected by facilitating their adaptability and independence in diverse social and educational settings (Matson & Kozlowski, 2011).

Review of Indonesia Language Learning

Learning Indonesian in Indonesia is an integral part of the national curriculum, aiming to develop students' literacy and communication skills (Pakpahan et al., 2023). Indonesian is taught as a main subject and as a language of instruction in various scientific disciplines. One of the challenges in learning Indonesian is the diversity of students' mother tongue backgrounds, considering that Indonesia consists of various ethnicities and regional languages. Therefore, the approach must be inclusive and able to bridge this linguistics.

Examples of successful implementation can be seen in literacy programs in elementary schools, which combine conventional learning methods with digital technology. For example, interactive reading applications attract students' interest in practicing reading and writing more often. Apart from that, teachers also often use collaborative learning strategies, such as group discussions, which encourage students to think critically and creatively when using Indonesian.

Conditions for learning Indonesian are also influenced by the availability of resources, such as textbooks, learning media, and teacher training (Indriyani et al., 2023). In urban areas, access to these resources is relatively better compared to rural areas. Therefore, the government continues to strive to improve the distribution of educational resources so that equal distribution of learning quality can be achieved throughout Indonesia.

Overall, Indonesian language learning in Indonesia continues to develop, supported by innovation in teaching methods and educational technology. Although there are still challenges, especially related to the diversity of regional languages and limited resources in some regions, ongoing efforts to improve the quality of education are expected to produce a more literate and communicative generation in Indonesia.

METHOD

This research used a literature review as a method. We examine the effectiveness of using an augmented reality-based PECS to improve the communication skills of autistic students in Indonesian language subjects. This research consists of three stages, as shown in Figure 2.

The results of this review aim to provide a comprehensive understanding of the potential benefits and challenges associated with integrating AR-based PECS in educational settings for autistic students.

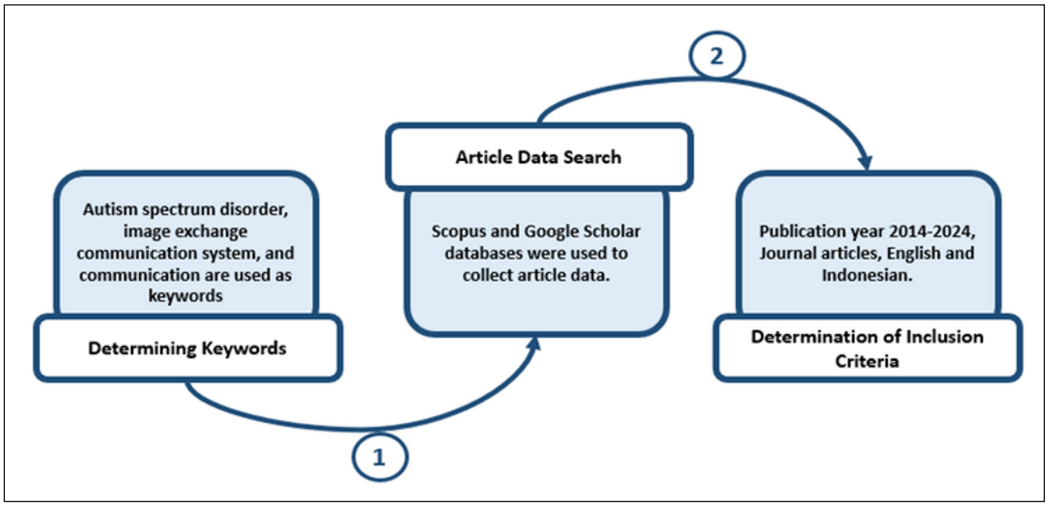

Figure 2. Research stages

Determining Keywords

The first step taken in this research is to determine the keywords that will be used to collect article data. The keywords used in this research are:

1. For Scopus:

- `TITLE-ABS-KEY ("autism spectrum disorder") AND TITLE-ABS-KEY ("Picture Exchange Communication System") AND TITLE-ABS-KEY ("communication") AND PUBYEAR > 2013 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j"))

These keywords were chosen to filter relevant and specific articles, particularly those about the use of PECS and its impact on communication in autistic students.

2. For Google Scholar:

- "Autism spectrum disorder" AND "picture exchange communication system" AND "communication" AND "education"`

Searches using these keywords were designed to achieve broader coverage of relevant sources, including those not covered in the Scopus database.

The selection of keywords is based on terminology that is often used in related research and is directly relevant to this research topic. In addition, the determination of these keywords took into account the focus of the research, namely the integration of PECS technology with technological approaches such as AR in educational settings for students with ASD.

Article Data Search

The second step after determining the keywords is searching for article data. Scopus and Google Scholar databases were chosen for this purpose. Scopus-indexed articles are collected directly from [Scopus] (https://www.scopus.com), while Google Scholar-indexed articles are gathered with the help of the Publish or Perish application and from [Google Scholar] (https://scholar.google.com). This process ensures a comprehensive and diverse collection of research articles relevant to the study's focus on AR-based PECS and its impact on communication skills in autistic students.

Determination of Inclusion Criteria

The final stage involves determining inclusion and exclusion criteria to ensure the articles used are appropriate to the research focus. The criteria set are as follows:

1. Inclusion Criteria:
   (a) Only journal articles were considered relevant documents for this research.
   (b) Articles published between 2014 and 2024.
   (c) Articles in English and Indonesian.
   (d) Articles sourced from Google Scholar (https://scholar.google.com) and Scopus (https://www.scopus.com) databases.

(e) Articles that explicitly discuss communication skills, children with autism, communication training methods, education, and augmented reality technology.

2. Exclusion Criteria:
   (a) Articles that were not in English or Indonesian were excluded.
   (b) Articles with incomplete identity data, such as year of publication or citation information.
   (c) Articles in books, proceedings, technical reports, or other documents that are not scientific journal articles.

   The data collection process was carried out on July 5, 2024. Based on the search results:
   (a) A total of 82 articles were found in the Scopus database.
   (b) A total of 98 articles were found in the Google Scholar database.

The article selection process was carried out systematically to ensure that only articles that met the inclusion criteria were used in the analysis. Articles that did not meet the exclusion criteria were excluded from further processing, hereby ensuring the rigor and relevance of the literature review results.

RESULTS AND DISCUSSION

Summary of Findings from Previous Studies

The findings from previous research regarding the use of Augmented Reality-based PECS are presented in Table 1.

Based on Table 1, the use of PECS proves highly beneficial for enhancing communication skills in autistic children (Taryadi et al., 2019; Taryadi & Kurniawan, 2018; Lutfianti et al., 2023; Travis & Geiger, 2010; Pérez-Fuster et al., 2022; Wang et al., 2022; Zhang et al., 2023). These studies demonstrate that PECS helps autistic children express their needs, wants, and feelings effectively. Moreover, findings suggest that PECS can mitigate negative behaviors stemming from communication frustrations.

In addition to improving communication skills, the PECS method can also enhance learning skills in autistic children (Khowaja et al., 2020). This method facilitates communication and increases their engagement in teaching and learning activities. PECS offers a clear structure that is easily understood by autistic children, enabling them to follow instructions and tasks better. Thus, PECS plays a crucial role in promoting more inclusive and effective learning environments for children with special needs.

The integration of PECS with AR has received a highly positive response and can capture student interest. Augmented reality is recognized as a highly effective technology in understanding educational and treatment methods (Hossaeini & Foutohi-Ghazvini, 2016). Using AR with PECS provides a more interactive and immersive learning experience,

Table 1
Research regarding the use of Augmented Reality-based PECS

Research and Year (Ref.)	Journal	Results
Taryadi et al. (2019)	Journal of Telematics and Informatics	The research results demonstrate that the proposed application aligns with the aesthetic design principles of the MDA framework, making it highly acceptable to autistic children and providing a positive impact. Additionally, it creates a more enjoyable learning environment for both autistic children and teachers.
Taryadi and Kurniawan (2018)	Journal of Physics: Conference Series	The study results indicated that the average level of communication skills before treatment was 47%. During the treatment phase, this average increased to 65%. Following the intervention, it increased further to an average of 76%.
Hossaeini and Foutohi-Ghazvini (2016)	Journal of Modern Rehabilitation	The research results demonstrate significant differences in children's performance before and after implementing the play learning method. Furthermore, the study highlights augmented reality as a highly effective technology in enhancing educational and treatment methods.
Lutfianti et al. (2023)	Educational Insights	The research results show that Augmented Alternative Communication (AAC) through PECS media can improve the communication skills of autistic children.
Travis and Geiger (2010)	Child Language Teaching and Therapy	The results from this study indicated highly effective treatment outcomes for requests, while outcomes for comments and length of verbal utterances varied. Both participants demonstrated a significant increase in intentional communicative acts (ICA), notably in demand (function) and the development of communication forms.
Pérez-Fuster et al. (2022)	Children	The results of this study suggest that autistic children can improve their RJA (Responding to Joint Attention) skills with targeted and engaging interventions based on accessible augmented reality technology tools.
Wang et al. (2022)	Applied Sciences	The results showed that our help request module interface was effective in assisting children with ASD at various levels. The proposed AR sentence intervention helps them create their scenarios, organize communication with their peers, and request help.
Zhang et al. (2023)	International Journal of Disability, Development and Education	The results showed that the three participants who acquired the target request skill were able to generalize its use to similar unexpected situations (different classrooms with different teachers), and they also met this criterion during the maintenance sessions. This study contributes to the evidence supporting the use of the PECS-TS for visually impaired (VI) and intellectually disabled (ID) students.
Khowaja et al. (2020)	IEEE Access	The research results demonstrate that A) is beneficial for children with ASD in learning various skills.
Hou et al. (2024)	International Journal of Developmental Disabilities	The results of this study demonstrated a significant increase in verbal and nonverbal communication behaviors following a two-month PECS intervention. A larger proportion of children in the robot-based intervention group showed significantly improved social communication skills, both verbal and nonverbal, compared to those in the human-based intervention group.

Table 1 *(continue)*

Research and Year (Ref.)	Journal	Results
Munir et al. (2024)	Data and Metadata	The results of this research highlight that studies on the communication skills of autistic children remain a significant research trend, showing increased interest from researchers between 2015 and 2022. Additionally, this research suggests that the characteristics of project-based learning can enhance autistic children's communication skills, particularly when augmented with AR.
Munir et al. (2018)	International Journal of Emerging Technologies in Learning (Online)	The results of the research indicate that learning with the MESE application improves students' reading and memorization skills, although some sessions showed a decline or stability.
Khoirunnisa et al. (2023)	Computers	The results of this research indicate that developing a prototype tailored to the characteristics of autistic children is crucial for ensuring that the information conveyed is readily accepted.
Khoirunnisa et al. (2024)	Journal of Special Education Technology	The research results indicate that using a personalized learning model based on AR can enhance student learning outcomes in reading words and syllables. However, there was no significant improvement in learning outcomes for letter recognition.

which enhances student motivation and engagement. Through AR, children can experience vivid and contextual visualizations, making it easier to understand and retain information. Research indicates that this technology serves as a valuable tool in supporting inclusive and adaptive education for children with autism.

Publication Trends (2015–2024)

Figure 3 illustrates the research development using the PECS based on the Scopus database, while Figure 4 depicts the development based on the Google Scholar database. Analysis of Figures 3 and 4 reveals that research on PECS shows similar trends, characterized by fluctuations in annual publication numbers (peaks and dips). The primary difference lies in the total number of documents found. Figure 3 indicates that the highest peak in publications occurred in 2022, with 12 documents and the lowest peak was in 2016–2017, with three documents each. Conversely, Figure 4 shows the highest peak in 2017 with 14 documents and the lowest peak in 2015–2016 with five documents each.

These results reflect heightened awareness and interest in developing effective intervention methods for children with autism. Increased studies in specific years, such as 2022, can be attributed to greater support from academic institutions and governments for research in education and therapy for children with special needs. Conversely, fluctuations in publication numbers may result from variability in research funding, shifts in educational policies, and advancements in technology supporting PECS applications.

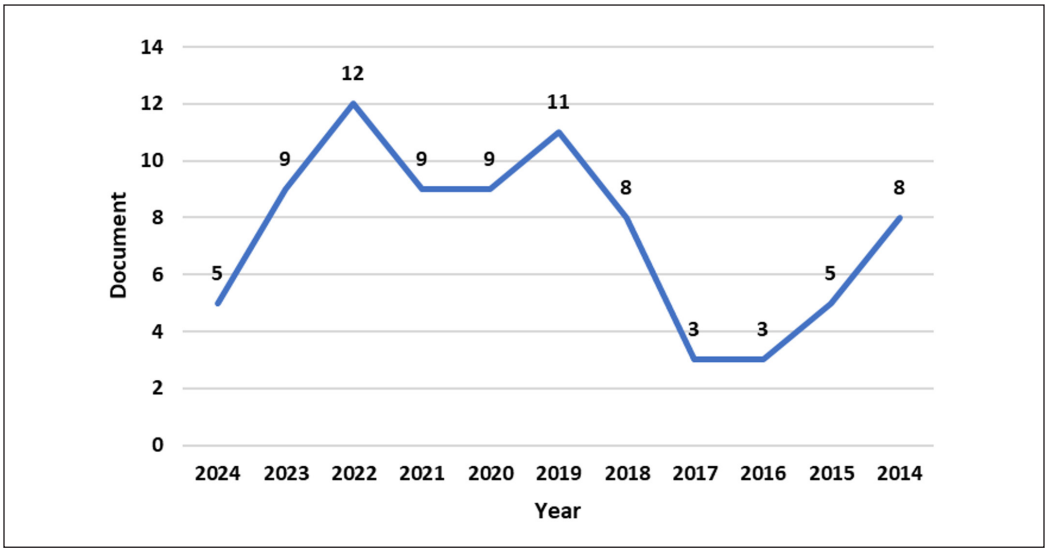

Figure 3. Development of the number of publications per year (Scopus)

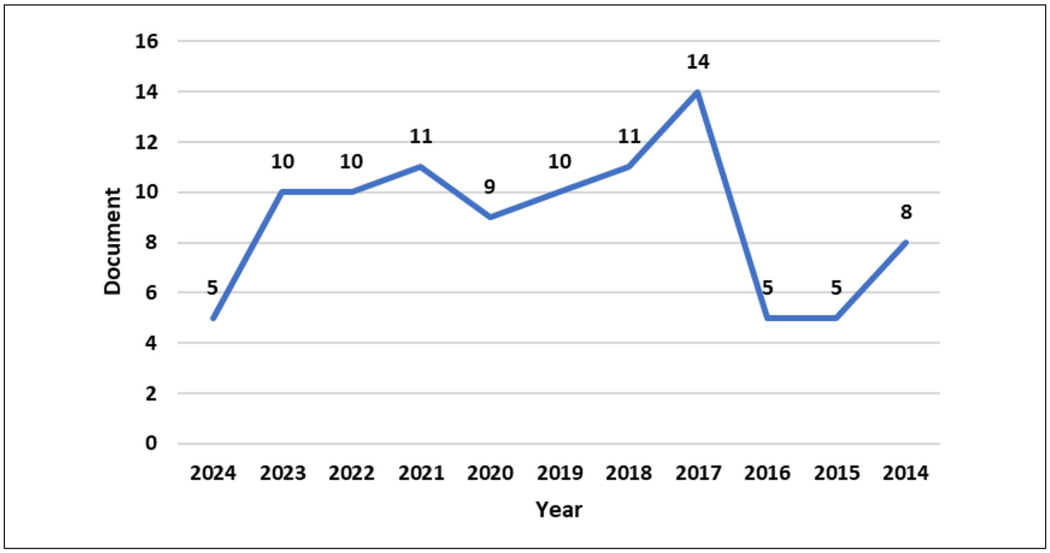

Figure 4. Development of the number of publications per year (Google Scholar)

In years with a few publications, such as 2016–2017, researchers may have been in the early stages of integrating new technologies like augmented reality with PECS. As technology advances over time, more research can be conducted, potentially leading to increased publications in subsequent years. These fluctuations indicate that while there is sustained interest in PECS, external factors such as funding and technological developments significantly influence research productivity (Khowaja et al., 2020).

Influential Publication Sources

Figure 1 shows that Advances in Neurodevelopmental Disorders, Developmental Neurorehabilitation, and Autism are the three main sources that contribute most to this research area, with 4 and 3 articles contributing, respectively. The existence of these journals as main references shows the high relevance and quality of the publications produced. Advances in Neurodevelopmental Disorders and Developmental Neurorehabilitation, for example, frequently publish in-depth research on intervention and rehabilitation for children with developmental disorders, which provides an important basis for other researchers in developing new methodologies and approaches.

In addition, the autism journal is known as one of the leading journals that specifically focuses on the autism spectrum, offering a variety of research ranging from diagnosis and intervention to educational policy. The dominance of these three journals reflects the tendency of the research community to rely on reliable sources that have high credibility in the field of neurodevelopmental disorders and autism. This also indicates that the research in these journals has a significant impact and is widely recognized by researchers and practitioners in the field, which ultimately contributes to improving the quality and effectiveness of interventions and understanding of developmental disorders in children.

Productive Regions

Figure 5 displays the top 10 countries/regions based on the number of articles published. From this data, the United States contributed the most publications compared to other countries (N=34). Followed by India (N=10) and England (N=8). Of the total publications, the United States accounted for 34%. The dominance of the United States in these publications can be interpreted as an indication of high investment in research and

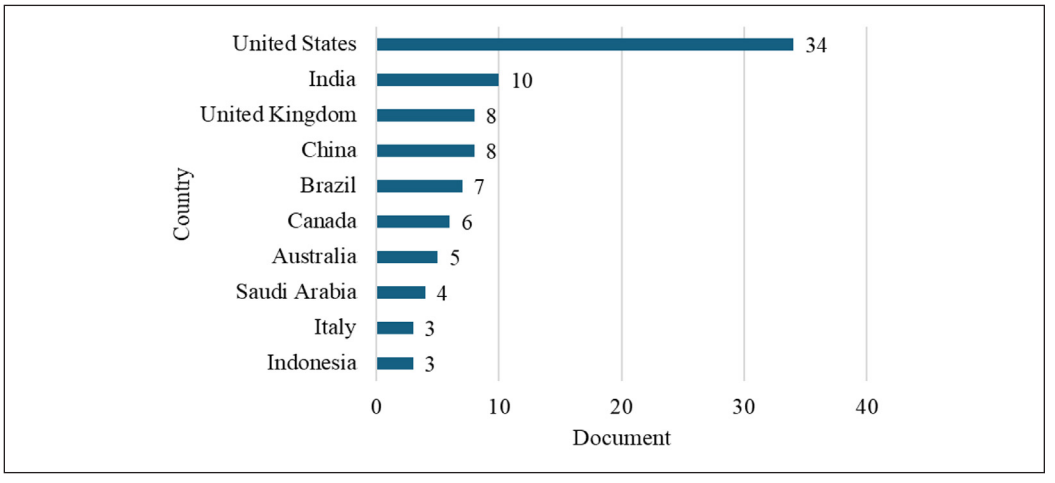

Figure 5. Top 10 countries: Article counts

development, as well as efforts by governments and educational institutions to improve the quality and quantity of research.

The dominance of the United States in the number of publications shows the country's commitment to supporting scientific research through various initiatives, such as large funding for research projects, partnerships between universities and industry, and the existence of a strong research network. On the other hand, the positions of India and the UK as the second and third largest contributors to publications indicate that these countries are also starting to pay greater attention to scientific research. The significant difference in the number of publications between the United States and other countries reflects gaps in available research resources and infrastructure. However, with increasing globalization and international collaboration, this gap is hoped to decrease so that research can develop more evenly worldwide.

Research Subject Area

Figure 6 presents subject areas frequently used in research. From these data, the medical field is the topic most frequently researched, with a percentage of 28% (N=48) of the total articles. This shows the high interest and need for research in the field of medicine, which is likely driven by efforts to find better and innovative health solutions. The field of psychology followed second with 18% (N=32), reflecting the importance of understanding behavior and mental health in modern society. Social sciences came in third with 14% (N=24), indicating the important role of social studies in addressing various societal issues.

Additionally, health professions (N=18, 10%) and neuroscience (N=15, 10%) also made significant contributions, highlighting the relevance of interdisciplinary research in

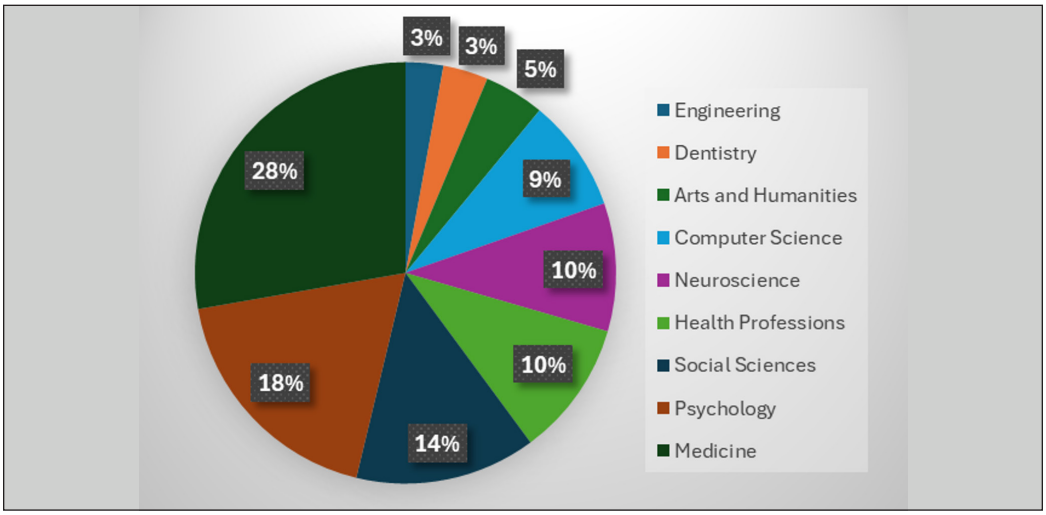

Figure 6. Frequently investigated subject areas and research trends

the health field. Computer science (N=15, 9%) reflects technological developments and their applications in various aspects of life, including medical and social. Meanwhile, the fields of arts and humanities (N=8, 5%), dentistry (N=6, 3%), and engineering (N=5, 3%) show that although their contributions are relatively small, there is still significant attention to these fields. This data indicates the diversity and broad spectrum of research conducted, as well as the importance of collaboration between scientific disciplines to solve complex problems in society.

Autism Spectrum Disorder (ASD) Communication Skills

Communication skills in individuals with ASD commonly face substantial challenges. Studies demonstrate a broad spectrum of communication abilities among those with ASD, ranging from limited language skills to proficient use of complex language in specific contexts (Tager-Flusberg, 2006). Factors including the severity of ASD, level of intelligence, and co-occurrence of other developmental disorders can influence the range of communication skills and individual exhibits (Tager-Flusberg, 2006).

Management of communication skills in individuals with ASD involves an interdisciplinary approach that includes speech therapy, behavioral therapy, and special educational strategies designed to systematically support the development of communication skills (Koegel et al., 2001; Kasari & Smith, 2013). A structured and consistent approach can help individuals with ASD to improve their ability to communicate with their surroundings, as well as facilitate better social and academic integration.

As explained, ASD is a neurobiological condition that can impact various facets of an individual's communication skills. Individuals with ASD frequently encounter difficulties in comprehending and utilizing both verbal and nonverbal language. Verbal communication in individuals with ASD often involves limitations in complex language use and may include echolalia and the repetition of words or phrases. They may struggle with constructing structured sentences or comprehending language in diverse social contexts (Tager-Flusberg, 2007).

In addition to verbal communication, nonverbal communication skills are crucial in ASD. This encompasses the ability to utilize facial expressions, eye contact, hand gestures, or body positioning to convey meaning and engage with others (Mundy et al., 1990). Children with ASD often struggle with interpreting emotional expressions from others or expressing their feelings nonverbally.

Effectiveness of AR-based PECS in Communication with Autistic Children

The PECS is an alternative communication method that utilizes pictures to aid children with ASD in communication (Bondy & Frost, 2001). PECS has demonstrated effectiveness in enhancing both verbal and nonverbal communication skills among children with ASD,

enabling them to express their needs, desires, and emotions more effectively (Bondy & Frost, 2001; Howlin et al., 2007).

AR, as an adjunct to PECS, has emerged as an innovative approach to supporting communication in children with autism. AR enhances learning experiences by blending virtual and real-world elements, which can enhance visual and interactive appeal, particularly for children with ASD (Billinghurst et al., 2015). Recent studies highlight that integrating PECS with AR can increase motivation among autistic children to engage in communication and interaction while also aiding in a better understanding of language context (Taryadi et al., 2019; Taryadi & Kurniawan, 2018; Lutfianti et al., 2023; Travis & Geiger, 2010; Hou et al., 2024).

Although still relatively new, the integration of AR with PECS shows promise as a method to enhance communication effectiveness and learning outcomes in autistic children. This technology supports their social interactions and provides enhanced visual stimuli for understanding language and abstract concepts (Ramdoss et al., 2011). Therefore, the combination of PECS with AR holds significant potential to enhance the quality of life for autistic children by improving their communication abilities across various contexts.

Using AR-based PECS with students with ASD can have a long-term positive impact on their communication skills. With AR technology, students can more easily access symbols and images that represent their needs or desires, making conveying messages easier. This can accelerate the development of their non-verbal communication skills, which are very important in everyday interactions. Through the use of AR, students can be invited to practice communicating in various situations, both at home, school and in public environments, so that they can more easily adapt their skills to different contexts. In addition, AR-based PECS also supports the development of social skills in autistic students. By facilitating more effective communication, students can more actively participate in social interactions with classmates, teachers, and family. However, although AR-based PECS can provide many benefits, there are also potential limitations, such as dependence on technological devices or difficulty transitioning from the use of technology-based symbols to direct interaction with others. Therefore, ongoing supervision and support are very necessary so that this positive impact can be achieved optimally.

As explained, the use of AR-based PECS for children with ASD is considered effective. However, the effectiveness of using AR-based PECS is highly dependent on individual differences among autistic students, such as age, severity of autism, sensory preferences, and social and cognitive abilities. The following is a further explanation regarding the effectiveness of using AR-based PECS for children with ASD:

1. Younger children tend to be more interested in the visual and interactive elements provided by AR, thereby increasing their engagement with AR-based PECS (Bremner, 2023). In contrast, older children, who may be more familiar with the use of technology, can adapt more quickly and use the more complex features of

AR to improve their communication. Therefore, adjusting the design based on age is essential to maximize the effectiveness of AR-based PECS.

2. Students with milder levels of autism severity may be better able to use AR independently, allowing them to utilize AR-based PECS in a more independent context. Meanwhile, students at higher levels of severity may require additional support in interacting with this technology, either through hands-on guidance or simpler visual elements. This shows the importance of being able to adjust the level of difficulty or interactivity in AR applications according to the severity of the student's condition (Khowaja et al., 2020).
3. Every autistic student has different sensory preferences (Gentil-Gutiérrez et al., 2021). Some may be more sensitive to visual or sound elements, while others may be more comfortable with simpler elements or more focused on movement. The design of AR-based PECS must be flexible enough to accommodate these varying preferences, allowing students to customize their experience to be more comfortable and effective in communicating.
4. Children with better social and cognitive skills tend to master the use of AR more quickly to improve their communication. However, students with difficulties in social or cognitive aspects may require a more personalized approach and longer adaptation time. Therefore, ongoing evaluation and adjustments in design are essential to ensure that AR-based PECS can be implemented effectively according to students' social-cognitive needs.

The Role of Augmented Reality (AR) in Education

AR plays a significant role in education by providing a highly interactive and immersive learning approach. AR technology facilitates the integration of virtual elements, such as images, videos, and 3D animations, into the real world through devices like smartphones or tablets. Its application in education enhances learning experiences, making them more engaging and boosting student motivation and participation.

In educating children with autism, AR can be applied with the AR-based PECS system, which helps children communicate using images. This system allows children to exchange virtual images for desired objects or actions. This AR-based implementation of PECS can be applied at various levels of education, from early childhood education (PAUD) to elementary school, especially in subjects that involve communication, such as Indonesian, Mathematics and Science. AR-based PECS can also be used in both formal settings, such as schools, and non-formal settings, such as therapy centers or home learning, allowing for flexibility in teaching approaches (Bai et al., 2014).

One of the advantages of AR is its capability to present educational content visually and contextually, which aids in students' comprehension of complex concepts. AR can

be utilized for virtual simulations and experiments that might be impractical or unsafe to conduct in real-world settings, thereby offering safe and comprehensive learning opportunities (Radu, 2014).

Research indicates that integrating AR in education can enhance student learning outcomes. In their meta-analysis, Küçük et al. (2016) demonstrated that AR increases learning motivation and provides a more enjoyable and effective learning experience. Therefore, AR represents a technology with significant potential for integration into educational curricula across various levels.

In the education of autistic children, AR plays a crucial role in enhancing student engagement and motivation. AR facilitates the creation of interactive and immersive learning environments where students can interact with virtual objects in real-world contexts. This technology aids autistic children in comprehending abstract concepts more easily through clearer and more realistic visualizations (Chen et al., 2015). Moreover, the use of AR in the education of children with autism can alleviate anxiety and enhance attention, addressing common challenges associated with autism spectrum disorders (Escobedo et al., 2014).

Other studies indicate that AR can be utilized to bolster academic skills like reading, writing, and arithmetic through applications tailored to the specific needs of children with autism (Bai et al., 2014). Therefore, integrating AR into the education of children with autism serves as a visual aid and a versatile medium to support various aspects of children's development. Figure 7 exemplifies the application of AR as a learning medium for autistic children, as researched by Julianingsih and Huda (2022).

Figure 7. An example of using AR is educating autistic children (Julianingsih & Huda, 2022)

The Importance of AR Research in the Education of Children with Autism in Indonesia

In Indonesia, the use of AR technology to enhance the learning experience of children with ASD has become a rapidly growing research area globally. These studies show that AR is useful not only for improving the academic skills of children with autism but also for reducing anxiety and increasing their attention in educational contexts.

Indonesia, as a country with an increasing number of children with autism (Riany et al., 2016), has great potential to develop and integrate AR technology into the education of children with autism. Research related to the use of AR in Indonesia, such as that conducted by Saripudin et al. (2022) and Julianingsih and Huda (2022), provides an overview of the application of this technology in a local context. Therefore, a recent review of the application of AR for children with autism in Indonesia is very relevant, considering the need to understand the challenges and opportunities in this country, which has different cultural and educational characteristics compared to other countries.

By focusing on AR technology, Indonesia can gain deeper insight into its effectiveness in addressing the specific needs of children with autism and contribute to global research that has developed in various countries. Further research in Indonesia could enrich knowledge about the application of AR in developing countries and provide guidance for wider implementation in the future.

Advantages and Challenges of Using the PECS in Learning

One of the primary advantages of PECS is its effectiveness in enhancing the communication skills of children with autism. Using pictures, PECS enables children to express their wants and needs clearly and clearly, thereby reducing frustration and negative behaviors associated with communication difficulties (Bondy & Frost, 2001). Research demonstrates that PECS can improve verbal and nonverbal communication abilities and enhance social skills in children with autism (Charlop-Christy et al., 2002). Furthermore, PECS is highly adaptable to individual needs, allowing for personalized and effective interventions (Preston & Carter, 2009).

However, implementing AR-based PECS may require a greater investment, especially in the procurement of technological devices such as tablets or smartphones and the development of appropriate applications. In regions with limited resources, this can pose a significant challenge due to budget constraints for providing the necessary equipment and training. Moreover, the ongoing maintenance and updates of the software can add to operational costs in the long term.

In addition to these financial challenges, implementing PECS presents several other obstacles. One of the primary hurdles is the need for intensive training for teachers and parents to ensure the effective use of PECS. Logistical challenges also arise when providing

PECS materials, particularly in schools with limited resources. Furthermore, research indicates that children may require a significant amount of time to master the effective use of PECS, emphasizing the importance of patience and consistency throughout the process (Alsayedhassan et al., 2016).

Although our current research focuses on AR-based PECS for autistic children, it would also be important to explore its application to children who are blind or have other sensory disabilities. In this case, modifications and adjustments are required, such as adding devices to accommodate visual impairments. Therefore, we plan to investigate these modifications further in our future research to ensure that AR-based PECS can be effectively applied to a wider range of sensory disabilities.

The Impact of Using the AR-Based PECS on Indonesian Language Subjects

The impact of implementing a PECS based on AR in Indonesian language subjects can significantly enhance the communication skills and engagement of autistic students. AR-based PECS introduces interactive and dynamic visual aids that capture students' interest, thereby making learning more enjoyable and effective. This technology enables students to comprehend language concepts more readily by providing realistic and contextual visual representations. Research supports that AR in education can bolster learning motivation, improve material comprehension, and enhance information retention (Billinghurst et al., 2015).

The study by Fletcher-Watson et al. (2016) demonstrated that AR-based technology aids in developing communication and social skills among students with ASD. When integrated with PECS, AR enhances student engagement by enabling interaction with vibrant images and captivating animations. AR also promotes collaborative learning environments, facilitating peer communication and teamwork in project-based activities utilizing this technology.

In Indonesian language subjects, integrating AR-based PECS can significantly enhance students' understanding of sentence structure, vocabulary, and grammar through interactive and engaging methods. This approach can positively impact verbal and nonverbal communication skills, fostering increased participation in classroom activities and enhancing overall academic achievement.

However, although many studies demonstrate the effectiveness of AR-based technology in improving the communication and learning skills of students with ASD, some studies also note the existence of challenges that need to be overcome (Chen et al., 2018). These challenges include the risk of overstimulation in students with high sensory sensitivity, the need for special training for teachers to operate AR-based devices, and limited access to this technology in some schools. In addition, the application of AR-based PECS in Indonesian language learning requires adaptations that take into account local language

and cultural characteristics. This adjustment includes selecting visual content relevant to students' daily lives, as well as developing interactive materials that support grammar mastery and contextual understanding. By overcoming these obstacles, AR-based PECS has the potential to be an inclusive and effective learning tool in supporting the unique needs of students with autism.

Comparison of AR, VR, MR, and XR Technologies in Education for Students with Autism

In this research, we focus on the application of AR in improving the communication skills of students with autism and realize the existence of related technologies such as Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR). While these technologies have advantages and disadvantages, understanding their differences in educational contexts, particularly for students with autism, is critical. Therefore, we will add a discussion regarding the comparison of these four technologies through a study of relevant literature.

Table 2 compares AR, VR, MR, and XR technologies based on the results of the literature review.

Table 2
Comparison of AR, VR, MR, and XR technologies

Technology	Description	Advantages	Disadvantages	Applications in the Education of Students with Autism
AR	Technology that combines virtual elements with the real world.	Interaction with the real environment. Can be used with mobile devices (smartphone /tablet).	Depends on the quality of the hardware. Can be less immersive than VR.	Helping students with autism interact with objects or symbols visually, such as in the use of the Picture Exchange Communication System (PECS).
VR	Technology creates a completely virtual environment with which users can interact.	Immersive, can provide a more immersive experience. Suitable for simulating social situations and practicing social skills.	Requires special devices such as VR headsets. May cause disorientation or fatigue in some users.	Can be used for social skills practice or simulating real -ife situations for students with autism.
MR	A combination of AR and VR allows interaction with visual objects recorded in the real world.	Provides richer interactions with the real and virtual world. Can be used in more dynamic learning situations.	Requires more sophisticated and expensive hardware. Still in the development stage for educational applications.	Can help students with autism practice social or communication skills in more realistic and interactive situations.

Table 2 *(continue)*

Technology	Description	Advantages	Disadvantages	Applications in the Education of Students with Autism
XR	An umbrella term that includes AR, VR, and MR creates a wider world of experiences.	Flexibility to cover a wide range of immersive experiences. Can be adapted to various contexts and learning objectives.	Still in the exploration stage for wider educational applications. Requires complex hardware and software.	Enables the development of more diverse and adaptive educational applications for students with autism, depending on the context of use.

CONCLUSION

This research examines the effectiveness of employing an AR-based PECS to enhance the communication skills of autistic students in Indonesian language subjects. According to the Scopus database, most publications occurred in 2022 (12 documents), with the lowest peaks observed in 2017 and 2016 (three documents each). Similarly, the Google Scholar database data indicated the highest peak in 2017 (14 documents), with the lowest peaks in 2016 and 2015 (five documents each).

In addition, the research results highlight that integrating PECS with augmented reality technology significantly enhances the communication skills of autistic students. The analyzed studies indicate that AR enhances the learning experience by providing engaging and interactive visual stimuli, thereby accelerating language comprehension and usage. This integration also supports more effective communication and participation in Indonesian language learning among autistic students. Despite challenges such as the need for adequate equipment and teaching training, the observed benefits underscore substantial potential for further research and broader implementation within the education system.

Although AR-based PECS may improve the communication skills of students with autism, it should be noted that in conducting research involving students with ASD, ethical considerations are essential, especially related to obtaining information acquisition and safeguarding the well-being of participants during the research. Before research is carried out, basic things that must be considered include obtaining consent from caregivers, transparency and openness, attention to student welfare, both physical, emotional and psychological, and maintaining the confidentiality of student data.

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REFERENCES

Alsayedhassan, B., Banda, D. R., & Griffin-Shirley, N. (2016). A review of picture exchange communication interventions implemented by parents and practitioners. *Child and Family Behavior Therapy, 38*(3), 191-208. https://doi.org/10.1080/07317107.2016.1203135

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Bai, Z., Blackwell, A. F., & Coulouris, G. (2014). Using augmented reality to elicit pretend play for children with autism. *IEEE Transactions on Visualization and Computer Graphics, 21*(5), 598-610. https://doi.org/10.1109/TVCG.2014.2385092

Baio, J., Wiggins, L., Christensen, D. L., Maenner, M. J., Daniels, J., Warren, Z., Kurzius-Spencer, M., Zahorodny, W., Rosenberg, C. R., White, T., & Durkin, M. S. (2020). Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2016. *Morbidity and Mortality Weekly Report, 69*(16), 503-503.

Billinghurst, M., & Duenser, A. (2012). Augmented reality in the classroom. *Computer, 45*(7), 56-63. https://doi.org/10.1109/MC.2012.111

Billinghurst, M., Clark, A., & Lee, G. (2015). A survey of augmented reality. *Foundations and Trends® in Human–Computer Interaction, 8*(2-3), 73-272. http://dx.doi.org/10.1561/1100000049

Bondy, A. S., & Frost, L. A. (1994). The picture exchange communication system. *Focus on Autistic Behavior, 9*(3), 1-19.

Bondy, A., & Frost, L. (2001). The picture exchange communication system. *Behavior Modification, 25*(5), 725-744. https://doi.org/10.1177/0145445501255004

Bremner, L. (2023). *Augmented Reality facial expression tracking interface to improve Theory of Mind in children with ASD, based on design principles created through a user centred design process* (Doctoral dissertation). University of Huddersfield, England. https://pure.hud.ac.uk/ws/portalfiles/portal/70873988/Louisa_Bremner.pdf

Charlop-Christy, M. H., Carpenter, M., Le, L., LeBlanc, L. A., & Kellet, K. (2002). Using the picture exchange communication system (PECS) with children with autism: Assessment of PECS acquisition, speech, social-communicative behavior, and problem behavior. *Journal of Applied Behavior Analysis, 35*(3), 213-231. https://doi.org/10.1901/jaba.2002.35-213

Chen, C. H., Lee, I. J., & Lin, L. Y. (2015). Augmented reality-based self-facial modeling to promote the emotional expression and social skills of adolescents with autism spectrum disorders. *Research in Developmental Disabilities, 36*, 396-403. https://doi.org/10.1016/j.ridd.2014.10.015

Chen, Y., Fanchiang, H. D., & Howard, A. (2018). Effectiveness of virtual reality in children with cerebral palsy: A systematic review and meta-analysis of randomized controlled trials. *Physical therapy*, *98*(1), 63-77. https://doi.org/10.1093/ptj/pzx107

Dargan, S., Bansal, S., Kumar, M., Mittal, A., & Kumar, K. (2023). Augmented reality: A comprehensive review. *Archives of Computational Methods in Engineering*, *30*(2), 1057-1080. https://doi.org/10.1007/s11831-022-09831-7

Escobedo, L., Tentori, M., Quintana, E., Favela, J., & Garcia-Rosas, D. (2014). Using augmented reality to help children with autism stay focused. *IEEE Pervasive Computing, 13*(1), 38-46. https://doi.org/10.1109/MPRV.2014.19

Fletcher-Watson, S., Pain, H., Hammond, S., Humphry, A., & McConachie, H. (2016). Designing for young children with autism spectrum disorder: A case study of an iPad app. *International Journal of Child-Computer Interaction, 7*, 1-14. https://doi.org/10.1016/j.ijcci.2016.03.002

Frost, L. (2002). The picture exchange communication system. *Perspectives on Language Learning and Education, 9*(2), 13-16. https://doi.org/10.1044/lle9.2.13

Gentil-Gutiérrez, A., Cuesta-Gómez, J. L., Rodríguez-Fernández, P., & González-Bernal, J. J. (2021). Implication of the sensory environment in children with autism spectrum disorder: Perspectives from school. *International Journal of Environmental Research and Public Health*, *18*(14), Article 7670. https://doi.org/10.3390/ijerph18147670

Geschwind, D. H. (2009). Advances in autism. *Annual Review of Medicine, 60*(1), 367-380.

Hosseini, E., & Foutohi-Ghazvini, F. (2016). Play therapy in augmented reality children with autism. *Journal of Modern Rehabilitation, 10*(3), 110-115.

Hou, S., Cai, P., Yu, L., Cui, H., Hu, J., & Wei, Z. (2024). Improving the social communication skills of preschoolers with autism spectrum disorder: robot-based intervention on Picture Exchange Communication System use. *International Journal of Developmental Disabilities*, 1-16. https://doi.org/10.1080/20473869.2024.2345957

Howlin, P., Gordon, R. K., Pasco, G., Wade, A., & Charman, T. (2007). The effectiveness of picture exchange communication system (PECS) training for teachers of children with autism: A pragmatic, group randomised controlled trial. *Journal of child Psychology and Psychiatry, 48*(5), 473-481. https://doi.org/10.1111/j.1469-7610.2006.01707.x

Indriyani, V., Kurniawati, E., & Ramadhan, A. (2023). What is the teacher's view of the development of digital teaching materials in Indonesian language learning in middle schools? *Cetta: Jurnal Ilmu Pendidikan*, *6*(4), 757-769. https://doi.org/10.37329/cetta.v6i4.2749

Johnson, C. P. (2008). Recognition of autism before age 2 years. *Pediatrics in Review*, *29*(3), 86-96.

Julianingsih, D., & Huda, A. (2022). Rancang bangun media pembelajaran komunikasi anak autis berbasis augmented reality [Design and construction of communication learning media for autistic children based on augmented reality.]. *Jurnal Pendidikan Tambusai, 6*(1), 1192-1201.

Kasari, C., & Smith, T. (2013). Interventions in schools for children with autism spectrum disorder: Methods and recommendations. *Autism, 17*(3), 254-267. https://doi.org/10.1177/1362361312470496

Kaufmann, W. E., Cortell, R., Kau, A. S., Bukelis, I., Tierney, E., Gray, R. M., Cox, C., Capone, G. T., & Stanard, P. (2004). Autism spectrum disorder in fragile X syndrome: communication, social interaction, and specific behaviors. *American Journal of Medical Genetics Part A, 129*(3), 225-234. https://doi.org/10.1002/ajmg.a.30229

Khoirunnisa, A. N., Munir, & Dewi, L. (2023). Design and prototype development of augmented reality in reading learning for autism. *Computers*, *12*(3), Article 55. https://doi.org/10.3390/computers12030055

Khoirunnisa, A. N., Munir, M., Shahbodin, F., & Dewi, L. (2024). Augmented reality based personalized learning in autism spectrum disorder reading skills. *Journal of Special Education Technology, 39*(4), 513-526. https://doi.org/10.1177/01626434241236738

Khowaja, K., Banire, B., Al-Thani, D., Sqalli, M. T., Aqle, A., Shah, A., & Salim, S. S. (2020). Augmented reality for learning of children and adolescents with autism spectrum disorder (ASD): A systematic review. *IEEE Access, 8*, 78779-78807. https://doi.org/10.1109/ACCESS.2020.2986608

Koegel, R. L., Koegel, L. K., & McNerney, E. K. (2001). Pivotal areas in intervention for autism. *Journal of Clinical Child and Adolescent Psychology, 30*(1), 19-32. https://doi.org/10.1207/S15374424JCCP3001_4

Küçük, S., Kapakin, S., & Göktaş, Y. (2016). Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. *Anatomical Sciences Education, 9*(5), 411-421. https://doi.org/10.1002/ase.1603

Lutfianti, Z., Ataqi, A.E., Asmiati, N., Putri, E., Puspitasari, R., Widya, L.A., Hikmatullah, H., Saputra, N., Sukmariah, S., Handayani, A., & Jazilatusyifa, J. (2023). The application of augmentative alternative communication (AAC) through picture exchange communication system (PECS) media to improve communication skills of children with autism. *Educational Insights, 1*(2), 97-105. https://doi.org/10.58557/eduinsights.v1i2.23

Matson, J. L., & Kozlowski, A. M. (2011). The increasing prevalence of autism spectrum disorders. *Research in Autism Spectrum Disorders, 5*(1), 418-425. https://doi.org/10.1016/j.rasd.2010.06.004

Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and developmental Disorders, 20*(1), 115-128. https://doi.org/10.1007/BF02206861

Munir, M., Al Husaeni, D. F., Rasim, R., Dewi, L., & Khoirunnisa, A. N. (2024). Bibliometric mapping of trends of project-based learning with augmented reality on communication ability of children with special needs (Autism). *Data and Metadata*, *3*, 261-261. https://doi.org/10.56294/dm2024261

Munir, M., Setiawan, W., Nugroho, E. P., Kusnendar, J., & Wibawa, A. P. (2018). The effectiveness of multimedia in education for special education (MESE) to improve reading ability and memorizing for children with intellectual disability. *International Journal of Emerging Technologies in Learning (Online)*, *13*(8), Article 254. https://doi.org/10.3991/ijet.v13i08.8291

Pakpahan, H. M., Suherni, S., Pujiati, L., & Girsang, R. (2023). The effectiveness of Indonesian education curriculum reform on the quality of processes in learning. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 564-569. https://doi.org/10.29303/jppipa.v9i1.3930

Parisi, L., Di Filippo, T., & Roccella, M. (2015). The child with autism spectrum disorders (ASDS): Behavioral and neurobiological aspects. *Acta Medica Mediterranea*, *31*(6), 1187-1194.

Pérez-Fuster, P., Herrera, G., Kossyvaki, L., & Ferrer, A. (2022). Enhancing joint attention skills in children on the autism spectrum through an augmented reality technology-mediated intervention. *Children, 9*(2), Article 258. https://doi.org/10.3390/children9020258

Preston, D., & Carter, M. (2009). A review of the efficacy of the picture exchange communication system intervention. *Journal of Autism and Developmental Disorders, 39*, 1471-1486. https://doi.org/10.1007/s10803-009-0763-y

Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing, 18*, 1533-1543. https://doi.org/10.1007/s00779-013-0747-y

Ramdoss, S., Lang, R., Mulloy, A., Franco, J., O'Reilly, M., Didden, R., & Lancioni, G. (2011). Use of computer-based interventions to teach communication skills to children with autism spectrum disorders: A systematic review. *Journal of Behavioral Education, 20*, 55-76. https://doi.org/10.1007/s10864-010-9112-7

Riany, Y. E., Cuskelly, M., & Meredith, P. (2016). Cultural beliefs about autism in Indonesia. *International Journal of Disability, Development and Education*, *63*(6), 623-640.

Saripudin, D., Ratmaningsih, N., & Anggraini, D. (2022). Smart maps Indonesia based on augmented reality as digital learning resources of social studies. *The New Educational Review*, *67*(1), 172-182.

Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research, 6*(3-4), 219-224. https://doi.org/10.1016/j.cnr.2006.06.007

Tager-Flusberg, H. (2007). Evaluating the theory-of-mind hypothesis of autism. *Current Directions in Psychological Science, 16*(6), 311-315. https://doi.org/10.1111/j.1467-8721.2007.00527.x

Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and communication in autism. *Handbook of Autism and Pervasive Developmental Disorders, 1*, 335-364. https://doi.org/10.1002/9780470939345

Tang, A., Owen, C., Biocca, F., & Mou, W. (2003). Comparative effectiveness of augmented reality in object assembly. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 73-80). ACM Publishing. https://doi.org/10.1145/642611.642626

Taryadi, T., & Kurniawan, I. (2018). The improvement of autism spectrum disorders on children communication ability with PECS method Multimedia Augmented Reality-Based. *Journal of Physics: Conference Series, 947*, Article 012009.

Taryadi, T., Kurniawan, I., & Binabar, S. W. (2019). Improved communication skills of children with autism spectrum disorder using augmented reality based on PECS (picture exchange communication system). *Journal of Telematics and Informatics, 7*(4), 185-197.

Travis, J., & Geiger, M. (2010). The effectiveness of the picture exchange communication system (PECS) for children with autism spectrum disorder (ASD): A South African pilot study. *Child Language Teaching and Therapy, 26*(1), 39-59. https://doi.org/10.1177/0265659009349971

Wang, C. P., Tsai, C. H., & Lee, Y. L. (2022). Requesting help module interface design on key partial video with action and augmented reality for children with autism spectrum disorder. *Applied Sciences, 12*(17), Article 8527. https://doi.org/10.3390/app12178527

Wetherby, A. M. (2006). Understanding and measuring social communication in children with autism spectrum disorders. *Social and Communication Development in Autism Spectrum Disorders: Early Identification, Diagnosis, and Intervention*, *18*(3), 3-34.

Zhang, Y., Zhang, J., Zhang, J., Sutherland, M., & Huang, S. (2023). Teaching requesting skills to children with visual impairment and intellectual disability by using picture exchange communication system combined with tangible symbols. *International Journal of Disability, Development and Education, 71*(7), 1152-1172. https://doi.org/10.1080/1034912X.2023.2295911