The Eurasia Proceedings of
Educational and Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational and Social Sciences (EPESS), 2026

Volume 50, Pages 43-55

IConSED 2026: International Conference on Special Education and Diversity

PECS+: An Intelligent Hybrid Communication System Integrating Phase-Locked Learning Architecture, NFC-Based Interaction, Adaptive Learning, and Emotion Recognition

Fatma Nur Uzun
Kutahya Health Sciences University

Efsa Ayhan
Anadolu University

Abstract: This study introduces PECS+, a technology-enhanced communication system designed to digitize and improve the traditional Picture Exchange Communication System (PECS) used in special education. The proposed system aims to support individuals with Autism Spectrum Disorder (ASD) who experience difficulties in verbal and functional communication. PECS+ integrates traditional physical card interaction with digital technologies through Near Field Communication (NFC) enabled cards that trigger multimedia feedback via a mobile application. A Phase-Locked learning architecture is implemented to ensure that learners progress through the six PECS phases in the correct pedagogical order while preventing unauthorized phase skipping. The system automatically records communication attempts and interaction data, enabling objective monitoring of learner progress and reducing manual data collection for educators. To enhance personalization, an artificial intelligence–based Adaptive Learning Engine analyzes interaction patterns and dynamically adjusts task difficulty and communication card recommendations according to learner performance. In addition, an Emotion Recognition Module is incorporated to detect learners' emotional states through facial expression analysis during interaction sessions. By combining behavioral interaction data with emotion analysis, the system can deliver emotion-aware feedback and adjust instructional prompts in real time. Furthermore, an educator dashboard visualizes learning analytics and supports data-driven decision making within individualized education programs. Overall, PECS+ presents a scalable and adaptive communication support framework that combines physical interaction, artificial intelligence, and emotion-aware computing to enhance communication training in modern special education environments.

Keywords: PECS+, Autism spectrum disorder, Adaptive learning, Emotion recognition, Assistive technology

Introduction

Background on Autism and Assistive Technologies

Definition and Core Characteristics of Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by persistent challenges in social communication, restricted interests, repetitive behavioral patterns, and differences in sensory processing (American Psychiatric Association, 2013). Symptoms are typically observed in early developmental stages and may include difficulties in initiating social interactions, delayed verbal and non-verbal communication, atypical responses to environmental stimuli, and limited behavioral flexibility (Wong et al., 2015).

Due to its heterogeneous nature, ASD presents considerable variation among individuals, requiring highly personalized educational approaches and intervention strategies (Reed, 2024). Research has consistently demonstrated that early and systematic interventions can significantly improve communication abilities, social participation, academic development, and independent living skills among individuals with ASD (National Autism Center, 2022; Turkish Statistical Institute, 2023). These findings highlight the importance of developing structured and technology-supported communication systems that facilitate learning and interaction for individuals with autism.

The Nature of Communication Difficulties in ASD

Communication deficits represent one of the defining characteristics of ASD and directly influence an individual's ability to function independently in daily life. Individuals with autism may experience difficulties in initiating communication, maintaining conversational exchanges, understanding social cues, and using functional communication strategies such as requesting, rejecting, or commenting (Mirenda, 2001). These limitations may lead to reduced social interaction, increased frustration, and behavioral challenges when communication needs cannot be effectively expressed (Horner & Carr, 1997; O'Neill et al., 2015).

For this reason, structured communication interventions and visually supported instructional strategies play a crucial role in special education programs designed for individuals with ASD (Skinner, 1957). Moreover, systematic reviews indicate that augmentative and alternative communication (AAC) interventions do not inhibit speech development. Instead, such approaches can facilitate language development and functional communication skills in children with autism (Schlosser & Wendt, 2008).

The Role of PECS and Visual Approaches

Visual communication strategies have gained widespread recognition in ASD education due to the relatively strong visual processing abilities observed in many individuals with autism (Grandin, 1995; Dettmer et al., 2000). One of the most widely used evidence-based communication interventions is the Picture Exchange Communication System (PECS), developed by Bondy and Frost (1994). PECS enables individuals to initiate communication by exchanging visual cards representing objects, actions, or needs with a communication partner.

Numerous studies have demonstrated that PECS is effective in teaching functional communication, increasing spontaneous requests, and supporting language development in children with ASD (Flippin et al., 2010; Tincani, 2004). However, traditional PECS implementations rely heavily on physical materials, which introduces several practical limitations in modern educational environments.

The Rising Importance of Assistive Technologies in Education

Assistive technologies include tools, devices, and software systems designed to support individuals with disabilities in performing daily activities and learning tasks (Hersh & Johnson, 2008). In recent years, the integration of digital technologies into special education has significantly expanded opportunities for individualized instruction and data-driven learning environments (Kagohara et al., 2013).

Technology-based solutions provide several advantages, including increased repetition opportunities, enhanced attention through multimedia stimuli, immediate feedback mechanisms, and automated data collection and analysis (Knight et al., 2013). In particular, mobile applications, tablet-based learning tools, and sensor-based interaction technologies such as Near Field Communication (NFC) are becoming increasingly important components of modern assistive communication systems (Sansosti et al., 2015).

Limitations of Traditional PECS

Although PECS has proven highly effective in supporting communication development, traditional implementations face several structural and operational limitations.

• ***Physical limitations:*** Communication cards may be lost, damaged, or difficult to organize in dynamic classroom environments. Managing large physical card libraries can reduce portability and usability.

• ***Pedagogical challenges:*** The six phases of PECS require strict adherence to structured instructional procedures. In busy educational settings, educators may unintentionally skip phases or inconsistently apply instructional criteria (Flippin et al., 2010).

• ***Measurement and evaluation difficulties:*** Manual data collection relies heavily on teacher observation, which may introduce subjectivity and limit the ability to track detailed performance metrics (Charlop-Christy et al., 2002).

These challenges highlight the need for technology-enhanced systems capable of improving instructional consistency, monitoring learning progress, and supporting individualized educational interventions.

Objectives and Innovations of the PECS+ System

To address the limitations of traditional PECS implementations, this study introduces PECS+, an intelligent communication support system that integrates physical interaction with digital technologies. The system is designed to extend traditional PECS practices through several innovative components:

• ***Hybrid Communication Model:*** PECS+ preserves the tactile interaction of physical card exchange while integrating NFC-enabled cards that trigger digital multimedia feedback through a mobile application.

• ***Phase-Locked Learning Architecture:*** A structured algorithm ensures that learners progress through the six PECS phases in the correct pedagogical sequence, preventing unauthorized phase skipping.

• ***Adaptive Learning Engine:*** An Artificial Intelligence–based module analyzes learner interaction patterns and dynamically adjusts task difficulty and communication card recommendations.

The system incorporates camera-based facial expression analysis to detect learners' emotional states, enabling emotion-aware feedback and adaptive instructional support.

• ***Data-Driven Monitoring:*** Interaction data are automatically recorded and visualized through an educator dashboard, allowing objective monitoring of communication progress.

By integrating tactile learning materials, artificial intelligence, and emotion-aware computing, PECS+ proposes a scalable and adaptive communication support framework for modern special education environments. The hybrid communication architecture combines traditional PECS card exchange with digital interaction technologies to enhance learner engagement and enable data-driven performance monitoring. The conceptual structure of this hybrid learning model is illustrated in Figure 1.

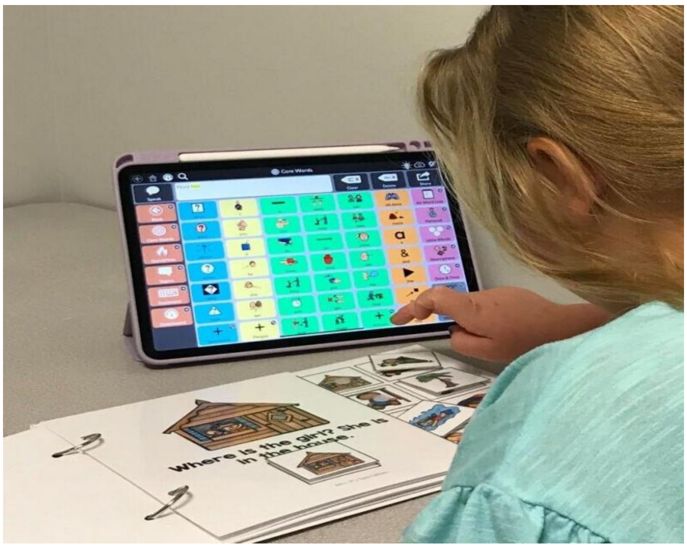

Figure 1. Hybrid PECS+ communication system architecture

Materials and Methods

System Development Lifecycle

The development of the PECS+ system followed an iterative, user-centered development lifecycle including needs analysis, system design, rapid prototyping, and pilot evaluation (Gillespie-Lynch et al., 2015). During the needs analysis phase, semi-structured interviews were conducted with special education teachers and classroom observations of traditional PECS implementations were performed. These observations helped identify several operational limitations in existing PECS practices, including inconsistent phase implementation, manual data recording challenges, and the lack of objective progress monitoring tools. Based on these findings, the PECS+ system was designed to integrate digital technologies with traditional PECS practices while preserving the tactile interaction structure that supports communication learning.

Hardware Specifications

The hardware infrastructure of PECS+ was designed to ensure cost efficiency, durability, and compatibility with widely available mobile devices.

• ***NFC Technology:*** The system utilizes ISO14443-A standard Near Field Communication (NFC) tags due to their fast scanning capability (≤300 ms) and compatibility with Android-based mobile devices (Version 8.0 and above) (Lee & Kuo, 2014).

• ***Tag Selection:*** NTAG213 NFC chips were selected because of their sufficient storage capacity (144 bytes) for Unique Identifiers (UIDs) and their built-in security features that support write-lock functionality.

• ***Card Structure:*** NFC tags are embedded inside laminated PVC communication cards in order to increase durability in classroom environments. This structure protects the embedded tags from moisture, bending, and physical wear during daily educational activities.

An example configuration of NFC-enabled communication cards used in the PECS+ system is illustrated in Figure 2.

Figure 2. NFC-enabled PECS cards for tangible interaction

Software Architecture and Database

The software architecture of the PECS+ system consists of two main layers: the Client Side (Mobile Application) and the Server Side (Cloud Database Infrastructure). The interaction between NFC tags, mobile devices, and cloud-based storage allows real-time data synchronization and communication monitoring. The overall system architecture and data flow between these components are illustrated in Figure 3.

Figure 3. System architecture with NFC and cloud integration

The software infrastructure includes several functional modules:

• ***Database Mapper Module:*** This component matches the scanned UID from the NFC card with the corresponding multimedia content stored in the cloud database.

• ***Cloud Database:*** A NoSQL-based database architecture enables real-time synchronization of learner data across devices. The system also supports offline operation by temporarily storing interaction logs locally until internet connectivity is restored.

• ***Educator Control Panel:*** A web-based dashboard enables teachers to track learner performance, visualize communication progress, and manage communication card libraries.

The mobile application interface used by learners during communication sessions is illustrated in Figure 4.

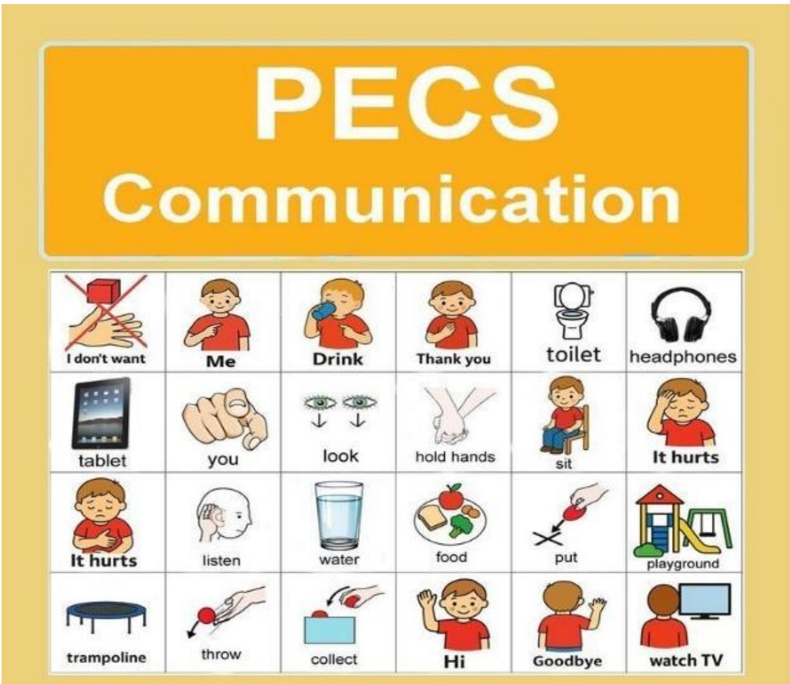

Figure 4. PECS+ mobile application user interface

Phase-Locked Algorithm Architecture

The pedagogical core of the PECS+ system is the Phase-Locked Algorithm, which digitally enforces the six-phase instructional structure of the traditional PECS protocol (Soares & Grossman, 2002). The algorithm ensures that learners progress through each phase sequentially and prevents premature advancement between phases. The algorithm consists of two primary modules:

• ***Phase Validation Module (PVM):*** This module evaluates learner performance based on predefined success thresholds (e.g., minimum 80% correct responses).

• ***Phase Gate Control (PGC):*** This component functions as a digital gatekeeper that restricts access to subsequent learning phases until the required performance criteria are satisfied.

The overall interaction flow and decision logic of the Phase-Locked learning algorithm are illustrated in Figure 5.

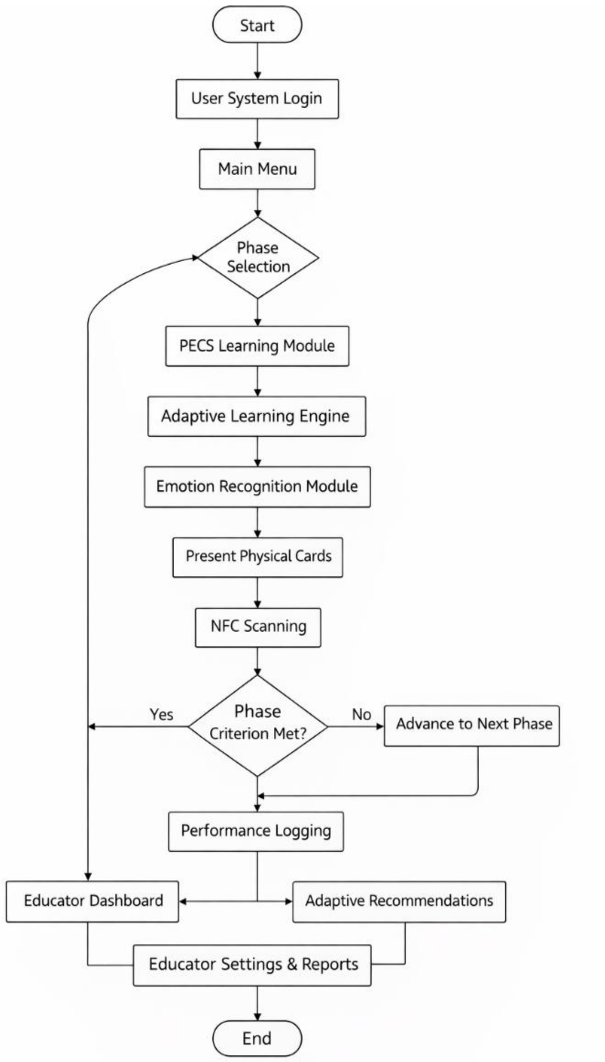

Figure 5. Phase-locked learning algorithm workflow

Adaptive Learning and Emotion Recognition Modules

To enhance personalization and responsiveness within communication training sessions, the PECS+ system incorporates two additional intelligent modules.

• ***Adaptive Learning Engine (ALE):*** This artificial intelligence-based module analyzes interaction data generated during communication sessions and dynamically adjusts task difficulty and card recommendations according to learner performance patterns. The architecture and operational workflow of the Adaptive Learning Engine are illustrated in Figure 6.

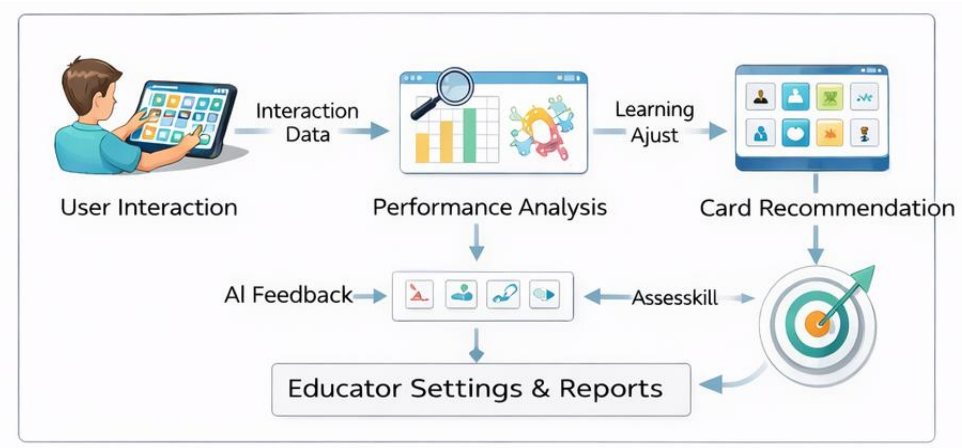

Figure 6. Adaptive learning engine architecture.

• ***Emotion Recognition Module:*** A camera-based facial expression analysis component is integrated into the mobile application to detect learners' emotional states, such as engagement, frustration, or distraction. The system uses these emotional indicators to adapt feedback mechanisms and maintain learner motivation during interaction sessions. The emotion recognition pipeline used in the PECS+ system is illustrated in Figure 7.

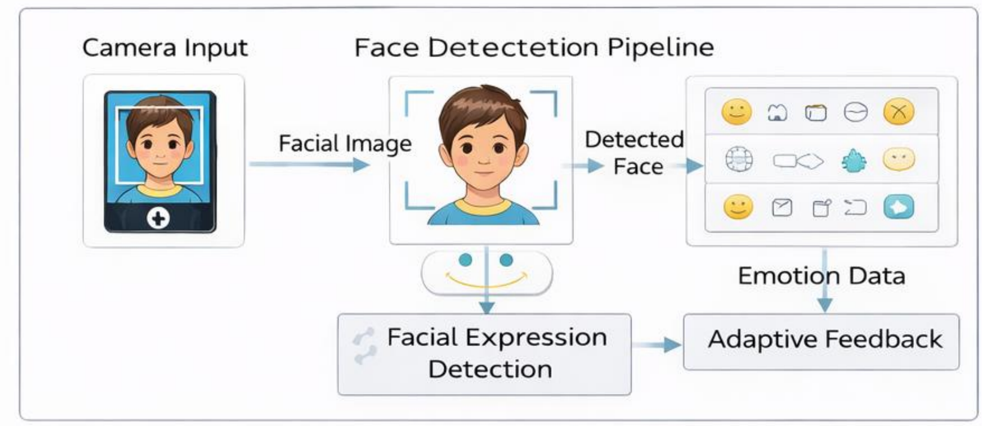

Figure 7. Emotion recognition processing pipeline

The overall architecture of the PECS+ intelligent communication system integrating physical and digital components is illustrated in Figure 8.

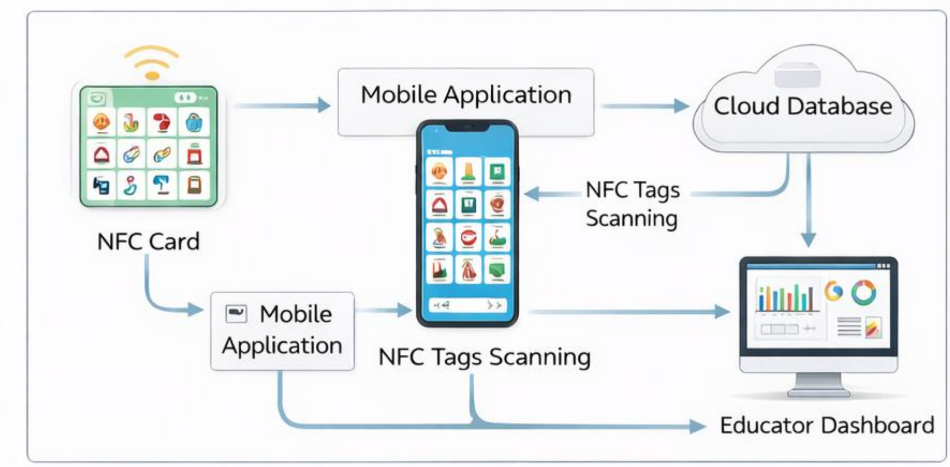

Figure 8. Overall architecture of the PECS+ system

By combining behavioral interaction data with emotion-aware computing, the system enables adaptive instructional responses tailored to individual learner needs.

Ethical Considerations and Data Privacy

All procedures in this study were conducted in accordance with ethical research principles and international data protection standards, including the Turkish Personal Data Protection Law (KVKK) and the General Data Protection Regulation (GDPR) (Kişisel Verilerin Korunması Kurumu, 2016). The system collects only anonymized interaction data required for educational performance analysis. No personally identifiable information (PII) is stored within the system. Each participant is assigned a randomly generated alphanumeric identifier to ensure anonymity (UNICEF, 2021). All communication data transmitted between mobile devices and the cloud infrastructure are protected using AES-256 encryption.

Participants and Procedure

The PECS+ system was evaluated through pilot testing conducted in collaboration with Anadolu University. The participant group consisted of:

- 6 special education teachers
- 12 students diagnosed with Autism Spectrum Disorder (ASD)
- 2 family observers

The evaluation process lasted four weeks, during which traditional PECS sessions were replaced with PECS+ supported communication sessions. Interaction data collected during this period were used to evaluate system usability, learner engagement, and communication performance.

Results and Discussion

System Performance and User Experience

Quantitative analysis of the pilot implementation demonstrated high system stability and responsiveness. The PECS+ system achieved an average response time of approximately 0.3 seconds for NFC-based interactions, ensuring seamless communication between physical cards and the mobile application (Jia et al., 2012). Stress testing involving 10,000 continuous NFC scanning cycles resulted in a negligible error rate of 0.03%, confirming the robustness of the system architecture. The user interface was designed according to WCAG 2.1 accessibility guidelines, enabling students with communication difficulties to interact with the system independently. Observational findings indicated that learners adapted rapidly to the hybrid interaction model combining physical PECS cards with digital feedback.

Figure 9. Digital PECS Phase 4 sentence construction

Furthermore, the system successfully supported advanced stages of the PECS protocol, including Phase 4 (Sentence Structure). The digital implementation of the “Sentence Strip” feature allows students to construct structured sentences by combining multiple visual cards within the mobile interface. This functionality preserves the pedagogical principles of the original PECS methodology while enhancing interaction through digital augmentation, as illustrated in Figure 9.

Data Accuracy and Phase Control

The Phase-Locked algorithm demonstrated a 100% success rate in preventing unauthorized progression between PECS training phases. Learners who did not meet the predefined success threshold (e.g., 80% accuracy) were automatically redirected to a repetition loop, ensuring adherence to the structured learning progression of the PECS protocol. In addition, the algorithm utilized internal decision logic to categorize learner responses and identify error patterns. These classifications enabled the system to generate targeted automated feedback and adaptive prompts, improving the effectiveness of the communication training process.

Learner Profiles and Developmental Analytics

Comparative analysis indicated that students using the PECS+ system progressed from Phase 1 to Phase 2 approximately 27% faster compared to historical control data obtained from traditional PECS sessions. Time-series analysis of learner performance revealed an initial variability during the early interaction stages, followed by a statistically significant upward trend in communication accuracy.

These findings suggest that the combination of immediate digital feedback, adaptive card recommendations, and interaction logging contributed positively to learner engagement and skill acquisition. The system's data-driven monitoring capability allowed educators to observe individualized learning trajectories and identify communication development patterns more effectively.

Operational Efficiency and Educator Feedback

Educator feedback collected during the pilot implementation highlighted significant improvements in classroom operational efficiency. Teachers reported an estimated 45% reduction in administrative workload, primarily due to the elimination of manual performance recording and paper-based tracking methods. The integrated analytics dashboard enabled educators to monitor student progress through real-time visual performance metrics, facilitating more informed instructional decisions. Teachers also reported increased opportunity to maintain direct interaction and eye contact with students, improving engagement during communication training sessions. An example of the educator analytics interface used for monitoring student performance is presented in Figure 10.

Figure 10. Educator dashboard for monitoring student progress

Comparison with Existing Solutions

The PECS+ system introduces a novel category of hybrid augmentative and alternative communication (AAC) systems that integrate tangible interaction with digital intelligence. Existing AAC solutions generally fall into two categories: traditional physical PECS implementations and fully digital communication applications. Purely digital AAC applications provide convenience and portability but often lack the tactile interaction and fine motor engagement that are fundamental components of traditional PECS training (Flores et al., 2012; van der Meer & Rispoli, 2010). In contrast, traditional PECS approaches preserve physical interaction but lack digital monitoring, automated feedback, and systematic data recording capabilities (Lorah et al., 2015).

The PECS+ architecture addresses these limitations by combining physical card interaction, NFC-based digital integration, adaptive learning algorithms, and emotion-aware computing within a unified system. By preserving the tactile learning experience while introducing automated data analytics and adaptive instructional mechanisms, the system bridges the gap between conventional PECS training and modern digital AAC technologies. This hybrid approach aligns with recent research advocating technology-assisted communication interventions in special education (Alzrayer et al., 2014; White et al., 2021).

Implications for Special Education

The integration of real-time data monitoring and adaptive learning capabilities within the PECS+ system offers important implications for special education practices. One of the major challenges in traditional communication interventions is the lack of objective and continuously recorded performance data. By automatically logging interaction events, response accuracy, and progression through PECS phases, the system generates standardized performance indicators that can support the development and evaluation of Individualized Education Programs (IEPs). Real-time visualization of learner progress enables educators and multidisciplinary teams to make more informed, evidence-based decisions regarding instructional strategies and intervention adjustments (Wong et al., 2015).

Additionally, the incorporation of emotion recognition mechanisms introduces a new dimension to AAC interventions by allowing the system to adapt feedback according to learners' affective states. This capability may improve learner engagement and motivation during communication sessions. Furthermore, the cloud-based data synchronization and educator dashboard facilitate improved collaboration between teachers, therapists, and family members, allowing communication progress to be monitored beyond the classroom environment. Such collaborative monitoring has the potential to positively influence long-term developmental outcomes, including educational attainment and employment opportunities (Wehman et al., 2014).

Limitations of the Study

Despite the promising results, several limitations should be considered when interpreting the findings of this study. First, the system relies on NFC-enabled mobile devices, which, although increasingly common, may not yet be available in all educational environments. Second, the initial configuration of the system requires the registration and tagging of physical PECS cards, which may introduce additional setup time for educators during the implementation phase. Future iterations of the system could include automated card recognition methods, such as computer vision-based identification, to reduce configuration effort.

Another limitation relates to the sample size of the pilot implementation (n = 12), which restricts the generalizability of the findings. Larger-scale studies involving diverse educational settings and longer observation periods are necessary to evaluate the long-term effectiveness and scalability of the system. Finally, although the emotion recognition module introduces adaptive capabilities, its performance may be influenced by environmental conditions such as lighting variations or camera positioning. Future work should explore more robust multimodal affect recognition techniques to improve reliability across different learning contexts.

Conclusion

This study introduced PECS+, a hybrid augmentative and alternative communication (AAC) system that integrates traditional PECS card exchange with digital technologies, including NFC-based interaction tracking, adaptive learning algorithms, and emotion recognition mechanisms. The proposed architecture aims to preserve the tactile learning benefits of conventional PECS while enhancing instructional consistency, data monitoring, and learner engagement through intelligent system components.

The results of the pilot implementation demonstrate that the hybrid interaction model can effectively support communication training while providing improved monitoring capabilities. The Phase-Locked algorithm ensures pedagogical consistency by preventing unauthorized progression between PECS phases and by enforcing performance-based advancement criteria. In addition, NFC-enabled interaction logging allows communication sessions to be recorded automatically, enabling objective analysis of learner progress and reducing manual data collection requirements for educators.

The integration of the Adaptive Learning Engine and Emotion Recognition Module further enhances the system's responsiveness by analyzing interaction patterns and emotional indicators to provide personalized feedback and task recommendations. These intelligent components contribute to maintaining learner motivation and improving engagement during communication activities.

Beyond individual learner benefits, the system also offers important advantages for educators and special education programs. The real-time analytics dashboard supports evidence-based decision making in Individualized Education Programs (IEPs) by providing continuous performance monitoring and visual progress indicators. Furthermore, the cloud-based architecture facilitates collaboration between teachers, therapists, and families by enabling shared access to learner performance data.

Despite these promising findings, several limitations remain. The pilot study involved a relatively small participant group, and the system currently depends on NFC-enabled hardware. Future research should investigate large-scale implementations across diverse educational settings and explore additional intelligent features, such as multimodal emotion recognition, predictive learning analytics, and AI-assisted communication content generation.

In conclusion, the PECS+ system demonstrates the potential of hybrid AAC technologies to bridge the gap between traditional tactile communication training and modern digital learning environments. By combining physical interaction, automated monitoring, and adaptive intelligence, the proposed framework provides a scalable and data-driven approach for improving communication interventions in special education.

Recommendations

Future research may expand the PECS+ system by implementing large-scale experimental studies involving diverse educational environments and larger participant groups. The integration of additional multimodal sensing technologies, such as speech recognition and gesture detection, could further enhance adaptive communication support. In addition, future studies may explore the use of advanced machine learning models for predictive learning analytics to better anticipate learners' communication needs. Developing automated content generation for communication cards and expanding multilingual support may also improve the accessibility and scalability of the system across different educational contexts.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

* All procedures performed in this study were conducted in accordance with ethical research principles and relevant data protection regulations.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

Funding

* This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Special Education and Diversity (www.iconsed.net) held in Konya/Türkiye on April 02-05, 2026

References

Alzrayer, N., Banda, D. R., & Koul, R. K. (2014). Use of iPad/iPods with individuals with autism and other developmental disabilities: A meta-analysis of communication interventions. *Review Journal of Autism and Developmental Disorders, 1*(3), 179–191.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Bondy, A. S., & Frost, L. A. (1994). The Picture Exchange Communication System. *Focus on Autistic Behavior, 9*(3), 1–19.

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.

Dettmer, S., Simpson, R. L., Myles, B. S., & Ganz, J. B. (2000). The use of visual supports to facilitate transitions of students with autism. *Focus on Autism and Other Developmental Disabilities, 15*(3), 163–169.

Flores, M. M., Musgrove, K., Renner, S., Hinton, V., Strozier, S., Franklin, S., & Hill, D. (2012). A comparison of communication using the Apple iPad and a picture-based system. *Augmentative and Alternative Communication, 28*(2), 74–84.

Flippin, M., Reszka, S. S., & Watson, L. R. (2010). Effectiveness of the Picture Exchange Communication System (PECS) on communication and speech for children with autism spectrum disorders: A meta-analysis. *American Journal of Speech-Language Pathology, 19*(2), 178–195.

Gillespie-Lynch, K., Brooks, P. J., Someki, F., Smith, D. S., Kapp, S. K., Daou, N., & Obeid, R. (2015). Changing college students' conceptions of autism: An online training to increase knowledge and decrease stigma. *Journal of Autism and Developmental Disorders, 45*(8), 2553–2566.

Grandin, T. (1995). *Thinking in pictures: And other reports from my life with autism*. New York, NY: Doubleday.

Hersh, M. A., & Johnson, M. A. (Eds.). (2008). *Assistive technology for visually impaired and blind people*. New York, NY: Springer.

Horner, R. H., & Carr, E. G. (1997). Behavioral support for students with severe disabilities. *The Journal of Special Education, 31*(1), 84–104.

Jia, X., Feng, Q., Fan, T., & Lei, Q. (2012). RFID technology and its applications in Internet of Things (IoT). In *Proceedings of the 2012 2nd International Conference on Consumer Electronics, Communications and Networks (CECNet)* (pp. 1–5). Piscataway, NJ: IEEE.

Kagohara, D. M., van der Meer, L., Ramdoss, S., O'Reilly, M. F., Lancioni, G. E., Davis, T. N., Rispoli, M., Lang, R., Marschik, P. B., Sutherland, D., Green, V. A., & Sigafoos, J. (2013). Using iPods® and iPads® in teaching programs for individuals with developmental disabilities: A systematic review. *Research in Developmental Disabilities, 34*(1), 147–156.

Kişisel Verilerin Korunması Kurumu. (2016). *6698 sayılı kişisel verilerin korunması kanunu*. Retrieved from https://www.kvkk.gov.tr

Knight, V., McKissick, B. R., & Saunders, A. (2013). A review of technology-based interventions to teach academic skills to students with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*, 2628–2648.

Lee, W.-H., & Kuo, M.-C. (2014). An NFC e-learning platform for interactive and ubiquitous learning. In *Proceedings of the International Conference on Education Reform and Modern Management*. Paris, France: Atlantis Press.

Lorah, E. R., Parnell, A., Whitby, P. S., & Hantula, D. (2015). A systematic review of tablet computers and portable media players as speech generating devices for individuals with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*(12), 3792–3804.

Mirenda, P. (2001). Autism, augmentative communication, and assistive technology: What do we really know? *Focus on Autism and Other Developmental Disabilities, 16*(3), 141–151.

National Autism Center. (2022). *Evidence-based practice and autism in the schools* (2nd ed.). Randolph, MA: Author. Retrieved from https://www.nationalautismcenter.org

O'Neill, R. E., Horner, R. H., Albin, R. W., Storey, K., & Sprague, J. R. (2015). *Functional assessment and program development for problem behavior* (2nd ed.). Stamford, CT: Cengage Learning.

Reed, P. (2024). Behaviour analytic theories of autism spectrum disorder. In *Handbook of early intervention for autism spectrum disorders* (pp. 127–156). Cham, Switzerland: Springer.

Sansosti, F. J., Doolan, M. L., Remaklus, B., Krupko, A., & Sansosti, J. M. (2015). Computer-assisted interventions for students with autism spectrum disorders within school-based contexts: A quantitative meta-analysis of single-subject research. *Review Journal of Autism and Developmental Disorders, 2*, 128–140.

Schlosser, R. W., & Wendt, O. (2008). Effects of augmentative and alternative communication intervention on speech production in children with autism: A systematic review. *American Journal of Speech-Language Pathology, 17*(3), 212–230.

Skinner, B. F. (1957). *Verbal behavior*. New York, NY: Appleton-Century-Crofts.

Soares, N., & Grossman, L. (2002). A picture's worth: PECS and other visual communication strategies in autism. *Journal of Developmental & Behavioral Pediatrics, 23*(4), 283.

Tincani, M. (2004). Comparing the Picture Exchange Communication System and sign language training for children with autism. *Focus on Autism and Other Developmental Disabilities, 19*(3), 152–163.

Turkish Statistical Institute. (2023). *Autism spectrum disorder data in Turkey*. Retrieved from https://data.tuik.gov.tr

UNICEF. (2021). *Keeping children safe online*. New York, NY: Author. Retrieved from https://www.unicef.org

van der Meer, L. A. J., & Rispoli, M. (2010). Communication interventions involving speech-generating devices for children with autism: A review of the literature. *Developmental Neurorehabilitation, 13*(4), 294–306.

Wehman, P. H., Schall, C. M., McDonough, J., Kregel, J., Brooke, V., Molinelli, A., Ham, W., Graham, C. W., Riehle, J. E., Collins, H. T., & Thiss, W. (2014). Competitive employment for youth with autism spectrum disorders: Early results from a randomized clinical trial. *Journal of Autism and Developmental Disorders, 44*(3), 487–500.

White, E. N., Ayres, K. M., Snyder, S. K., Cagliani, R. R., & Ledford, J. R. (2021). Augmentative and alternative communication and speech production for individuals with ASD: A systematic review. *Journal of Autism and Developmental Disorders, 51*(11), 4199–4212.

Wong, C., Odom, S. L., Hume, K. A., Cox, A. W., Fettig, A., Kucharczyk, S., Brock, M. E., Plavnick, J. B., Fleury, V. P., & Schultz, T. R. (2015). Evidence-based practices for children, youth, and young adults with autism spectrum disorder: A comprehensive review. *Journal of Autism and Developmental Disorders, 45*(7), 1951–1966.

Author(s) Information

Fatma Nur Uzun	**Efsa Ayhan**
Kütahya Health Sciences University, Faculty of Engineering and Natural Sciences, Department of Computer Engineering Kütahya, Türkiye ORCID iD: https://orcid.org/0000-0003-0153-3442 *Contact e-mail: *fatmanur.uzun@ksbu.edu.tr*	Anadolu University, Open Education Faculty, Department of Elderly Care Eskisehir, Türkiye ORCID iD: https://orcid.org/0009-0008-6034-3458

To cite this article:

Uzun, F. N. & Ayhan, E. (2026). PECS+: An intelligent hybrid communication system integrating phase-locked learning architecture, NFC-based interaction, adaptive learning, and emotion recognition. *The Eurasia Proceedings of Educational and Social Sciences (EPESS), 50,* 43-55.