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Original Article

Strategic Planning for Inclusive Education: Exploring and Validating the Measurement Model for Augmented Reality Applications Among Special Needs Children in Malaysia

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Abstract

Background: Augmented reality (AR) applications can enhance cognitive development, social skills, and emotional behaviors in children with special needs. However, limited research exists on integrating AR with the Picture Exchange Communication System (PECS) and the Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) methods. This study aimed to explore and validate a measurement model of AR applications combined with PECS and TEACCH methods among special needs children in Malaysia.

Methods: This cross-sectional study included 100 respondents selected using a stratified random sampling approach for a pilot study, with data analyzed through exploratory factor analysis (EFA). For the main field study, 300 teachers, parents, and caretakers of special needs children from four regions of Peninsular Malaysia participated by completing a self-administered survey questionnaire. Data from the field study were subsequently analyzed using confirmatory factor analysis (CFA).

Results: During the pilot study, EFA was conducted on 34 items, leading to the removal of one item due to low factor loading, leaving 33 items. Pooled CFA conducted on the field study data led to eliminating three additional items with low factor loadings, retaining 30 items with high factor loading. The model achieved an adequate fit, as confirmed by composite reliability, average variance extracted, and fitness indexes.

Conclusion: The measurement model for AR applications integrated with PECS and TEACCH methods among special needs children in Malaysia has been validated. It provides and is a reliable instrument for assessing the effectiveness of these applications in future research.

Keywords: Structural equation modeling, Early intervention, Special education, Augmented reality

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Introduction

Children with special needs have unique requirements that must be addressed in a particular manner, necessitating specific attention and different demands compared to typical children (1,2). These children also require a specialized education curriculum to meet their individual learning needs (3,4). Implementing an inclusion strategy by integrating them into mainstream education within regular learning settings is one approach to ensure they can interact with their peers, feel included in society, and subsequently, develop their self-confidence and daily living skills (5-7). In Malaysia, approximately 105 785 special education students are registered in accredited special education schools and institutes, ranging from preschool to high school levels across both rural and urban areas (8). Early diagnosis and intervention are crucial to begin the immediate process of specialized education programs and strategies for these children (9).

Early intervention programs are specifically designed to assist and support children with special needs such as those with autism spectrum disorder (ASD) by providing them with therapy, knowledge, support, and encouragement (10,11). The Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) approach is an educational intervention that helps ASD children to overcome their communication difficulties by considering a variety of elements such as different items, environments, and weather conditions, as well as employing activities to promote social behavior, cognitive skills, and psychological capabilities (12).

The TEACCH approach also assigns specialized workstations for children with special needs, such as those with ASD, in designated areas where they can complete tasks and activities assigned to them by their therapists, thereby creating an organized teaching and learning environment (12,13). Meanwhile, the Picture Exchange Communication System (PECS), an evidence-based, low-tech, portable, and easy-to-use tool, was developed for children with special needs who were either non-verbal or had delayed speech to help them develop communication skills, express their emotions, and convey their messages both at home or in the classroom (14). The PECS approach comprises six steps that assist children with ASD in initiating communication with their partners (15). Prior research has identified PECS as one of the most effective educational interventions for kids with ASD (16).

Numerous local studies have been conducted on topics such as instructional strategies, learning materials, information and communication technology (ICT), and teacher preparation (11,17). The use of augmented reality (AR) applications has been acknowledged as an effective tool for improving user experiences. Furthermore, most autistic students possess stronger visual memories than auditory ones, which enables them to focus and comprehend new information more effectively through visual learning or visual thinking. This also helps in better retention. Employing visual strategies in media can potentially contribute to the development of their communication skills (18).

In addition, children with special needs frequently face behavioral problems and struggle to learn fundamental life skills, leading to the development of a curriculum that emphasizes practical and real-life experiences (19). PECS and TEACCH programs are among the most successful intervention strategies for enhancing social communication, visual information processing, and inclusive educational support for children with special needs, particularly those with autism (16,20). Moreover, the PECS approach, widely used in special education centers and schools for children with special needs, is regarded as an efficient communication training tool, especially during the teaching and learning processes (21). TEACCH, on the other hand, is a structured intervention program designed especially for kids with autism. It addresses all characteristics of autism, as well as the unique challenges faced by each autistic child by using alternative communication techniques, environmental modifications, and systematic intervention (13).

To provide autistic children with better alternative interventions using the PECS technique, Shminan et al (16) developed a mobile-based learning program called AutiPECS for parents of children with ASD in Malaysia. This program helps parents of ASD children reduce their reliance on therapists and the need for costly treatments at autism centres. In contrast, Taryadi and Kurniawan (22) conducted research in Indonesia to design a new application specifically made for autistic children to investigate the potential of using the PECS approach within AR applications for learning, teaching, behavioral stimulation, and monitoring. Meanwhile, Amado et al (23) in Peru developed an AR mobile application aimed at enhancing cognitive skills in autistic children in both online and in-person classroom settings.

The TEACCH program has provided structured teaching methods as a recommendation that has been proven effective for children with autism, particularly when learning is visual and interactive, whether through conventional or digital methods (24,25). Researchers from various fields are now investigating the integration of PECS and TEACCH approaches into digital-based mediums such as computers and touchscreen mobile technology (26). Thus, the application of AR effectively contributes to the acquisition of these skills by providing a platform for individuals with special needs to increase their motivation and understanding of certain AR-related information (19).

Given the potential of PECS and TEACCH approaches in planning inclusive education, this study aimed to explore and validate a measurement model of AR applications integrated with PECS and TEACCH methods for children with special needs in Malaysia as part of strategic planning for inclusive education.

Materials and Methods

Study Design and Setting

This cross-sectional study was conducted from December 2021 to December 2022 on 300 respondents, including teachers, parents, and caretakers of special needs children, from four regions of Malaysia: the northern, east coast, southern, and central regions. The selected respondents represented a true population of 37 084 special needs children in Malaysia, aged between six and twelve years, enrolled in registered special needs schools and centers in 2021. To ensure the confidentiality of respondents' personal information, all the respondents provided written consent prior to the questionnaire distribution. Before the field study, a pilot study involving 100 respondents was conducted, and the data were analyzed using exploratory factor analysis (EFA) as suggested by previous research (27).

Sampling

A total of 300 respondents were selected from among parents and teachers of special needs children based on the recommendations of Hair et al (28) to ensure the robustness and reliability of the statistical analysis using structural equation modeling, as well as to enhance the representativeness of the overall population (29). A sample size of 300 is also sufficient when the model contains seven or fewer constructs, with fewer than three measuring items for each construct (30). To ensure the true population representativeness, respondents were proportionately selected from four designated regions of Malaysia using a proportionate stratified random sampling procedure.

Instrument for Data Collection

In this quantitative research, a 5-point Likert scale survey questionnaire was adapted and modified from previous studies (12,31,32) to align with the research objectives. The first part of the survey gathered demographic information about the respondents. The second part contained item statements related to the construct of AR. The third part contained statements related to the construct of perceived ease of use, while the fourth part focused on the construct of perceived usefulness. Additionally, the fifth part of the survey contained questions regarding the intention to use the technology. The sixth and the seventh parts contained the items related to perceived efficacy and training, respectively. On this scale, a rating of '1' indicates "strongly disagree", and a rating of '5' indicates "strongly agree". To achieve criterion validity, face validity, and content validity for the constructs and item statements of the measurement model, an expert review process was conducted as part of the pretesting phase before the pilot study (33). During the pilot study, the questionnaire was distributed to 100 selected respondents, including teachers and parents of special needs children, to collect pilot data (34). Afterward, EFA was conducted on the pilot study data to explore and measure the dimensionality of the items for each construct and to remove those with low factor loadings from the measurement model of the AR application integrated with PECS and TEACCH methods for special needs children. The EFA was performed using IBM-SPSS version 26.0 to explore the measurement model. Out of 34 items, 33 exhibited high factor loadings during the EFA procedure, and these items were retained in the survey and arranged according to their respective constructs. In the field study, a series of self-administered questionnaires were distributed to the selected 300 respondents who were given sufficient time to complete the survey without interruption and without disclosing their identities as stated in the consent form. The pooled confirmatory factor analysis (CFA) was then conducted on the field study data using IBM-SPSS Amos version 24.0 to validate the measurement model of AR applications combined with PECS and TEACCH methods for special needs children in Malaysia as a strategic planning framework for inclusive education.

Results

Table 1 represents the results of Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy for all six constructs. The KMO and Bartlett's test of sphericity were conducted to measure the adequacy and the suitability of data for factor analysis. A KMO value above 0.60 demonstrates that the sample is sufficient for the factor analysis (35). Meanwhile, Bartlett's test of sphericity with a P-value of less than 0.001 indicates significant correlations among at least some of the variables, which is essential for conducting factor analysis (36).

Based on Table 1, the KMO values for all six constructs were greater than 0.6, indicating that the sample size was adequate to proceed with the data reduction procedure and further analysis (30).

Based on the EFA results in Table 2, 9 items of AR with PECS and TEACCH constructs were retained for having high factor loading above 0.60. One item was deleted due to the factor loading below 0.60. Meanwhile, all other constructs (i.e., perceived efficacy, training, perceived ease of use, perceived usefulness, and intention to use) were retained and not deleted as their items displayed high factor loading under a single component. The construct of AR with PECS and TEACCH approaches was divided into two new dimensions, while the other constructs remained as single components. After EFA, only 33 reliable items out of 34 were retained. Table 3 displays the internal reliability for AR with PECS and TEACCH approaches, perceived usefulness, perceived ease of use, intention to use constructs, perceived efficacy, and training constructs.

As observed in Table 3, Cronbach's alpha values for all constructs were above 0.70, indicating high internal consistency and internal reliability of the constructs. The result of the EFA procedure demonstrated that the original 34 items of the AR with PECS and TEACCH methods across six constructs (perceived efficacy, training, perceived ease of use, perceived usefulness, and intention to use) were reduced to 33 high-loading items. The constructs were reliable since Cronbach's Alpha values exceeded 0.7 for all constructs. Additionally, Bartlett's test of sphericity indicated highly significant P values for all constructs ($P < 0.001$), and the KMO readings were greater than 0.7, exceeding the minimum threshold of 0.60. By eliminating non-reliable and low-factor loading items during the EFA procedure, the instrument's validity was enhanced. The remaining 33 items with high factor loadings (> 0.60) for the six constructs were analyzed using CFA. To optimize efficiency, the pooled CFA approach was used, and the results are displayed in Figure 1.

As presented in Figure 1, the fitness index values for probability value, root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and chi-square/degrees of freedom (df) have met the required thresholds, with respective values of 0.000, 0.070, 0.905, 0.894, and 2.864. Each item's factor loading reached the necessary threshold, which is greater than 0.6. The items within each construct also demonstrated unidimensionality, with factor loadings surpassing the minimum threshold of 0.6, indicating a

Table 1. The Value of Kaiser–Meyer–Olkin and Bartlett's Test Scores

Constructs	KMO (>0.6)	Bartlett's Test Score (<0.001)
AR with PECS and TEACCH approaches	0.794	0.000
Perceived usefulness	0.798	0.000
Perceived ease of use	0.766	0.000
Intention to use	0.725	0.000
Perceived efficacy	0.896	0.000
Training needed	0.836	0.000

Note. KMO: Kaiser–Meyer–Olkin; AR: Augmented reality; PECS: Picture exchange communication system; TEACCH: Treatment and education of autistic and related communication handicapped children.

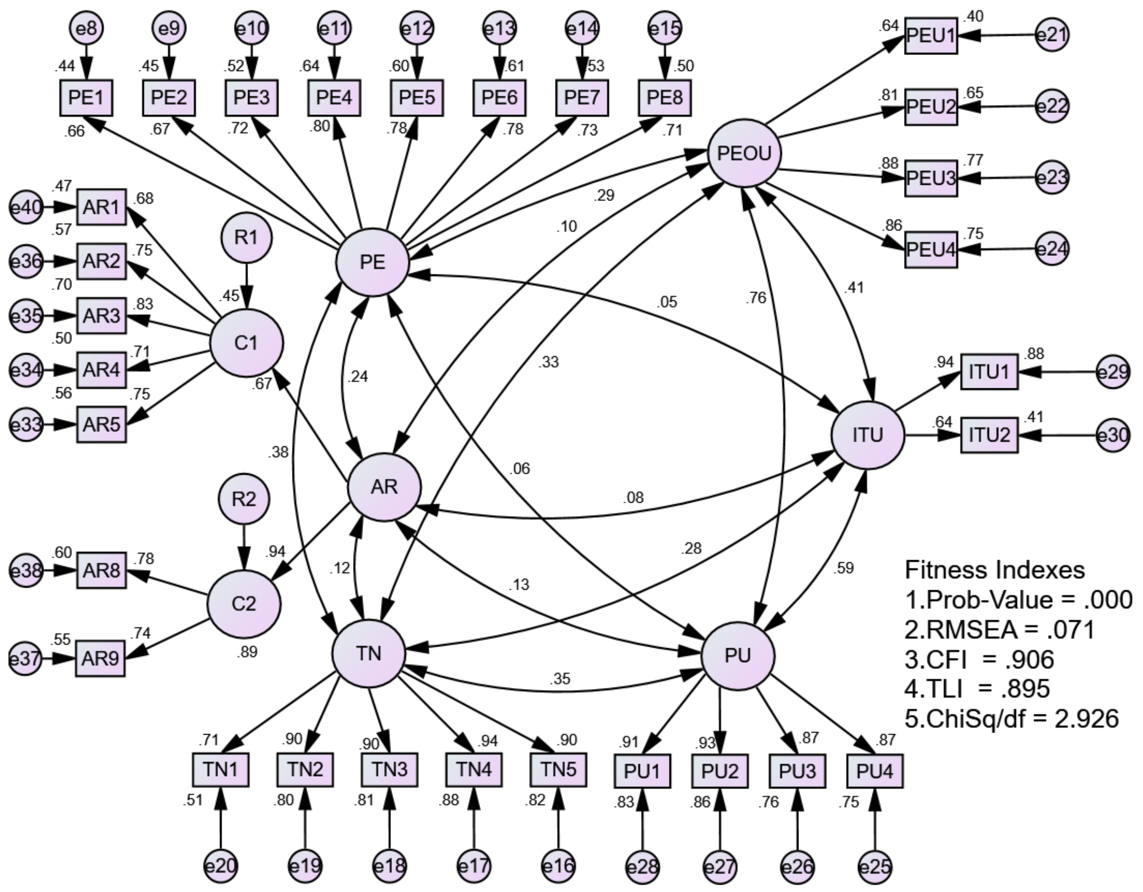

Figure 1. Result of Pooled Confirmatory Factor Analysis

Table 2. Rotated Component Matrix for AR With PECS and TEACCH Constructs

Rotated Component Matrix[a]		
	Component	
	1	2
AR1	0.826	
AR2	0.849	
AR3	0.846	
AR4	0.699	
AR5	0.829	
AR6	Item deleted	
AR7	0.668	
AR8		0.741
AR9		0.797
AR10		0.735

Note. AR: Augmented reality; PECS: Picture exchange communication system; TEACCH: Treatment and education of autistic and related communication handicapped children; a. Rotation converged in 3 iterations. Extraction Method: Principal component analysis; Rotation Method: Varimax with Kaiser normalization.

high level of validity.

Based on Table 4, the assessment of construct validity for all the latent constructs in the measurement model has met the requirement for construct validity.

As seen in Table 5, the average variance extraction (AVE) values for all constructs are above 0.45, and the composite reliability (CR) values exceed the minimum threshold of 0.60. Convergent validity for each construct was established through AVE calculations. Notably, all constructs within the measurement model exhibited convergence validity, surpassing the standard values of 0.5 for AVE and 0.45 for complex models. Before conducting the CFA, items with low factor loadings were excluded to avoid lowering the AVE (37). Therefore, it can be concluded that each construct in the measurement model achieved CR and convergent validity (30).

Table 3. Internal Reliability of the Constructs

	Constructs	No of Items	Cronbach's Alpha
1	AR With PECS and TEACCH approaches	9	0.832
2	Perceived usefulness	4	0.895
3	Perceived ease of use	4	0.958
4	Intention to use	3	0.874
5	Perceived efficacy	8	0.942
6	Training	5	0.937

Note. AR: Augmented reality; PECS: Picture exchange communication system; TEACCH: Treatment and education of autistic and related communication handicapped children.

Discussion

In line with the objective of this study to explore and validate a measurement model of AR applications integrated with PECS and TEACCH methods among special needs children in Malaysia, the measurement

Table 4. Assessment of Construct Validity for the Measurement Model

No	Category	Index	Level of Acceptance	Index Value	Comment
1	Absolute fit	RMSEA	<0.08	0.079	The required level is achieved.
2	Incremental fit	CFI	>0.9	0.904	The required level is achieved.
3	Parsimonious fit	χ^2/df	<3.0	2.875	The required level is achieved.

Note. RMSEA: Root mean square error of approximation; CFI: Comparative fit index.

Table 5. The AVE and CR of the Constructs

Construct	Items	Factor Loading	AVE (Minimum 0.45)	CR (Minimum 0.6)
AR with PECS and TEACCH methods	AR1	0.683	0.493	0.900
	AR2	0.754		
	AR3	0.834		
	AR4	0.707		
	AR5	0.748		
	AR8	0.775		
	AR9	0.743		
Perceived efficacy	PE1	0.662	0.537	1.000
	PE2	0.670		
	PE3	0.723		
	PE4	0.800		
	PE5	0.776		
	PE6	0.782		
	PE7	0.729		
	PE8	0.709		
Training	TN1	0.715	0.765	0.942
	TN2	0.896		
	TN3	0.902		
	TN4	0.939		
	TN5	0.904		
Perceived ease of use	PEU1	0.636	0.644	0.877
	PEU2	0.806		
	PEU3	0.880		
	PEU4	0.864		
Perceived usefulness	PU1	0.910	0.799	0.941
	PU2	0.927		
	PU3	0.871		
	PU4	0.866		
Intention to use	ITU1	0.935	0.644	0.778
	ITU2	0.643		

Note. AVE: Average variance extracted; CR: Composite reliability; AR: Augmented reality; PECS: Picture exchange communication system; TEACCH: Treatment and education of autistic and related communication handicapped children.

model was developed based on the Technology Acceptance Model (TAM) by Davis et al (38). The development of the measurement model involved six constructs: AR integrated with PECS and TEACCH methods, perceived efficacy, training, perceived ease of use, perceived usefulness, and intention to use. These constructs were adapted from previous research (12,31,32). To ensure criterion validity, face validity, and content validity of the measurement model, an expert review process was conducted as part of the pretesting process prior to the pilot study (33).

The results of EFA on the pilot study data indicated that all 33 items across six constructs were reliable. Each construct had a Cronbach's Alpha value above 0.7, Bartlett's test of sphericity yielded highly significant P values ($P<0.001$), and KMO values exceeded 0.7, surpassing the minimum threshold of 0.60. These findings are in line with previous research conducted by Georgiou et al (39). The results of EFA in the present study also confirm the validity and robustness of the item statements and constructs within the measurement model (34). Additionally, the results indicate that the extracted components for each construct, along with their corresponding items, are reliable (40). Meanwhile, the removal of unreliable items and those with low factor loadings during the EFA further enhanced the instrument's validity (41).

The results of pooled CFA for the measurement model in this study revealed that the factor loadings for items AR7, AR10, and ITU3 fell below the minimum threshold of 0.6. Therefore, these three insignificant items were removed as they affected the measurement model and caused the constructs to have a poor fit. The removal of items with low factor loadings was consistent with the methodology in previous research by Georgiou et al (39). After removing the low factor loading items, the fitness index values for Probability Value, RMSEA, CFI, TLI, and Chi-square/df were 0.000, 0.071, 0.906, 0.895, and 2.926, respectively. These values achieved the required level as suggested by Awang et al (30). Additionally, the factor loading for each remaining item surpassed the required value, which is more than 0.6 (42).

Based on the results of CFA, the AVE and CR were also met for all constructs in the measurement model. The required threshold for AVE exceeded 0.50 (43), while the required value for CR exceeded 0.60 (44). Thus, it can be concluded that convergent validity and CR for the constructs of the measurement model concerning AR applications with PECS and TEACCH methods for children with special needs in Malaysia were satisfactorily accomplished. However, since this study was conducted across four regions of Peninsular Malaysia, its findings cannot be generalized to the entire population of Malaysian special needs children. Since the respondents of this cross-sectional study were teachers, parents, and caregivers of special needs children, the results might not accurately reflect the true experience of special needs children due to the subjective interpretations and expectations of these individuals.

Conclusion

Regarding construct validity, the measurement model for all latent constructs met the literature-recommended acceptance thresholds. The model satisfied the criteria for absolute fit, incremental fit, and parsimonious fit, encompassing the three categories essential for construct validity. Discriminant validity was also confirmed as the measurement model remained free from redundant items, with modification indices remaining below the threshold of 15.0. Furthermore, the instrument demonstrated satisfactory CR. Following the CFA procedure, the measurement model for latent constructs associated with AR applications, incorporating PECS and TEACCH methods for special needs children in Malaysia, retained 30 items across six constructs. Therefore, the measurement model was regarded as reliable and validated to be used in future strategic planning in inclusive education research for special needs children in Malaysia.

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Authors' Contribution

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Competing Interests

The authors declare that there is no conflict of interests.

Ethical Approval

This study was approved by the Human Ethics Research Committee (UHREC) of Universiti Sultan Zainal Abidin, Malaysia (Code: UniSZA/UHREC/2021/422). Informed consent was distributed to all participants, ensuring that they understood the purpose of the study, the procedures involved, and their right to withdraw at any time without penalty.

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