International Journal of Evaluation and Research in Education (IJERE)
Vol. 14, No. 6, December 2025, pp. 4677~4688
ISSN: 2252-8822, DOI: 10.11591/ijere.v14i6.34093

Autism virtual reality education media integration in applied behavior analysis training

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Article Info

Article history:

Received Dec 15, 2024
Revised Jun 14, 2025
Accepted Jul 25, 2025

Keywords:

Applied behavior analysis
Autism spectrum disorder
Quality education
Special education
Virtual reality

ABSTRACT

This study examined the impact of autism virtual reality education (autism VR-Ed) media in enhancing college student teachers' skills in applied behavior analysis (ABA) for children with autism spectrum disorder (ASD). A total of 40 student teachers from Guangxi College for Preschool Education, China, participated in a three-month experiment using a 9-task autism VR-Ed media. Pre- and post-tests showed significant improvement in ABA skills, with scores rising from 18.05 (SD=3.00) to 41.10 (SD=2.25), $t(39)=-48.394$, $p<.05$. All participants achieved over 60 points, confirming effective skill acquisition. A perception survey revealed positive attitudes toward the media, highlighting its ease of use, engagement, and relevance to future professional needs. These results demonstrated the potential of VR technology to bridge the gap between theory and practice in special education by offering immersive learning experiences. Autism VR-Ed media enhanced ABA training beyond traditional methods, supporting the professional growth of special education teachers. This study contributed to integrating VR technology into special education curricula and improving teacher training quality, thereby effectively supporting the rehabilitation of children with ASD. Future research should explore the long-term benefits of VR-based training and its broader applications and assess its impact on the learning outcomes of children with ASD.

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1. INTRODUCTION

The education of children with autism spectrum disorder (ASD) is a complex social problem that needs to be solved urgently [1]. The prevalence of ASD continues to soar and core symptoms persist throughout life, requiring ongoing support and services [2]. According to a research, the prevalence of ASD in China is similar to the West, at around 1% [3]. To adequately address the needs of this growing population, training a sufficient number of highly skilled college student teachers for children with ASD rehabilitation becomes imperative [4]. Applied behavior analysis (ABA)-based intervention is typically utilized to support children with ASD, which has been widely used across the world [5]. However, China grapples with a substantial shortage of qualified behavior analytic professionals [6], [7], adversely affecting the quality of education and support for children with ASD.

In the realm of special education, a conspicuous gap exists in the training of college student teachers, specifically concerning ABA skills crucial for children with ASD. Conventional training methods

often prove insufficient in delivering immersive and effective learning experiences tailored to the distinctive challenges of children with ASD education. The diversity of learning needs among children with ASD demands nuanced skills from educators [8], a requirement not consistently met by traditional training programs. The indispensable confidence and competence needed for applying ABA techniques may be lacking in teachers, potentially impeding effective intervention. The inadequacy of traditional training methods becomes evident as they frequently lack practical application opportunities, resulting in a disparity between theoretical knowledge and its practical implementation in classrooms.

To address these challenges, our research focuses on integrating cutting-edge virtual reality (VR) technology to create autism virtual reality education (autism VR-Ed) media, which is an important study aimed at equipping college student teachers with the necessary ABA manipulation skills to effectively educate students with ASD. The core feature of VR technology is to build a highly immersive, interactive and visual learning environment, enabling learners to carry out realistic practice in virtual space and enhance learning effects through multi-sensory experience [9], [10]. By leveraging the characteristics of VR to build highly realistic training environments and objects, the nine training operation tasks in ABA are simulated: motivation and requirement training, imitation speaking training, naming training, movement imitation training, visual perception matching training, reception instruction training, receive naming training, complex listener identification training, and interactive language training. These nine training tasks are designed based on the principles of ABA, which represents an innovative instructional approach tailored for imparting skills to children with ASD [11], [12].

The development of autism VR-Ed media represents an innovative approach to college student teachers' education in the field of special education. By utilizing autism VR-Ed media, this research pioneers' new avenues for training college student teachers and promotes innovation within the discipline. Autism VR-Ed media offers an immersive and interactive learning experience, allowing college student teachers to simulate real-life scenarios and practice their skills in a safe and controlled environment. This innovative solution has the potential to revolutionize college student teachers' training practices globally, standardizing and advancing special education methods. Through the autism VR-Ed media, college student teachers can be equipped with the skills to support children with ASD, enhancing their learning experience and promoting inclusivity in education. Furthermore, this research demonstrates the potential of VR technology in solving real-world challenges. By harnessing emerging VR technology in education, students' learning effects can be effectively promoted [13], thereby positively impacting the lives of children with ASD. This innovation inspires further research and development, expanding the applications of VR in education, and advancing our understanding of effective teaching methods. The goal of this study was to assess the autism VR-Ed media for enhancing ABA skills of college student teachers in ASD rehabilitation; to evaluate the effectiveness of autism VR-Ed media; and to determine the college student teachers' perceptions towards autism VR-Ed media.

2. LITERATURE REVIEW

2.1. The current issues of ASD and its impact

ASD is a severe developmental disorder characterized by extensive developmental impairments, including social interaction difficulties, rigid behaviors, and narrow interests [14]. The core symptoms of ASD persist throughout life, have a profound impact on patients' learning, life, and interpersonal relationships, and require long-term support and intervention [15]. Although the specific cause of ASD has not yet been determined, studies have shown that it may be related to a complex interaction between genes and the environment [16]. In recent years, the incidence of ASD has increased significantly worldwide [17]. According to relevant data, the prevalence rate of ASD in China is about 1% [3], which means that out of a population of 1.4 billion, more than 10 million people may be affected, including more than 2 million children with ASD. Such a large patient group not only places a heavy burden on individuals and families, but also poses severe challenges to social resource allocation and public services. The contradiction between the supply and demand of behavior analytic professionals in China is particularly prominent, which is far from enough to meet the increasing actual needs of children with ASD [6], [7]. Faced with this situation, colleges and universities face tremendous pressure in cultivating special education professionals who can meet social needs.

2.2. The role of ABA in ASD rehabilitation and its teaching dilemmas

The ABA methodology is fundamentally grounded in principles derived from behaviorism, focusing on elucidating the relationships among behavior, antecedent stimuli, and consequent outcomes [18], [19]. It is the mainstream therapy for ASD rehabilitation intervention [20], focusing on analyzing and intervening in the behavior of individuals with ASD to enhance their social interaction, communication, and learning [21].

A meta-analyze study systematically evaluated the intervention effect of ABA on children with ASD. The study included 14 randomized controlled trials with a total of 555 participants. The results showed that ABA intervention has a positive effect on social interaction, communication, and other aspects [22]. Although ABA has significant effects on ASD intervention, it is important to state that traditionally cultivating ABA professionals fails to meet the demand for ASD rehabilitation education [6], [7]. The traditional teaching of ABA is limited by conditions such as venue, resources, ethics, mainly focusing on theoretical lectures, making it difficult to provide sufficient real simulation training scenarios. ABA skills cannot be trained effectively and in a standardized manner, making it difficult to continuously meet the rehabilitation education needs of children with ASD, which seriously hinders the development of the ASD rehabilitation education industry.

2.3. The use of VR in ASD rehabilitation and its teaching advantages

VR technology, with its immersive, interactive, and innovative characteristics, greatly compensates for the shortcomings of traditional teaching [23]. Integrating VR technology into the teaching process is expected to bridge the gap between classroom theoretical teaching and real-world practice [24]. VR offers a realistic and controlled virtual environment without any potential harm or risk to the well-being of actual students [25]. VR technology can provide personalized learning experiences tailored to specific training needs and individual learning styles [26]. In contrast to traditional training methods that rely heavily on theoretical knowledge and passive learning approaches, VR offers experiential learning opportunities [27]. Through virtual interactions, VR technology can significantly enhance observational and analytical skills [28]. As VR technology becomes more prevalent and sophisticated, its incorporation into the realm of ABA for ASD intervention has garnered significant attention [29]. The utilization of VR to replicate genuine scenarios has emerged as a focal point in enhancing the efficacy of interventions for individuals with ASD. For example, Shahmoradi and Rezayi [30] selected 17 eligible studies from 688 relevant studies to examine the effects of using a VR-based approach on cognitive impairment in children and adults with ASD. The results showed that in most of the studies, VR technology had some benefit in reducing cognitive problems. People with ASD showed significant improvements in various cognitive indexes such as task learning, attention, executive function, and daily skills.

However, despite these promising results, the implementation of VR technology in ABA skills training still faces several challenges. First, the development of high-quality VR content requires significant investment in both time and resources [31]. Second, VR technology has difficulty in fully replicating real-world interactions with ASD children [32]. Additionally, while VR provides a safe training environment, excessive reliance on virtual scenarios might limit college student teachers' ability to handle unexpected situations in real-world settings [33]. Therefore, a balanced approach combining both VR-based and traditional training methods might be more effective in preparing ABA professionals.

3. METHOD

3.1. Research design

This study employed a one-group experimental design to assess the impact of autism VR-Ed media on college student teachers' ABA skills and perceptions. The study population consisted of 110 college student teachers enrolled in the ABA course in the first semester of 2023. A voluntary sample of 40 college student teachers was recruited for the experiment. Most of the sample were freshmen, accounting for 70%; female students accounted for the majority, accounting for 97.5%; and the age of the students was mainly between 19 and 20 years old, accounting for 60%. Specific sample information is shown in Table 1. The Guangxi College for Preschool Education in China ethics committee approved the study protocol.

3.2. Research instruments

3.2.1. Exercise of autism VR-Ed media

The "exercise of autism VR-Ed media" referred to the procedural steps of the training tasks, which were primarily designed to evaluate respondents' mastery of ABA operational skills during practical exercises within the VR environment [11]. The exercise framework was meticulously designed by subject matter experts based on established ABA principles, encompassing nine comprehensive training components: motivation and requirement training, imitation speaking training, naming training, movement imitation training, visual perception matching training, reception instruction training, receive naming training, complex listener identification training, and interactive language training. Each exercise task was assigned different operational step scores based on complexity and importance, with the cumulative total score across all nine tasks reaching 78 points maximum. The scoring system employed a strict criterion where if one step in a task was performed incorrectly or all steps were executed improperly, the entire task exercise would receive a score of zero, ensuring accuracy and precision in skill demonstration.

Table 1. Gender, age, grade information of the respondents

Item		Frequency	Percentage (%)
Gender	Female	39	97.50
	Male	1	2.50
Age	18 years old and below	6	15.00
	19-20 years old	24	60.00
	21 years old or over	10	25.00
Grade	Freshman	28	70.00
	Sophomore	12	30.00
	Junior	0	.00

3.2.2. Achievement test of nine tasks

The "achievement test of nine tasks" served as a comprehensive assessment instrument designed to evaluate respondents' proficiency levels in executing ABA operational skills within VR contexts both before and after the experimental intervention period. The test items were systematically developed based on specific learning objectives derived from the content of the nine training tasks included in the exercises, ensuring comprehensive coverage of every critical operational step required for each task completion. The assessment structure consisted of five carefully crafted questions for each of the nine tasks, resulting in a total of 45 test items that thoroughly examined participants' theoretical understanding and practical application capabilities. The scoring system awarded one point for each correct answer, establishing a maximum total score of 45 points that provided a standardized measure of achievement across all participants.

3.2.3. Questionnaire of perceptions towards autism VR-Ed media

The questionnaire served as a comprehensive evaluation instrument designed to assess respondents' perceptions towards the autism VR-Ed media, specifically investigating whether the VR technology was compatible with ABA teaching tasks and measuring participants' acceptance and satisfaction with this innovative educational technology. The questionnaire design integrated two well-established theoretical frameworks, the technology acceptance model (TAM) and task-technology fit (TTF) theory [34], providing a robust foundation for understanding user adoption and technology effectiveness in educational contexts. The instrument comprehensively covered six critical dimensions including perceived usefulness (PU), perceived ease of use (PE), attitude (ATT), behavioral intention (BI), TTF, and user experience (UX), with a total of 29 carefully structured feedback questions addressing various aspects of technology interaction and learning experience. Each statement regarding participants' experience with the autism VR-Ed media was evaluated using a standardized 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), enabling precise measurement of participant perceptions and attitudes toward the VR-based training system.

3.3. Research procedure

3.3.1. Autism VR-Ed media construct method

Each component of the autism VR-Ed media was collaboratively designed by eight experts from special education and VR technology fields according to established principles of ABA, encompassing all critical elements including VR technology infrastructure, exercise protocols, and achievement test frameworks. To ensure the validity and reliability of the media's components, researchers employed the item objective congruence (IOC) method for comprehensive content validity assessment, providing a systematic approach to evaluate the alignment between content and learning objectives. Three senior experts, all holding the distinguished title of professor or doctoral level qualifications in relevant fields, were invited to participate in the rigorous evaluation process of the autism VR-Ed media's content using a standardized assessment scale. The evaluation framework utilized a three-point rating system ranging from -1 to +1, where +1 indicated content was considered to be in line with the objectives, 0 represented neutral assessment, and -1 signified content was considered to be inconsistent with the established learning objectives.

3.3.2. Experiment and data collection

To systematically evaluate the effectiveness of the autism VR-Ed media, the following steps were carried out during the experiment and data collection process:

- Do achievement test before studying with autism VR-Ed media (pre-test): before starting the experiment, achievement test was conducted on 40 volunteer college student teachers who participated in the experiment to understand the baseline level of those students' abilities.
- Study from autism VR-Ed media and complete the exercise after each task: during the experiment, college student teachers participated in nine training tasks of autism VR-Ed media, and the media would count the exercise scores based on the students' training status.

- Do achievement test after finished studying with autism VR-Ed media (post-test): after the experiment, achievement test was conducted on the 40 volunteer college student teachers who participated in the experiment to understand the progress of the students' ability levels after three months of training.
- Answer perceptions towards autism VR-Ed media questionnaire: after the experiment, a survey was conducted on 40 college student teachers who participated in the study using the questionnaire to understand the attitudes and viewpoints of college student teachers towards autism VR-Ed media and whether VR technology matches ABA skill training tasks.

3.3.3. Statistics hypothesis

The following were the statistical hypotheses formulated for this study:

- $H1_0$: the average post achievement test score was equal to pre achievement test score.
- $H1_1$: the average post achievement test score was unequal to pre achievement test score.
- $H2_0$: there was no relationship among the perception attributes towards Autism VR-Ed media.
- $H2_1$: there was relationship among the perception attributes towards Autism VR-Ed media.

3.3.4. Data analysis

The data analysis employed both descriptive and inferential statistical methods to comprehensively examine the research questions and provide robust evidence for the study's findings. Descriptive statistics including frequency distributions, percentages, means, and standard deviations were systematically calculated to summarize participant characteristics, demographic information, and response patterns across all measured variables. Paired sample t-tests were conducted to compare pre- and post-achievement test scores, enabling researchers to determine the statistical significance of changes in participants' knowledge and skills following the three-month VR intervention period. Additionally, correlation coefficients were computed to examine the strength and direction of relationships among participants' perceptions towards the autism VR-Ed media across multiple dimensions, with all statistical analyses performed using SPSS software to ensure accuracy and reliability of results.

4. RESULTS

4.1. The training tasks of autism VR-Ed media

Autism VR-Ed media encompassed nine distinct training tasks: i) motivation and requirement training: instruct children with ASD to perform specific behaviors or actions according to instructions; ii) imitation speaking training: teach children with ASD to learn new language expressions by imitating the language behaviors of others; iii) naming training: help children with ASD identify and name objects, people or things; iv) movement imitation training: guide children with ASD to imitate the actions of teachers or others; v) visual perception matching training: train children with ASD to pair visual input with corresponding objects or concepts; vi) reception instruction training: train children with ASD to understand and execute verbal instructions; vii) receive naming training: ask children with ASD to identify and name specific objects based on descriptions or diagrams; viii) complex listener identification training: improve the ability of children with ASD to understand and apply complex language structures; and ix) interactive language training: promote communication and interaction between children with ASD and others. Nine training tasks of Autism VR-Ed media as show in Figure 1.

Take the "naming training" task as an example, as shown in Figure 2. After the college student teacher enters the scene, a user will see a virtual child with ASD named Xiao Ming playing with a "car" toy, and hear the system voice introduce the task target "puppy" written on the black prompt board and the task requirement "Xiao Ming can correctly say the puppy on the card after seeing the card." Before the class starts, the blue prompt board will show the prompt "play with the car later", and the college student teacher will repeat this sentence. After the child with ASD puts down the car toy, the blue prompt board will show the prompt, "Please pick up the 'puppy' card from the table and show it to Xiao Ming." After the college student teacher picks up the card from the table, the blue prompt board will show the prompt "what is this?" The college student teacher needs to repeat this sentence. After the child with ASD answers "puppy", the blue prompt board will show the prompt "great! You are right, it is a puppy." After the college student teacher repeats this sentence, the blue prompt board will continue to show the prompt "please give Xiao Ming a toy." After the college student teacher takes the toy from the table to Xiao Ming, the task ends.

4.2. Comparing the pre and post achievement test

A paired-sample t-test was conducted to analyze differences between pre- and post-test achievement scores, providing comprehensive statistical evidence of the intervention's effectiveness. The results revealed that the average post-achievement test scores were statistically significantly higher than pre-test scores across

all domains (p<.05), as demonstrated in Table 2. For instance, in the "motivation and requirement training" domain, participants' scores increased significantly from a pre-test mean of 2.03±1.07 to a post-test mean of 4.55±.50, t(39)=-15.774, p<.05. These findings clearly indicate that the three-month autism VR-Ed media training had a positive and measurable impact on improving college student teachers' ABA operational skills.

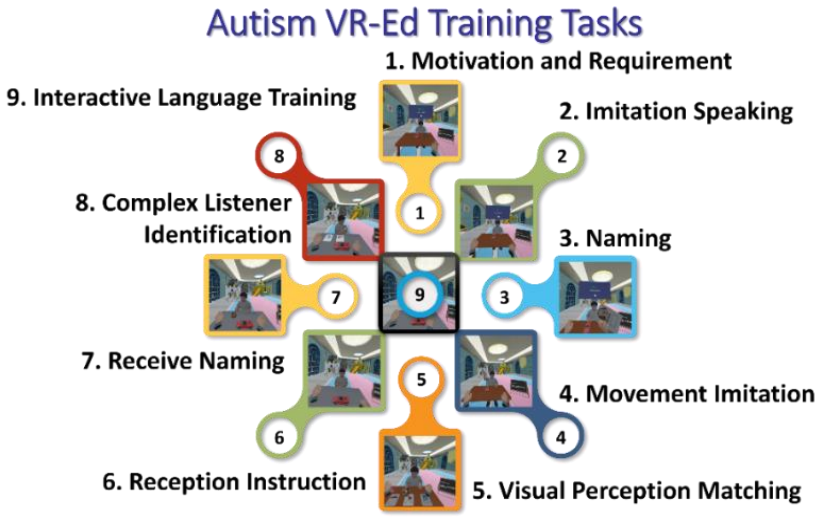

Figure 1. Autism VR-Ed training tasks (own work)

Figure 2. Screenshots of the naming training task

Table 2. Pre- and post-test scores and t-test results for training tasks

No	Task	$\bar{X}$±SD		t-value	p-value
		Pre-test	Post-test		
1	Motivation and requirement training	2.03±1.07	4.55±.50	-15.774	.000
2	Imitation speaking training	1.48±1.01	3.83±.84	-12.737	.000
3	Naming training	2.18±.90	4.48±.55	-16.298	.000
4	Movement imitation training	1.88±.97	4.65±.53	-18.533	.000
5	Visual perception matching training	1.88±.97	4.70±.56	-18.154	.000
6	Reception instruction training	2.15±.95	4.75±.54	-14.884	.000
7	Receive naming training	2.25±.95	4.65±.48	-15.459	.000
8	Complex listener identification training	1.93±1.10	4.70±.46	-14.782	.000
9	Interactive language training	2.30±1.02	4.80±.41	-14.559	.000
	Total	18.05±3.00	41.10±2.25	-48.394	.000

4.3. The results of exercises on autism VR-Ed media

The autism VR-Ed media system automatically recorded the training performance of college student teachers across nine predetermined tasks during the three-month intervention period, providing detailed insights into their learning progression. The comprehensive data collection system captured various aspects of participant engagement and skill development throughout the VR training sessions. Table 3 demonstrates that all participating college student teachers achieved average scores above 60 points throughout the exercises, indicating upper-average performance levels across all measured competencies. These findings confirm that college student teachers were able to successfully apply the skills practiced in the immersive VR scenarios, demonstrating effective knowledge transfer from virtual training to practical application.

4.4. The results of perceptions towards autism VR-Ed media

The data results of the "perceptions towards autism VR-Ed media" after the Pearson correlation coefficient analysis by SPSS are shown in Table 4. There is a positive correlation between variables, such as PU and PE, with a strong correlation ($r=.701$, $p<.01$). The analysis results indicate that the previous alternative hypothesis is fully accepted, and null hypothesis is rejected. Analysis of the perceptions questionnaire revealed an overall positive perception of the autism VR-Ed media as a training tool. According to Figure 3, the ease of use of new technology is closely related to its PU and ATT. The usefulness of VR technology is correlated with ATT and BI. Users' attitudes towards VR technology are correlated with BI. The compatibility of technology with tasks is related to its PU and PE. Users' experience is related to PE and PU.

Table 3. The summary of exercises on autism VR-Ed media

Item	Frequency	Percentage (%)
Below 30 points-lower average level	0	.00
30-60 points-average level	0	.00
Above 60 points-upper average level	40	100.00
Total	40	100.00

Table 4. Correlation among perception attributes towards autism VR-Ed

Variables	PU	PE	ATT	BI	TTF	UX
PU	1					
PE	.701**	1				
ATT	.746**	.649**	1			
BI	.640**	.811**	.691**	1		
TTF	.758**	.661**	.869**	.737**	1	
UX	.557**	.744**	.563**	.685**	.663**	1

Note. Statistical significance: **p<.01

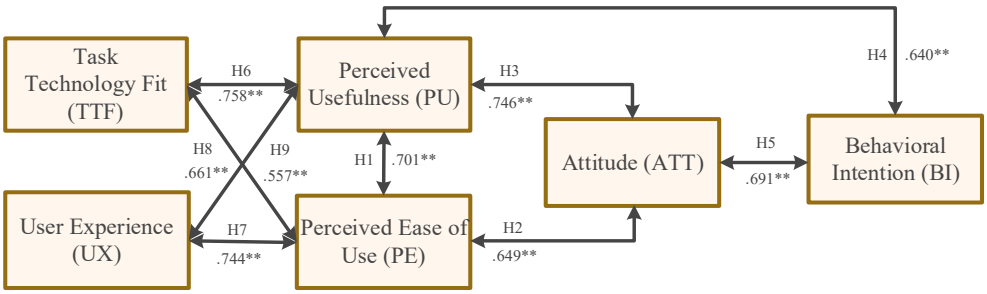

Figure 3. The correlational coefficients between each of perception score

5. DISCUSSION

5.1. Effectiveness of autism VR-Ed media and user perceptions

Findings from research objective one demonstrated a statistically significant improvement in the post-test achievement scores compared to the pre-test scores across all nine ABA training tasks after using the autism VR-Ed media. Additionally, all participating college student teachers achieved an upper average level score (above 60 out of 78 points) in the exercises conducted within the VR environment. These findings align with previous literature highlighting the potential of VR technology to bridge the gap between theoretical knowledge and real-world practice in education of children with ASD [24], [35]. The immersive

and interactive nature of VR can provide college student teachers with realistic training scenarios that mimic working with children with ASD, enhancing their practical skills [25], [27].

Findings from research objective 2 revealed positive relationships among the variables of PU, PE, ATT, BI, TTF, and UX towards the autism VR-Ed media. These findings are consistent with the TAM theory [36], [37] and TTF theory [38], which suggest that users' perceptions of a technology's usefulness, ease of use, and compatibility with tasks influence their ATT and BI to use it [34]. The strong positive correlations observed in this study indicate that college student teachers found the autism VR-Ed media useful, easy to use, and well-suited for ABA skill training tasks, fostering positive ATT and BI.

5.2. Contributions and implications

This study contributes to the growing body of knowledge on the application of VR technology in special education for children with ASD. By demonstrating the effectiveness of the autism VR-Ed media in enhancing ABA skills and exploring college student teachers' perceptions, it provides empirical evidence supporting the integration of VR into teacher training programs for education of children with ASD. Furthermore, the positive perceptions and high levels of TTF observed in this study suggest that VR-based training approaches can be well-received by college student teachers and align with the specific requirements of ABA skill development [39]. The results have implications for both theory and practice. Theoretically, the positive correlations among the variables related to technology acceptance and TTF reinforce the applicability of TAM and TTF theories in the context of VR-based training for college student teachers of children with ASD. These theories provide a framework for understanding how VR can enhance educational outcomes by aligning technology capabilities with user needs [38], [40]. Practically, the success of the autism VR-Ed media highlights the potential for incorporating VR technology into teacher training curricula [33], [41], particularly for developing practical skills in working with children with ASD. Educational institutions and ASD rehabilitation centers can consider adopting similar VR-based approaches to enhance the quality of training and better prepare college student teachers for the challenges of ASD education.

The findings of this study also have important policy implications. The demonstrated effectiveness and positive user perceptions of VR-based training suggest that policymakers should consider supporting the development and implementation of such programs in teacher education. This could involve funding initiatives to create high-quality VR training modules, providing professional development opportunities for educators to learn how to use VR effectively, and incentivizing educational institutions to adopt VR-based training programs. Furthermore, policymakers should consider the potential for VR-based training to address the current shortage of qualified special education teachers by providing scalable and accessible training solutions. This could involve developing online VR training modules that can be accessed by teacher candidates in remote areas or those who are unable to participate in traditional in-person training programs.

5.3. Limitations

While this study demonstrates the effectiveness of VR technology in ABA training, several limitations warrant consideration. The significant improvement in post-test scores may reflect practice effects or short-term learning rather than deep skill acquisition. Furthermore, positive user perceptions do not guarantee long-term adoption or improved student outcomes in real classroom settings. Practical implementation challenges, including resource constraints, technical support requirements, and the need for ongoing faculty development, must be addressed for large-scale adoption. This study, focused on ABA major students, aimed to cultivate practical skills for serving children with ASD. As an emerging field, ABA education faces limitations in equipment, resources, and teaching experience. Consequently, only 40 of the 110 registered students were selected as research subjects. Additionally, the one-group experimental design without a control group may impact the generalizability of results and the strength of causal inference. This limitation affects external validity but provides valuable practical experience for future research.

5.4. Recommendations

5.4.1. Recommendations for implementation

The positive findings of this study provide valuable and strong evidence for the implementation of autism VR-Ed media. To ensure effective implementation, several key recommendations emerge from this research. First, establishing long-term collaboration with eight experts from special education and VR technology fields will be essential to continue innovating and improving the autism VR-Ed media platform. Additionally, comprehensive training opportunities must be provided for relevant teaching staff to ensure they master key implementation steps and can effectively integrate and utilize VR technology to teach ABA skills. Furthermore, managers should develop detailed implementation management systems while maintaining good communication with teachers, students, and other relevant personnel to promote successful adoption of autism VR-Ed media and provide effective support for the platform's subsequent maintenance.

The study also highlights the importance of fostering close collaboration between educational institutions and ASD rehabilitation centers to promote college student teachers' acquisition of ABA skills through virtual practical training, thereby making their future educational interventions more practical and effective for children with ASD. Finally, educational institutions should engage in deep cooperation with technology companies to continuously innovate existing technologies, further enhance training experiences, and provide robust technical support for any challenges encountered during implementation. These comprehensive implementation strategies will collectively ensure the successful integration and sustained effectiveness of autism VR-Ed media in educational settings.

5.4.2. Recommendations for future research

To further expand upon the findings of this study, several key recommendations are proposed for future research directions. First, larger-scale, multi-site studies involving diverse sample populations, including parents of children with ASD, are necessary to further validate the effectiveness and perceptions of the autism VR-Ed media, thereby enhancing the generalizability of research results and better promoting human progress and development in this field. Additionally, future research should explore the relative effectiveness of autism VR-Ed media compared to traditional training methods through carefully designed controlled experiments, which will provide valuable insights for educational practice and evidence-based decision making. The development of additional training methods similar to autism VR-Ed media based on VR technology represents another crucial research avenue that could contribute significantly to the practice of educating children with ASD, ultimately improving the quality of life for individuals with ASD and their families. Furthermore, longitudinal studies investigating the long-term impact of VR-based training on college student teachers' performance and the subsequent outcomes for students with ASD they work with would provide essential insights into the sustained effectiveness of these interventions. By implementing these comprehensive research suggestions, it will be possible to further validate and refine autism VR-Ed media, driving its continuous improvement and maximizing its potential in innovating both the education of children with ASD and special education teacher training practices, thereby contributing to the broader advancement of inclusive educational methodologies.

6. CONCLUSION

This experimental study provides compelling evidence for the effectiveness of autism VR-Ed media in enhancing ABA skills among college student teachers preparing to work with children with ASD. The research successfully addressed both primary objectives by demonstrating significant improvements in participants' ABA competencies and revealing overwhelmingly positive user perceptions toward the VR-based training platform. Quantitative findings revealed substantial skill enhancement, with participants' achievement scores increasing dramatically from 18.05 (SD=3.00) to 41.10 (SD=2.25), representing statistically significant improvement that validates the educational efficacy of immersive VR technology in special education teacher preparation. The practical implications highlight the transformative potential of incorporating VR technology into teacher training curricula for special education. The autism VR-Ed media successfully bridged the critical gap between theoretical knowledge and practical application by providing realistic, immersive training scenarios that closely mimic real-world interactions with children with ASD. Consistently positive participant perceptions regarding the media's usefulness, ease of use, engagement level, and relevance to future professional requirements demonstrate strong user acceptance and sustainable adoption potential. These findings align with established TAM and TTF theories, reinforcing the theoretical foundation for VR integration in educational settings. The innovative nine-task training framework represents a comprehensive approach to ABA skill development that addresses the multifaceted nature of autism education. This study contributes significantly to the growing body of knowledge on VR applications in special education while providing empirical evidence supporting policy initiatives for technology integration in teacher preparation programs. Future research should explore longitudinal impacts, comparative effectiveness studies, and broader implementation strategies to maximize VR-based training potential in improving educational outcomes for children with ASD.

ACKNOWLEDGEMENTS

The researchers extend our sincere gratitude to the college student teachers and experts at Guangxi College for Preschool Education, China, for their valuable participation and contributions to this study.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
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D : **D**ata Curation
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E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee. All experimental procedures conducted in this study received ethical approval from the School of Special Education, Guangxi College for Preschool Education (IRB/20231006/SE-2023).

DATA AVAILABILITY

The data that support the findings of this study are available on request from the first author [YN]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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