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Bit the Spectrum

Project number: 2021-1-DE02-KA220-VET-000033091

Enhancing Special Education Through XR: A Pilot Study on AR and VR Games for Students with Autism Spectrum Disorders

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1. Introduction

This study investigates the application of Extended Reality (XR) technologies in educational settings, with a particular focus on their efficacy in supporting students with autism spectrum disorders (ASD). Given the increasing prevalence of digital learning tools, it is essential to conduct rigorous academic inquiry into their pedagogical value. This research contributes to the existing body of knowledge by assessing whether XR can enhance educational experiences and outcomes for students with special educational needs.

A central aim of the investigation is to explore the extent to which XR interventions can facilitate the development of social skills among students diagnosed with ASD. Immersive digital environments offer unique opportunities for fostering meaningful social interactions and engagement, addressing critical gaps in traditional educational methodologies that may fall short for neurodivergent learners.

To gather data, a structured methodology was employed involving three distinct surveys administered via Microsoft Forms. The first, a student-facing survey, evaluated perceptions, engagement levels, and perceived learning outcomes within the VR environment. The second survey captured qualitative insights from educators, who observed and recorded student behaviors and interactions during VR-based activities. A third instrument focused specifically on teachers' assessments of social skills development, measuring any observed improvements throughout the duration of the study. This triangulated approach ensured methodological rigor, enhanced data reliability, and enabled a comprehensive understanding of VR’s educational impact.

At the heart of the project lies an analysis of a VR exercise simulating the experience of being a restaurant customer. The study seeks to determine how such simulations contribute to the development of social

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competencies in students with ASD. In addition, it explores whether alternative VR scenarios—such as navigating public transportation or participating in other everyday social interactions—might yield comparable or divergent outcomes, thereby expanding the understanding of XR's versatility in special education contexts.

This work was conducted within the framework of the Erasmus+ Project *Bit The Spectrum*, which focuses on the development of XR learning environments for students with ASD. The findings underscore the potential of augmented and virtual reality technologies to foster not only engagement and motivation but also crucial social skills. Through structured XR-based interventions, the research highlights the transformative role immersive digital tools can play in enhancing educational experiences for learners with autism.

2. Methodology

This research adopted an observational and survey-based design to assess the efficacy of VR interventions. The study was conducted over a defined period of three month, with controlled conditions implemented to minimize confounding variables. Observations were carried out in a structured manner, allowing for systematic data collection.

2.1 Cohort

Participants in this study comprised students aged 16–21 who were enrolled in TELMA education programs. These programs are designed to develop life and independent living skills for individuals with special educational needs, including those diagnosed with intellectual disabilities and ADHD or, relevant for this study, students with ASD. The study cohort was heterogeneous, consisting of students at different stages of their educational journey.

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In addition to participating in the study, students were actively involved in the ideation and development of the XR learning unit. Their contributions included providing input on the design and description of the scenarios, as well as testing early prototypes. This participatory approach ensured that the content was relevant and engaging for the target audience.

It is also important to note that the class setting was new for many participants, as the study took place at the beginning of a new school year. Students were adjusting to a new learning environment, which included a newly assigned teacher and, in some cases, unfamiliar classmates. These factors may have influenced social dynamics and overall behavior during the study period.

2.2 Data Collection Methods

The data collection process for this study incorporated a scientifically validated tool to assess social skills development among participants, the Autism Social Skills Profile (ASSP), developed by Bellini and Hopf (2007). The ASSP is a widely recognized instrument designed to evaluate social functioning in children and adolescents with autism spectrum disorders (ASD). It measures social skills across three primary subscales: Social Reciprocity, Social Participation/Avoidance, and Detrimental Social Behaviors. Teachers, who systematically rated students' abilities in areas such as initiating and maintaining conversations, recognizing facial expressions, and engaging in peer interactions without external prompting, conducted the assessment.

Alongside the ASSP, a structured Teacher Observation Sheet was used to document student behaviors, engagement levels, and interaction patterns during VR sessions. This observation tool was designed to assess three key dimensions: Interest, encompassing enthusiasm and curiosity towards the VR exercises; Motivation, which evaluated students' persistence and willingness to overcome challenges; and Quality of Life,

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which measured students' ability to interact effectively within the VR environment. Teachers recorded their observations on a Likert scale and provided qualitative feedback to capture nuanced aspects of student engagement and behavior.

These teacher-led assessments provided insights into students' social interactions within the XR learning environment, offering qualitative support for the quantitative data collected through the ASSP. In addition, evaluation questionnaires were employed to collect further feedback from both students and teachers. These questionnaires incorporated Likert-scale assessments and open-ended questions to capture a comprehensive understanding of students' experiences with VR-based learning and its potential influence on their social skill development.

As a third data collection instrument, a questionnaire was developed for the learners to complete. It was intended to provide insights into the learners' perceptions—an aspect not captured by the first two instruments. However, the data collected through this method was not included in the analysis. The reasons for this decision are explained in more detail in Chapter 3.1 Presentation of Collected Data.

2.3 Data Analysis

The collected data was analyzed to assess the impact of XR-based learning environments on students' social skills and overall engagement. The analysis was performed using both descriptive statistics, measuring mean scores across three testing rounds, and paired t-tests to determine statistical significance in observed changes. The dataset included responses from the Autism Social Skills Profile (ASSP) and the Teacher Observation Survey, covering key dimensions such as Social Reciprocity, Social Participation, and VR perception, which included Interest, Motivation, and Quality of Life.

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The descriptive statistical analysis revealed numerical trends across the three evaluation rounds. In terms of social skills, fluctuations were recorded in Social Reciprocity, Social Participation, and Detrimental Social Behaviors. However, some dimensions remained stable across the rounds, indicating that certain social competencies were not significantly influenced by the XR environment. Regarding the teacher observations on VR perception, the data showed a decline in Interest and Motivation over time, while Quality of Life remained relatively consistent. This pattern suggests that while students initially exhibited enthusiasm for the VR exercises, their sustained engagement with the platform decreased.

To assess whether these observed changes were statistically meaningful, paired t-tests were conducted between different rounds. The results confirmed a significant increase in Detrimental Social Behaviors, with a p-value of less than 0.05, verifying a meaningful change over time. In contrast, Social Reciprocity and Social Participation did not show statistically significant improvements, suggesting that the VR experience did not lead to substantial development in these aspects of social skills. Additionally, a noticeable decline in Interest and Motivation was observed across the study period, with the statistical significance of these findings reinforcing the patterns identified in the descriptive statistics.

The results of the statistical testing are presented in the Results section, where the mean scores across all evaluation rounds provide a structured overview of the data. The correlation analysis, which examined the relationship between students' social skills development and their perception of the VR experience, also revealed that no strong correlation existed between increased social skills and VR engagement. This suggests that the XR intervention did not directly translate into measurable improvements in social behavior. However, a moderate relationship was identified between Motivation levels and Quality of Life, implying that students who remained engaged in VR sessions reported a

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more positive overall experience. This finding highlights the importance of maintaining student motivation to optimize the perceived benefits of XR learning environments.

By presenting these statistical findings separately from their interpretation, the subsequent sections will explore the significance of these trends and their broader implications. The Discussion section will provide an analysis of the potential reasons for the decline in motivation and engagement, while also considering how XR learning environments can be further refined to enhance social skills training.

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3. Results

3.1 Presentation of Collected Data

The results of the pilot study are based on two primary data sources: the Autism Social Skills Profile (ASSP) and the Teacher Observation Survey. The statistical analysis of these datasets provides insights into changes in social skills and engagement with the XR learning environment across three evaluation rounds.

Social Skills Profile (ASSP)

The mean scores across rounds for Social Reciprocity were 2.00 (Round 1), 2.02 (Round 2), and 1.94 (Round 3). For Social Participation, the means were 2.11 (Round 1), 2.10 (Round 2), and 2.09 (Round 3). The Detrimental Social Behaviors construct showed an increase over time, with mean scores of 1.92 (Round 1), 1.94 (Round 2), and 2.03 (Round 3).

Paired t-tests were conducted to determine whether the observed changes were statistically significant. The analysis showed that the increase in Detrimental Social Behaviors was significant between Round 1 and Round 3 ($t = 2.45$, $p = 0.012$). However, changes in Social Reciprocity ($t = -1.32$, $p = 0.27$) and Social Participation ($t = -0.91$, $p = 0.38$) were not statistically significant. These findings indicate that while social participation and reciprocity remained relatively stable, the increase in detrimental behavior was a significant trend.

Teacher Observation Survey Analysis

The Teacher Observation Survey evaluated three key dimensions: Interest, Motivation, and Quality of Life. The mean scores for Interest were 4.17 (Round 1), 3.97 (Round 2), and 3.79 (Round 3). Motivation followed a similar downward trajectory with scores of 3.48 (Round 1), 3.72 (Round 2), and 3.46 (Round 3). Quality of Life remained more stable, with scores of 3.43 (Round 1), 3.85 (Round 2), and 3.67 (Round 3).

Statistical testing revealed significant decreases in both Interest ($t = -2.25$, $p = 0.047$) and Motivation ($t = -2.81$, $p = 0.032$) between Rounds 1 and 3. Quality of Life did not

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show a statistically significant change (t = -1.12, p = 0.27), indicating that while students' enthusiasm for the XR experience declined, their perceived overall well-being remained stable.

Student Questionnaire

The student questionnaires collected during the study were not included in the subsequent analysis due to highly inconsistent response rates. Discussions with the teachers revealed that many students had adjusted their answers in an effort to please the instructor or to avoid drawing negative attention to themselves. This tendency toward socially desirable responding significantly limited the validity of the data. Consequently, it was decided not to take the student responses into account in the further evaluation.

3.2 Comparison of Methodologies

The pilot study employed two complementary methodologies for data collection: the Autism Social Skills Profile (ASSP) and the Teacher Observation Survey. While both instruments aimed to measure students' social skills and engagement with the XR learning environment, they differed in approach, data type, and level of subjectivity.

Teachers, who assessed student development across rounds based on their observations, completed the ASSP. This structured Likert-scale instrument allowed for standardized scoring across key constructs such as Social Reciprocity, Social Participation, and Detrimental Social Behaviors. However, while the ASSP provided quantifiable metrics, it was still subject to observer bias due to the teachers' individual interpretations of behavioral changes. Furthermore, since the assessment occurred at distinct intervals, it may not have fully captured fluctuations in student behavior between evaluation points. Similarly, the Teacher Observation Survey relied on educator assessments, focusing on three key dimensions—Interest, Motivation, and Quality of Life. This method provided a more immediate, context-sensitive evaluation of student engagement during XR learning experiences. However, because the survey required subjective teacher ratings, it was susceptible to expectation bias and variations in perception across different assessors.

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Comparing and evaluating these methods is challenging as each survey measured different aspects of student engagement and development. The Student Feedback Surveys, while designed to provide quick and direct insights into user experience, were ultimately excluded from the analysis. The response rate was inconsistent, and feedback from teachers indicated that students may have tailored their answers to align with perceived expectations or to avoid negative judgment. These factors raised concerns about the reliability of the data, leading to the decision to omit these responses from further evaluation. Future user-based assessments should take those issues into account.

The Teacher Feedback Surveys required detailed knowledge of students and involved interpretation of behavioral cues. While more reliable than student self-assessments, responses sometimes overlapped across categories such as motivation, interest, and interaction quality. The ASSP Assessments were the most time-consuming but allowed for detailed, structured evaluations. Some questions were ambiguous or context-dependent, requiring thorough teacher knowledge of each student. Teachers reported feeling uncertain in evaluating some aspects due to limited familiarity with individual student behaviors.

General reflections emphasized the importance of longer measurement periods and improved survey precision. Additionally, social skills development is influenced by broader experiences, such as daily interactions and aging, which may impact results. Future assessments may benefit from refining surveys to reduce ambiguity, incorporating post-session student interviews to improve response accuracy, and ensuring teachers have a comprehensive understanding of students before evaluating social skill development.

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4. Discussion

4.1 Interpretation of Results

The present study explored the impact of XR-based learning environments on students' social skills, engagement, and well-being. The results suggest a mixed impact, with stable social reciprocity and participation, a significant increase in detrimental social behaviors, and a decline in motivation and interest. These findings contribute to the broader discussion on the effectiveness of XR interventions for social skill development.

Existing research highlights the potential of VR-based interventions to enhance social skills, particularly among individuals with Autism Spectrum Disorder (ASD). Former research has consistently shown moderate to strong effects in improving communication, emotion regulation, and social interactions, especially in structured, immersive settings (Yang et al., 2025; Karami et al., 2021). Studies indicate that immersive VR is most effective for complex social training, whereas non-immersive VR is better suited for foundational skills (Yang et al., 2025). Furthermore, research comparing traditional and VR-based emotional training suggests that VR can accelerate the acquisition of social competencies, particularly in recognizing and responding to emotions (Frolli et al., 2022). However, the variability in effectiveness across studies underscores the importance of targeted intervention design and individual adaptability to XR environments.

Why did our study yield different results?

Despite the promising findings in previous research, the present study did not observe significant improvements in Social Reciprocity or Social Participation. Instead, a notable increase in Detrimental Social Behaviors was detected. Several factors may explain these discrepancies when compared to prior studies.

One potential explanation lies in the lack of structured social training within the XR environments used in this study. Many VR-based interventions that have demonstrated significant improvements in social skills are explicitly designed for

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social skills training, incorporating interactive simulations where participants can practice conversations, emotional recognition, and negotiation strategies (Karami et al., 2021). In contrast, the XR application used in the present study, while intended to foster social skill development, was not exclusively designed for this purpose. Its primary learning objectives also included promoting independence and safe navigation in public spaces. However, these specific skills were only partially assessed through the Social Skills Profile, which may explain the absence of a measurable impact on social behavior.

Differences in the target population may also have influenced the results. Many previous studies have focused on children and adolescents with Autism Spectrum Disorder (ASD), particularly those categorized as having high-functioning autism (HFA) (Yang et al., 2025). In contrast, the present study included adolescents and young adults aged 16 to 21, and no classification into high- or low-functioning subgroups was made. This decision was intentional, as it aligns with the standard procedures followed by the participating educational institution. However, the heterogeneous nature of the participant group may have contributed to greater variability in responses, making it more challenging to detect clear and consistent trends in social skill development.

Another crucial factor is the timeframe of the study. Data collection occurred over a period of three months, a duration that aligns with the recommendations of Bellini and Hopf (2007) for assessing behavioral changes using the Autism Social Skills Profile (ASSP). However, it is important to note that even the data collected in the third evaluation round may still reflect behavioral tendencies from the initial phase of the intervention. This limitation stems from the study being conducted within the time constraints of an EU-funded project, making it impossible to extend the measurement period. For future research, a longer intervention period is recommended to allow for a more comprehensive and reliable assessment of behavioral changes over time.

The method of data collection used in this study may also have influenced the findings. Studies that have reported significant improvements in social skills often relied on controlled behavioral observations within VR environments, rather than

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assessments conducted by educators or caregivers (Frolli et al., 2022). In this study, teachers who had direct experience with the students in an educational setting carried out both data collection methods. While this approach ensured that assessors were familiar with the participants and their behaviors, it also introduces the potential for observer bias, as teachers' perceptions and expectations may have unconsciously influenced their assessments. While it is believed that teachers were best suited for evaluating student progress in this context, their strong role in the assessment process must be acknowledged as a methodological limitation. This circumstance was further underscored by the student feedback, which could not be utilized due to issues affecting its validity and reliability.

The observed decline in motivation and interest over time further differentiates this study from prior research. While engagement with the XR environment decreased across evaluation rounds, it is important to emphasize that the VR unit used in this study was not a passive intervention. Students actively participated in the experience, interacting with the virtual environment and engaging in decision-making processes relevant to the learning objectives. Despite this active participation, motivation still declined over time, suggesting that initial novelty effects wore off and that additional engagement strategies may be required to sustain long-term interest. This contrasts with previous findings that have shown interactive VR environments to generally foster sustained engagement (Karami et al., 2021). To counteract potential declines in motivation, future XR-based interventions should incorporate more dynamic elements, such as adaptive challenges, progressive levels of difficulty, and increased user agency, ensuring that the learning experience remains engaging and meaningful throughout multiple sessions.

The increase in Detrimental Social Behaviors may also be linked to potential negative effects of XR on behavior. Some studies have raised concerns about sensory overload and frustration in immersive VR settings, particularly among children with sensory processing difficulties (Yang et al., 2025). While the results of this study suggest that frustration or overstimulation may have played a role in the increase in detrimental behaviors, this interpretation does not fully align with the generally

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positive feedback received on motivation and interest as well as Quality of Life. Moreover, teachers reported that the study began at a time when new class groups were forming. Based on their experience, students tend to express themselves more freely as they become more comfortable in their environment, which may include an increase in disruptive or socially inappropriate behaviors. This raises the possibility that the observed increase in detrimental social behaviors was partially influenced by external classroom dynamics rather than the XR intervention itself. However, due to the absence of a control group, it is not possible to definitively determine the extent to which these external factors affected the results.

Finally, the quality of the XR learning experience must also be considered. As with any educational intervention, individual learning outcomes depend not only on the student's engagement but also on the design and implementation of the learning material. The lack of a non-intervention control group makes it difficult to draw firm conclusions about the underlying causes of the observed trends. Future studies should incorporate control groups and alternative intervention conditions to enable a more precise evaluation of causal relationships between XR-based learning and social skill development.

4.2 Implications for Future Use of VR in Education

The findings of this pilot provide insights into both the potential benefits and challenges of using XR-based learning environments in educational settings. While previous research has highlighted the effectiveness of Virtual Reality (VR) in fostering social skill development and engagement, our study underscores the necessity of intentional design, targeted interventions, and sustained engagement strategies to maximize the educational impact of VR technology. Moving forward, several key implications must be considered for the effective integration of VR in education.

One of the most significant findings of this study was that social reciprocity and participation did not show significant improvements, and detrimental social behaviors increased over time. This suggests that for VR to effectively support social skill development, it must be explicitly designed to facilitate structured social interaction

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training rather than relying on incidental learning opportunities. Future VR applications should include interactive role-playing exercises, emotion recognition tasks, and real-time social feedback mechanisms. Research has shown that purpose-built VR interventions tailored to social learning objectives yield better outcomes than generalized learning environments (Karami et al., 2021; Yang et al., 2025). Therefore, integrating scenario-based social training into VR learning modules is essential to achieving measurable social skill gains.

A key challenge observed in this study was the decline in student motivation and interest over multiple rounds of VR exposure. While VR initially captured students' enthusiasm, engagement diminished over time, aligning with previous research that has indicated that VR-based learning must incorporate elements of adaptive interactivity to sustain student interest (Karami et al., 2021) and need a design with cognitive and affective user engagement in mind (Makransky and Lilleholt, 2018). This suggests that gamification elements, adaptive difficulty levels, and personalized learning paths should be prioritized in future VR educational tools. Providing students with agency in their learning process, such as allowing them to make meaningful decisions within the virtual environment, could help mitigate disengagement. Furthermore, a multi-modal approach that blends VR experiences with real-world social interaction and reflection sessions may further enhance learning retention and engagement.

The increase in detrimental social behaviors observed in this study suggests that some students may have experienced frustration, sensory overload, or difficulties adapting to VR-based interactions. This is consistent with prior studies that have raised concerns regarding the cognitive and sensory demands of immersive VR environments, particularly for individuals with sensory processing challenges (Yang et al., 2025). To address this, VR-based educational interventions must be designed with accessibility in mind, incorporating adjustable settings for sensory stimuli, customizable interaction speeds, and progressive exposure techniques. By allowing for individualized adaptations, educators can ensure that VR remains an inclusive and beneficial tool for a diverse range of learners.

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The study further highlighted the importance of teacher observations in assessing students' social skill development. While VR can provide structured social scenarios and controlled learning experiences, teacher guidance remains critical in helping students translate these experiences into real-world interactions (Parong and Mayer, 2018). Future implementations of VR in education should be paired with teacher-led debriefing sessions, in which educators can facilitate discussions, reinforce learning points, and guide students in applying new skills in daily life. Additionally, training programs should be developed to help teachers effectively integrate VR technology into their pedagogy, equipping them with strategies to assess and support students' learning within virtual environments.

Given the limitations of this study, future research should aim to incorporate control groups to better isolate the effects of VR interventions on social skill development. The absence of a non-intervention comparison group in this study makes it difficult to determine whether observed changes were directly caused by the XR intervention or influenced by external classroom dynamics. Additionally, future studies should consider longer intervention periods to assess whether extended exposure leads to greater improvements in social reciprocity and participation. Longitudinal studies would also help determine whether the decline in motivation observed in this study is a temporary effect or a more persistent trend that requires further pedagogical innovation.

The results of this study suggest that while VR has significant potential as an educational tool, its effectiveness depends on intentional design, structured social interaction training, and sustained engagement strategies. The integration of adaptive learning pathways, teacher-led instruction, and accessibility considerations will be critical in optimizing VR for educational use. As VR technology continues to evolve, future research should explore how personalized, gamified, and interactive XR experiences can maximize both student engagement and social skill development.

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5. Conclusion

This pilot study investigated the use of immersive XR environments to foster social skill development among students with autism spectrum disorders in a vocational education context. While the results did not indicate significant improvements in core social interaction metrics, the findings offer valuable insights into the design, implementation, and challenges of XR-based educational interventions for neurodivergent learners.

One of the key contributions of this study lies in its participatory approach, where students were not only research subjects but also actively involved in the design and testing of the VR unit. This highlights the importance of learner-centered development in educational technology design, particularly for special needs education.

The observed decline in engagement suggests that sustained interactivity, gamification, and adaptive design should be central considerations in future XR applications.

For practitioners, the results emphasize the need for targeted training content, teacher support, and continuous evaluation mechanisms when implementing VR in special education. Teachers play a critical role not only in assessing behavioral change but also in guiding students to transfer virtual learning into real-world contexts.

Future research should build on these findings by incorporating longitudinal designs, control groups, and diverse XR scenarios tailored to specific social skill domains. By further refining immersive learning tools, the field can move closer to creating inclusive, motivating, and effective learning environments for students on the autism spectrum.

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