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ORIGINAL ARTICLE

Stepping into *Virtual School*: a pilot study of VR-based social skills training (SST) integrating emotion- and knowledge-based approaches

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Abstract
Social Skills Training (SST) is widely used to improve social functioning, but more research is needed on specific training components to maximize its effectiveness. Recent VR-based SST programs have primarily focused on knowledge transfer, lacking a comprehensive approach. This pilot study examined the feasibility of *Virtual School*, a newly developed VR-based SST program that integrates both knowledge- and emotion-based strategies. Thirty-one non-clinical children and adolescents participated in three training modules targeting empathy, social communication, and anger control. Self-evaluations were obtained using a Visual Analogue Scale (VAS) embedded in the VR environment before and after each module. The program showed acceptable usability and engagement, and partial support was found for the concurrent validity of the VAS. Preliminary outcomes indicated significant improvements in social communication and anger control, with the greatest gains in anger control, whereas the empathy module did not show significant changes. These findings underscore the feasibility and potential of the VR-based SST program in enhancing social skills by combining knowledge- and emotion-based strategies. VR technology allows realistic simulations of social environments and emotion elicitation, supporting more effective social skills training. Further research with larger samples, improved assessment methods, and advanced program versions is recommended to strengthen evidence of effectiveness and broaden generalizability.

Keywords Social skill training · Virtual reality · Empathy training · Social communication training · Anger control training

1 Introduction

Social skills are a fundamental resource that reflects a child's ability to navigate the social and emotional demands of their environment (Arda and Ocak ; Dawson et al. 2012; Eisler and Frederiksen 2012). Extensive research demonstrates that strong social skills positively impact psychological well-being, academic success, and adaptive functioning throughout life (Denham ; Denham et al. 2012; Bierman and Montamedi, 2015). However, the development of these skills can be hindered by factors such as genetics, early traumatic events, parenting styles, temperament, neurological differences, and mental health conditions (Constantino et al. ; Kurczewska et al. 2024; Ometto et al. 2016; Schafer and Schiller). Deficits in social skills are linked to the onset and persistence of emotional and behavioral disorders during childhood and adolescence (Derntl and Habel 2011; Hinshaw ; Segrin and Flora 2000; Quinn et al. 1999).

Social Skills Training (SST) is among the most widely adopted and empirically supported interventions for improving social functioning. SST programs typically target core domains such as interpersonal problem-solving, social information processing, and adaptive social behaviors (Cooper et al. 1999; McClelland et al. 2007; Williams White et al. 2007). Meta-analyses generally report positive outcomes (Schneider and Byrne 1985; Beelmann et al. 1994), but effect sizes vary substantially across studies (de Mooij et al. 2020; Durlak et al. 2011). One explanation for

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this variability lies in the heterogeneous composition of SST programs. De Mooij et al. (2020) demonstrated that psychoeducation (exercises focused on knowledge transfer) and skill-building components (exercises aimed at enhancing interpersonal communication skills)—largely knowledge-based interventions—tended to produce stronger effects. In contrast, psychophysical components (e.g., relaxation, posture improvement, self-confidence building, and trust enhancement) and cognitive-emotional components (e.g., emotion recognition, cognitive restructuring, impulse control, and mindfulness) yielded weaker or less consistent outcomes.

These findings indicate that the effectiveness of SST may depend not only on what is trained but also on how and where training is delivered. Traditional SSTs are often conducted in structured, decontextualized environments such as clinics or classrooms (Halford and Hayes 1991; Liberman and Eckman 1989; Spence 2003; Wang et al. 2012). While such settings provide opportunities for instruction and role-play, they may fail to replicate the dynamic and emotionally salient contexts of everyday social interactions (Ke et al. 2022; Parsons and Mitchell 2002). Emotion-based components—including empathy, emotion regulation, and perspective-taking—particularly require vivid, context-dependent experiences to be effectively acquired (Ghasemian and Kumar 2017; Spence 2003). However, conventional formats offer limited ecological validity and insufficient opportunities for realistic practice and feedback (Parsons and Mitchell 2002; Corrigan and Basit, 1999; Scott and Dixon 1995). This contextual mismatch may help explain why emotion-based components often show weaker outcomes compared with knowledge-based ones.

Recent advances in Virtual Reality (VR) offer a potential means to overcome these barriers. VR enables users to engage in immersive, lifelike scenarios that closely approximate real-world environments, thereby creating conditions conducive to practicing both behavioral and emotional skills (Gillies and Pan 2018; Parsons and Mitchell 2002). However, evidence on VR-based SST also remains mixed. Systematic reviews and trials have documented positive effects on social behavior (Coffey et al. 2017; Craig et al. 2016; Kampmann et al. 2016), but effect sizes remain inconsistent. Howard and Gutworth (2020) identified that most VR-SST programs prioritized knowledge-based instruction, which yielded significant training effects, whereas emotion-based or combined approaches were rarely implemented and showed less consistent outcomes. Importantly, the limited number of emotion-based studies makes it premature to draw firm conclusions about their efficacy. Indeed, several more recent studies outside the scope of these reviews have demonstrated improvements in socio-emotional functioning through VR-integrated emotion-based training (Papoutsi et al. 2021; ; Wang et al. 2021). Taken together, these findings suggest that VR holds promise as a platform for enhancing SST, but that more rigorous research is needed to establish its effectiveness, particularly for emotion-based components. When appropriately designed, VR may uniquely benefit such components by eliciting authentic emotional responses and simulating socially complex contexts that traditional methods cannot easily recreate (Lorenzo et al. 2016; Walker and Venker Weidenbenner 2019).

Against this backdrop, we developed *Virtual School*, a VR-based SST program that integrates both knowledge-based and emotion-based approaches. The program is organized into three modules targeting empathy, social communication, and anger control, grounded in the cognitive-social learning model. This dual-focus design aims to address the variability observed in prior SST research by combining didactic, knowledge-oriented exercises with immersive, emotion-based experiences. The present pilot study sought to evaluate the program's feasibility in terms of acceptability (participation and dropout rates), usability (subjective immersion and fatigue), and preliminary outcomes. Preliminary outcomes were assessed using an embedded Visual Analogue Scale (VAS) to capture participants' real-time subjective experiences during training (Aitken 1969; McCormack et al. 1988). While observable behavioral change typically requires multiple training sessions (Spence 2003), subjective experiences represent critical early markers of self-perceived social competence (Elliott and Gresham 1993; Durlak et al. 2011). Concurrent validity of these measures was also examined against established clinical scales to strengthen the interpretability of the findings.

Our study posits the following hypotheses: (1) The acceptability and usability of the program are expected to be at an appropriate level; (2) baseline VAS scores within the VR program will show significant correlations with relevant psychological characteristics, as assessed by both parent- and self-report questionnaires, thereby supporting the concurrent validity of the program; and (3) participants will demonstrate improvement in their self-evaluations following the use of the VR program. Additionally, we will further investigate the relationships between training parameters and various psychological factors, including mood symptoms such as depression and anxiety, which are well-established as influencing the expression of social skills (Bolsoni-Silva and Loureiro ; Fauber et al. 1987; Levitan and Nardi 2009; Segrin 2000; Segrin and Taylor 2007).

2 Materials and methods

2.1 Participants

Our study aimed to achieve a power of 0.75 with a moderate effect size of d = 0.50. Using G*power software, a total sample size of 30 participants for a two-tailed *t*-test and 15 participants for ANOVA was determined, considering a significance level of 0.05 (Anderson et al. 2017; Faul et al. 2007). To account for potential attrition, we recruited 34 children and adolescents through online advertisements. Screening for mental illnesses involved administering the Wechsler Intelligence Scale for Children ver. 4 (WISC-IV) and Mini International Neuropsychiatric Interview-KID Ver. 6.0 (MINI-KID 6.0) conducted by a psychiatrist or clinical psychologist (Gwak, Oh, and Kim, 2011; Sheehan et al. 2010). The Korean Child Behavior Checklist (K-CBCL) was completed by parents to ensure absence of problematic behavior and emotion (Oh and Lee 1990). Three individuals were excluded due to significant depression or ADHD-related symptoms. All participants signed an informed consent.

2.2 General procedure

Participants underwent an assessment of their demographic and clinical characteristics, followed by psychological evaluations. They were then instructed on the proper use of the VR equipment, including how to operate the VR controllers to interact with the virtual environment. Seated in a comfortable chair within a quiet room, participants used a head-mounted display (HMD) to immerse themselves in the four-sided VR setting (Sharples et al. 2008). They followed the text and audio instructions provided within the VR program to complete the training tasks in a predetermined order. With no time constraints on each task, the total duration varied among participants, ranging from 25 to 40 min. After completing the VR tasks, participants were asked to complete questionnaires assessing the usability of the VR program.

2.3 VR-based social skill training

2.3.1 Virtual school

The program integrates a combination of therapeutic components designed to enhance social skills by drawing on both knowledge- and emotion-based strategies. However, the focus shifts depending on the specific characteristics of the skills being targeted. For instance, the empathy training module primarily emphasizes cognitive-emotional elements, such as recognizing and expressing emotions. In contrast, social communication training concentrates on developing conversational skills applicable across diverse social contexts. The anger control training module adopts a more comprehensive approach, integrating both cognitive-emotional and skill-building techniques to address anger regulation effectively. Psychoeducation, along with related psychophysical components, is incorporated into all three modules to maximize the program's overall benefits. Below is a explanation of the theoretical frameworks and detailed content of each training module.

Module 1. Empathy Training.

The tasks in the empathy training targeted the cognitive-emotional component, aiming to enhance the ability to understand one's own emotional responses and to adopt the perspectives and feelings of others (Goldstein and Michaels 2021; Paulus and Meinken 2022). The training consisted of two tasks, which were presented sequentially. Task 1, a preliminary step to Task 2, aimed to enhance individuals' emotional self-recognition. In a virtual classroom, participants were asked by the teacher to express their current mood by labelling it with an emotional word. They were then asked to rate the intensity of the emotion using 0–100 Emotion Thermometer and to elaborate on the context in which the emotion had been elicited. Task 2 focused on promoting to recognize other's emotion and expressing empathy in four distinct VR scenarios (Table 1). In all situations, the participant was asked to label the friend's feeling using an emotional word and to deliver a voice message in a sympathetic and helpful manner. Self-competence in 'perspective taking' and 'empathic concern' were evaluated based on two questions, "How much can you adopt perspectives of your friends?" and "How much do you consider your friend's feelings?" before and after the training using a 0 ('not at all')-100 ('very much') VAS (Fig. 1a). The mean of the two VAS scores was referred to as the *empathy score.*

Module 2. Social Communication Training.

This training module was developed to enhance communication skills, particularly in the realm of pragmatic language abilities. Successful social conversation hinges on socio-cognitive mentalizing, alongside key cognitive functions such as inhibitory control, which helps individuals resist the impulse to center discussions around personal interests, and working memory, which supports the ability to sustain and update conversational topics in real time (Abbot-Smith et al. 2023; Baddeley 1992; Baixauli-Fortea et al. 2019; Hughes and Leekam 2004). By focusing on these foundational skills through a knowledge-based approach, the module aims to provide participants with a structured framework for improving their communicative competence in social contexts (Craig-Unkefer and Kaiser 2003; Gresham and Elliott 1993; Ladd and Mize 1983). When participants began the task, they were placed in a virtual classroom and

Table 1 Brief description of the *Virtual School* activities

Module 1. Empathy training		
Task 1. Self-recognition		
Description: The virtual teacher asked users to express their mood by labeling them with an emotional word and rating intensity using a 0–100 Emotion Thermometer		
Task 2. Expressing empathy		
Description: Users were asked to recognize others' emotions and express empathy in four VR scenarios		
Situations		
	Death of a friend's dog	The user gets to know that the dog of an intimate friend euthanized due to terminal cancer
	Congratulate a friend	A friend luckily wins the fabulous giveaway
	Give comfort to a friend	The friend who had been bullied at school confessed feelings of worry and sadness
	Express worries	A friend shares the terrifying experience of a suspicious person chasing after her on her way home last night
Module 2. Social communication training		
Description: Users made an attempt to initiate or join the conversation with the friends by expressing their thoughts and feelings verbally following the audio-guided instructions		
Situations		
	A new semester	Exchange greetings and introductions with new friends
	Time for class end	Express the feeling like to hang out with friends after school
	A group activity	Suggest making up the group together to friends for class activity
	Recess time	Friends are talking about the voluntary activity which they are supposed to participate in this week. The user suggests joining them
	A group discussion	Speak out one's opinion confidently in discussion
Module 3. Anger control training		
Task 1. Self-statement		
Description: Users learned the calming self-talk to regulate emotions effectively. They applied the technique using strategies of deep breathing and relaxation, challenging negative thoughts, and generating positive statements that counteract negative thoughts		
Situations		
	In a computer room	Mischievous seniors start an argument and force the user out of the computer room while the user is working on a school assignment in the computer room.
	Board game	When the user and some friends are playing a game of Jenga, another friend comes closer and shake the table to collapse deliberately
	A new mobile phone	A friend drops the user's new mobile phone by mistake; however, he makes no apologies and rather blames the user for not putting a cell phone case on
	Spill milk	A classmate spill milk on the user's desk unwatchfully and the desk is soaked with milk. But he twists the thing by blaming the user putting the milk on the corner of the desk
Task 2. I-message		
Description: Users were asked to take responsibility for others' feelings and communicate using a specific sequential format: 1) identify the emotion, 2) describe others' behavior, and 3) express the impact and their needs		
Situations		
	Art homework	A friend ridicules and devaluates the user's completed art homework
	New hairstyle	Some classmates laugh at user's new hair style
	A pen as a gift	A friend borrows the user's pen which was given as birthday present, and after a while the pen is broken by dropping. He says, "This is just a cheap knockoff!"

Table 1 (continued)

	Leave school early	The user leave school early because of illness. As soon as the user come out of the school, one teacher scolds the user, misconstruing the situation as playing truant

prompted to choose one of five situations that could occur in real school life: 1) a new semester, 2) the end of class, 3) a group activity, 4) recess time, 5) a group discussion (Table 1). After selecting a situation, the virtual environment transitioned to a scene involving interaction with virtual classmates. Voice guidance instructed participants to observe and listen to their surroundings, providing detailed explanations of the circumstances to ensure understanding. Participants then attempted to *initiate* and *join* conversations with the friends by expressing their thoughts and feelings verbally (Chezan et al. 2020; LeCroy 2008);. If they pressed the 'help' button, additional instruction or examples were provided. Participants evaluated two questions asking their subjective competence in communication skills using a 0–100 VAS scale before and after the task (Fig. 1b). The average of these two VAS scores was *social efficacy score*.

Module 3. Anger Control Training.

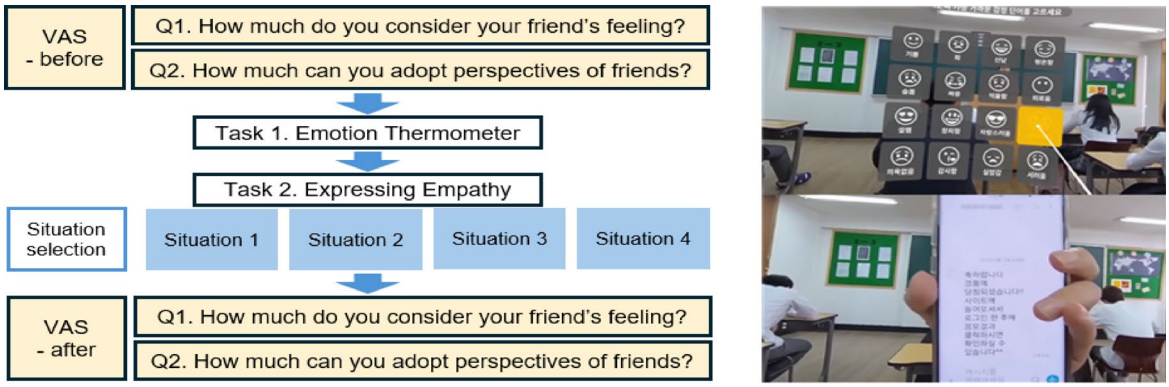
The anger control training involved practicing cognitive-behavioral methods, assertiveness techniques, and physical relaxation exercises for anger management, adopting a comprehensive approach that incorporated both skill-building and cognitive-emotional components (Day et al. 2008; DiGuiseppe and Tafrate 2003; Effendi and Mardiyah 2020; Rosner 2011). The training consisted of two tasks, where participants engaged in both psychoeducation and interactive role-playing sessions. In Task 1, participants received psychoeducation on *self-statements*, a fundamental technique for anger management (Dowd 2002; Dush et al. 1983). The lecture provided an overview of three specific types of self-statements—self-talk, thought-stopping, and relaxation—accompanied by a demonstration from a virtual student. Following the lecture, the role-playing involved four distinct anger-provoking scenarios that could realistically occur in a school setting. Each participant rated their subjective anger on a 0–100 VAS immediately after each anger-provoking situation. They then rated their level of anger repeatedly after applying the self-statement technique (Fig. 1c). The VAS scores were referred to as the *anger score* to quantify participants' levels of anger. In task 2, participants were introduced to the *I-message* communication skills, which facilitates assertive and nonviolent expression of feelings (Bruce and Berghuis 2011; Feindler 1995; Tsai 2019). Participants were asked to take responsibility for other's feeling and communicate using a structured sequential format; 1) identify their emotion (e.g. "I feel angry") → 2) describe the other person's behavior (e.g. "When you interrupted me") → and 3) express the impact and their own needs (e.g. "It made me feel disrespected, and I would appreciate it if you could let me finish speaking") (Beccio, 1994; Gordon 2000). During the role-playing session, participants applied the I-message skill in four different anger-provoking situations (Table 1). They were also asked to select and apply one of the three types of self-statements learned in Task 1, followed using the I-message technique to appropriately express their anger. Visuo and audio guided instructions were provided to assist them. As in Task 1, participants rated their subjective anger, referred to as the *anger score* before and after applying both the self-statement and I-message techniques using the VAS scale (Fig. 1c).

2.3.2 Virtual environment

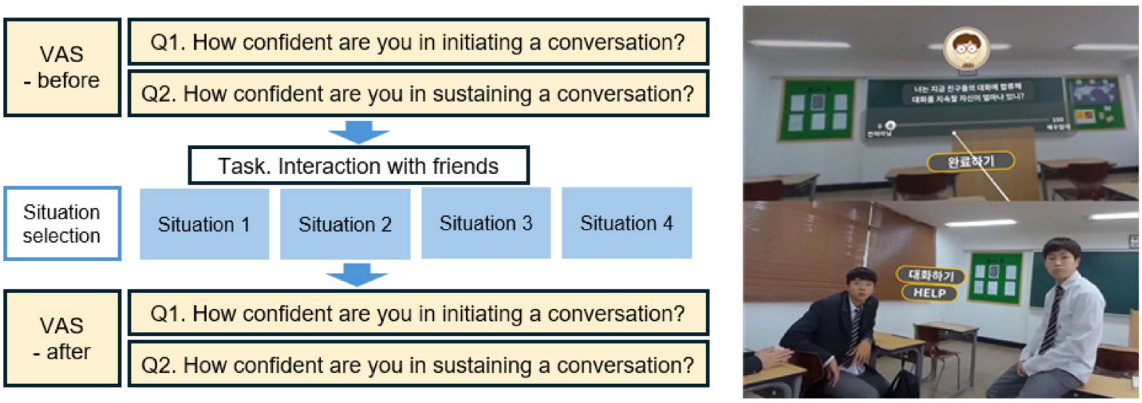
The VR program consists of three training modules with multiple tasks designed to provide diverse scenarios that simulate real-life school situations. Sitting on a comfortable chair in a quiet room, participants used a head-mounted display (HMD) device to enter the four-side immersive VR situation, delivered in a first-person point of view, allowing for great fidelity and interaction with virtual environment. All tasks in the program were recorded in 360° panoramic video, featuring of avatars or professional actors performing according to a pre-made scenario. The VR system was developed on a mobile-based platform, with the content designed using Unity 5.6.5 f1 software (Unity Technologies, San Francisco, CA). The program was downloaded on a Samsung Galaxy 8 + smartphone and used with a Samsung Gear VR (Samsung Electronics, Seoul, Korea). The program connected to a server that encoded the demographic information and the user type data collected during testing.

2.4 Psychological measurements

All Participants completed several self- and parent-report assessments before the VR tasks. The Validity of the assessment tools within the VR program was evaluated using specific questionnaires corresponding to each training module; the Interpersonal Reactivity Index (IRI) for empathy training, Social Self-Efficacy Scale (SSES) for social communication training, and State-Trait Anger Expression Inventory (STAXI) for anger control training. The scores of the above questionnaires are expected to be positively correlated with baseline scores on the VR tasks. Psychological states were assessed using the Children's Depression Inventory(CDI) and the State-Trait Anxiety Inventory (STAI). The Presence



(a)



(b)

(c)

Fig. 1 **a**. Schematic diagram including measuring process and screenshots of the empathy training in *Virtual School*. **b**. Schematic diagram including measuring process and screenshots of the social communication training in *Virtual School*. **c**. Schematic diagram including measuring process and screenshots of the anger control training in *Virtual School*

Questionnaire (PQ) and the Simulator Sickness Questionnaire (SSQ) were administered to evaluate the usability of our program. Below is an elaboration of each questionnaire.

Interpersonal Reactivity Index (IRI).

The IRI, developed by Davis (1980), is one of the most widely used self-report questionnaires for assessing individuals' empathic tendencies and is frequently employed to measure the effectiveness of empathy training (Haut et al. 2019; Paulus and Meinken, 2022). It evaluates four components: fantasy (the tendency to identify with fictional characters), perspective taking (the ability to adopt others' viewpoints in everyday situations), empathic concern (the tendency to feel compassion and sympathy for others' misfortunes), and personal distress (the propensity to feel discomfort in response to others' distress). Each dimension is measured with 7 items, totaling 28 items overall. In this study, only two subscales—perspective taking and empathic concern—relevant to our training program were used. Responses were scored on a Likert-type scale ranging from 0 to 4.

The Social Self-Efficacy Scale (SSES).

The Social Self-Efficacy Scale (SSES), one of the subscales of theSelf-Efficacy Scale (SES; Sherer et al., 1982), measures an individual's confidence in their abilityto perform effectively in social situations. The SSES consists of six items, with responses rated ona 5-point Likert-type scale. Previous studies have reported acceptable internal consistency forthe SSES, with coefficient alpha values ranging from .71 to .76 (Sherer et al., 1982). Scores on theSSES were expected to be positively correlated with baseline VAS scores obtained during the VRtasks.

Social Skills Rating System (SSRS).

The Social Skills Rating System (SSRS; Gresham and Elliott, 1990) is a standardized, norm-referenced checklist designed to evaluate an individual's social functioning. Responses are rated on a Likert scale from "0" (never) to "2" (very often), across 30 to 40 items, which collectively contribute to a total social skills score. The SSRS exhibits high internal consistency and acceptable test–retest reliability (Van der Oord et al. 2005). Given the use of various age-specific versions of the SSRS in this study, total raw scores were converted into t-scores for analysis. The SSRS will be employed as a supplementary measure to the SSES for exploring preliminary intervention effectiveness.

State-Trait Anger Expression Inventory (STAXI).

The Korean version of the STAXI questionnaire was used (Cronbach's $\alpha = 0.72$) (Lee and Cho 1999; Spielberger 1988). It is a 44-item inventory which measures state anger, trait anger and anger expression. For this study, only three subscales related to anger expression, which assess how respondents behave when angry or furious, were included. The 'Anger In' scale measures the frequency of anger suppression, the 'Anger Out' scale measures the frequency of anger expression toward others, and the 'Anger Control' scale measures the frequency of attempts to actively modify and control the experience of anger. The sum score of each subscale was used for the analysis.

Children's Depression Inventory (CDI).

The CDI (Kovacs, 2014) is a widely used self-report scale designed to assess depression in school-age children and adolescents. The CDI consists of 27 items, each of which allows the child to select among alternatives on a 3-point scale. Adequate reliability and validity have been reported (Saylor et al. 1984). The total score of the CDI was used to examine whether the degree of depression in participants is related to the effect of VR training.

State-Trait Anxiety Inventory (STAI).

The State-Trait Anxiety Inventory (STAI) is a self-administered questionnaire that provides a reliable measure of anxiety (Spielberger et al. 1971). It consists of two subscales: state anxiety (S-anxiety), which assesses how individuals feel "right now" (reflecting temporary anxiety in specific situations), and trait anxiety (T-anxiety), which evaluates how individuals generally feel (representing their overall tendency to experience anxiety). Each subscale contains 20 items, with total scores ranging from 20 to 80. While there is no formal cut-off score, a total of 40 or higher is typically considered indicative of elevated anxiety levels. For participants under 12 years old, the children's version of the STAI (STAI-C), was used (Spielberger, 1973).

Presence Questionnaire (PQ).

To assess the level of presence, the psychological feeling of *being there* within the VR environment, we employed the PQ version 3.0 (Witmer et al. 2005). The PQ originally includes 29 items, each rated on a 7-point Likert scale with Cronbach's alpha values reported to range from 0.57 to 0.89 (Witmer et al. 2005). The total possible scores range from 29 to 203, with 0–67 indicating low presence, 68–133 indicating medium presence, and scores above 133 indicating high presence. For this study, we included 22 items focused on adaptation, involvement, or interface quality, while excluding 7 items which were not relevant to our VR program. As a result, the adjusted total score range was 22–154.

Stimulator Sickness Questionnaire (SSQ).

The SSQ was employed to evaluate the level of simulator sickness experienced during the test (Bruck and Watters, 2009, Kennedy et al. 1993). Symptoms were rated on a 4-point Likert scale from 0 to 3, and subscale scores were calculated for nausea, oculomotor disturbances, and disorientation. Higher scores reflect greater levels of VR-induced sickness.

2.5 Statistical analysis

Descriptive statistics were used to examine the demographics, psychological assessment data. We confirmed the normality of the data using the Shapiro–wilk test, skewness and kurtosis test, and visually inspecting Q-Q plots. Pearson correlation coefficients between VAS scores and psychological assessment scores were calculated. 2 (time) X 2 (task) repeated-measures ANOVA was conducted to compare the VAS scores in each training module. The sphericity assumption in repeated-measures ANOVA was satisfied with Mauchly's W approaching 1. Effect sizes were calculated in $\eta 2$. Additionally, the VAS change rate was computed in order to quantify the effect using the formula of [(preVAS score)-(postVAS score)/preVAS score], with higher value meaning greater effectiveness (Jo et al. 2022). Comparison of VAS change rates between the tasks in each training module was analyzed by paired t-test. The association between VAS change rate and psychological assessment score was also analyzed. Statistical significance was accepted at an alpha level of 0.05. All analyses were performed using the SPSS 26.0 (SPSS Version 26.0; IBM Corporation, Armonk, NY, USA).

3 Results

3.1 Demographic characteristics

Descriptive statistics for demographic information and psychological scale scores obtained in the study are presented in Table 2. A total of 31 students who met the inclusion criteria participated, with the final sample size varying from 25 to 31 depending on the training module. In the social communication training, two participants did not complete the VR task, and four data points were excluded due to random responses or outliers identified in the normality test. In the anger control training, one participant did not complete the task, and two were identified as outliers. Table 2 provides the age and sex ratio of the participants, along with the mean scores for full scale IQ (FSIQ), CDI, STAI, PQ and SSQ. None of the participants showed clinically significant depression or anxiety scores (CDI = 9.19–9.91, STAI = 58.00–59.64). The mean scores and standard deviation (SD) for SSQ and PQ are also presented in Table 2.

Table 2 Demographics and psychological characteristics

	Empathy training	Social communication training	Anger control training
N (M/F)	31 (11/20)	25 (8/17)	27 (10/17)
Age (years)			
M/SD	12.70 (1.21)	12.72(1.40)	12.48 (1.40)
range	11–15	10–15	10–15
FSIQ	108.83 (10.50)	108.92 (10.52)	108.70 (11.26)
CDI	10.30 (5.88)	9.88 (5.61)	9.56 (5.74)
STAI	60.93 (11.47)	60.16 (11.59)	58.63 (11.08)
PQ	112.57 (16.59)	112.92 (18.09)	113.30 (18.89)
SSQ	12.76 (3.46)	9.33 (2.27)	11.22 (3.15)

3.2 Hypothesis 1. Acceptability and usability of the *Virtual School*

Although data from 4 to 6 participants were excluded from the analysis due to dropout or data quality issues (e.g., outliers, random responses), at least 80% of participants successfully completed the VR program without experiencing technical discomfort or psychological resistance. Regarding usability, mean scores and standard deviation of PQ and SSQ are provided in Table 2. Although 7 items were excluded, the PQ scores ranged from 112.57 to 113.30 indicating a medium level of the original version (0–67:low, 68–133:medium, ≥134:high). Moreover, the mean SSQ scores ranged from 9.33 to 12.76, which were lower than the previously reported mean score of 29.9. The mean SSQ scores indicated an acceptable level of cybersickness in our program, while PQ scores reflected adequate user engagement. These results imply that the VR program strikes a balance between immersive engagement and user comfort, which are key factors in usability.

3.3 Hypothesis 2: Correlations between baseline VAS scores and psychological assessments

A significant correlations were found between the baseline empathy score in VR and the perspective taking subscale in the IRI (Supplementary Table 1). Baseline social efficacy score in the VR program were significantly correlated with the SSES ($r(25) = -0.476$). Meanwhile, baseline anger level was not correlated with STAXI subscales. Both empathy scores and social efficacy scores showed strong positive correlations with the STAI, with particularly notable relationships with state anxiety. Additionally, in the empathy training, significant correlations were found with the CDI (see supplementary Table 1).

3.4 Hypothesis 3: Improvement in self-evaluation measured by VAS after VR experience

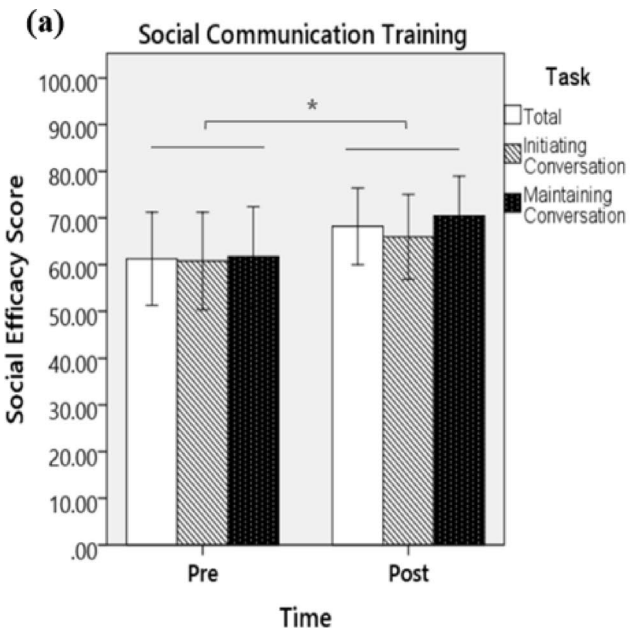
The mean and standard error of the VAS for each training module are shown in Table 3. There was no interaction effect in social communication training; however, the main effect of time (pre- and post-training) was significant, with a medium effect size [$F(1, 24) = 6.684$, $p = 0.016$, $\eta 2 = 0.218$]. There was no significant effect of task (Initiating

Table 3 Descriptive information of the behavioral parameters in each training module

	N	pre-training	post-training
		M (SE)	
Empathy score	31	78.68 (2.69)	77.95 (2.63)
Perspective taking		77.61 (2.90)	79.55 (2.87)
Empathetic feeling		79.74 (2.85)	76.36 (2.66)
Social efficacy score	25	61.26 (5.00)	68.20 (4.10)
Initiating conversation		60.80 (5.22)	65.96 (4.55)
Maintaining conversation		61.72 (5.35)	70.40 (4.27)
Anger score	27	48.13 (4.69)	42.93 (4.66)
self-statement		58.89 (4.57)	55.43 (5.26)
I-message		37.36 (4.61)	30.43 (4.47)

conversation and maintaining conversation), and the change rate between the tasks also did not differ significantly (Fig. 2(a)). In anger control training, there was no interaction effect, but both main effects of time (pre- and post-training) and task (self-statement and I-message) were significant (Fig. 2(b)). Effect sizes were large for time [$F(1, 26)=70.40$, $p=0.000$, $\eta 2 = 0.730$] and medium for task [$F(1, 26)=6.035$, $p=0.021$, $\eta 2 = 0.188$] (Table 4). The main.

effect of task was significant, indicating slightly higher anger scores in the self-statement condition compared to the I-message condition. The VAS change rate, referred to as the anger control rate, was significantly higher in I-message rather than for Self-statement ($t(26)= -3.369$, $p=0.02$). No significant change was observed before and after empathy training, and the change rates between the two tasks were also not significant.



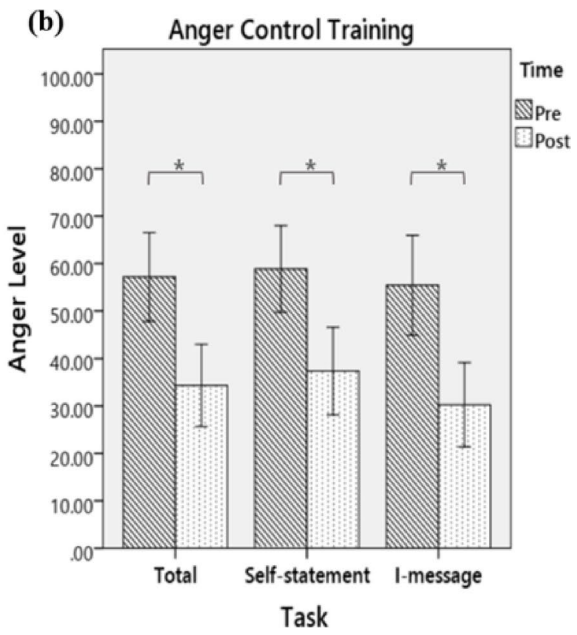


Fig. 2 Changes in VAS parameters before and after training. **a** Social communication training: a significant main effect of time was observed. **b** Anger control training: significant main effects of both time and task were observed. Different labels were applied to the x- and y-axes in each panel for clarity and ease of interpretation

Table 4 Statistical results of social communication training and anger control training

		df	*F*	*p*	*η2*
Social communication Training	Time * Task	24	2.134	0.157	
	Time	1	6.684	**0.016***	0.218
	task	1	0.743	0.397	
Anger control training	Time * Task	26	1.862	0.184	
	Time	1	6.035	**0.000*****	0.730
	task	1	70.400	**0.021***	0.188

3.5 Further analyses: relationships between the training effects and psychological measures

Since there was no significant training effect in the empathy training, the data of the other two modules were included. In anger control training, significant associations were identified between the anger control rates in both tasks and state anxiety ["Self-statement": $r(27)= -0.436$, $p=0.023$, "I-message": $r(27)= -0.476$, $p=0.012$), SSRS total score ["Self-statement": $r(27)=0.424$, $p=0.027$, "I-message": $r(27)= -0.398$, $p=0.040$) (supplementary Fig. 1). In the social communication training, the change rate of the VR social efficacy score was not significantly correlated with any psychological measures.

4 Discussion

In this preliminary study, we examined the usability of a newly developed VR-based SST for non-clinical youth. Regarding the hypothesis 1, results showed adequate

acceptability, with dropout rates lower than typically observed in this age group. PQ and SSQ scores further indicated that the program achieved a favorable balance between presence and minimal discomfort, consistent with prior findings that immersion and cybersickness are inversely related (Weech et al. 2019). These outcomes suggest that the program meets usability standards and can be further optimized by leveraging VR's advantages, such as spatial flexibility and interactive feedback (Mütterlein and Hess 2017).

With respect to Hypothesis 2, concurrent validity was supported for the empathy and social communication modules, which correlated significantly with established assessments. In contrast, no correlation was observed in the anger control module. This discrepancy is best understood as a construct difference: the VAS captures immediate, state-level anger intensity, whereas the STAXI assesses trait-like expression styles. Rather than indicating a validity failure, this distinction highlights the suitability of the VAS for assessing acute affective responses to anger triggers, which are closely aligned with the intervention's objectives. The absence of correlation is therefore unsurprising and consistent with the divergent constructs assessed. To strengthen construct validity in future research, the VAS could be complemented with additional state-based measures and physiological indicators (e.g., HRV, EDA) to provide convergent evidence of anger regulation in VR contexts.

Further analyses indicated significant associations between baseline VAS scores and anxiety across all three training modules. Notably, in the anger control module, anger control rates showed a negative correlation with state anxiety, implying that elevated anxiety may attenuate training effects. These findings indicate that individuals with higher levels of anxiety may feel less confident in utilizing social skills, consistent with evidence that emotional instability affects self-evaluation in SST (Antshel et al. 2011; Moe and Zeiss 1982; Segrin 2000). From this perspective, a VR-integrated approach could be a promising alternative to traditional interventions. Prior research has shown that VR-based programs reduce anxiety symptoms, including anxious arousal and avoidance in social situations (Firth et al. 2018; Kim et al. 2017). Drawing on exposure therapy principles (Foa 2011), VR offers customizable real-life scenarios, a controlled and safe environment, and opportunities for repetitive practice. Our program therefore shows potential not only for alleviating emotional distress but also for strengthening specific social skills through an immersive and supportive learning environment.

Turning to Hypothesis 3, significant improvements were observed in both social communication and anger control training. The social communication module, which emphasized knowledge-based skill-building, led to higher social efficacy scores, indicating enhanced subjective social confidence after a single session. This improvement likely reflects gains in pragmatic language competence and socio-cognitive mentalizing, as participants practiced sustaining topics, respecting peer perspectives, and inhibiting self-centered responses (Matthews et al. 2018; Abbot-Smith et al. 2023). Repeated role-play tasks further functioned as behavioral rehearsal, consolidating conversational strategies through active practice (Van Hasselt et al. 1981). The anger control module demonstrated the largest VAS changes, reflecting reduced immediate anger intensity. In this module, participants were exposed to anger-provoking scenarios that integrated knowledge-based skill-building with emotion-focused management strategies (Howard and Gutworth 2020). A comparison of techniques showed that the I-message strategy produced significantly greater reductions in VAS scores than self-statements, indicating superior efficacy in anger regulation. Unlike self-statements, the I-message approach combined emotion recognition and relaxation with explicit verbal expression of anger, and this interactive process may have amplified its impact (Bruce and Berghuis 2011; Tsai 2019). Furthermore, VAS change rates in both tasks correlated significantly with SSRS scores, suggesting that individuals with stronger observable social skills were more effective in controlling anger. This underscores the potential value of leveraging existing social competencies to enhance anger regulation in VR training. The robust effects observed in the anger control module may be accounted for by learning mechanisms that, while sharing some similarities with social communication training, emphasize different processes. Participants engaged in emotional projection, as the anger-inducing scenarios enabled vivid recognition of emotional reactions (Novaco 1975; Yizengaw 2022). The I-message strategy further fostered perspective-taking by requiring acknowledgment of the other's behavior and emotions before expressing one's own needs (Bruce and Berghuis 2011). Finally, structured role-play enhanced role comprehension, facilitating a shift from passive responses to assertive communication. Collectively, these processes—emotional awareness, perspective-taking, and assertive role practice—likely contributed to the particularly strong outcomes observed (Feindler 2006; Goldstein and Glick 1994).

Unlike the anger control and social communication modules, empathy training did not produce significant changes in VAS scores. Several factors may account for this discrepancy. First, from a content perspective, empathy relies more heavily on affective resonance and mutual attunement than on immediate cognitive or behavioral responses (Davis 1990; Yalçın and DiPaola 2020). However, the present design emphasized one-directional, single-shot responses (e.g., voice messages), providing limited opportunities for

reciprocal feedback or iterative adjustment. From a mechanistic perspective, this limitation was amplified by the 360-degree video format, which, while effective for contextual realism, lacked interactivity and contingent feedback. This mismatch between the demands of empathy training and the affordances of the chosen technology constrained the activation of core learning processes, such as mutual attunement and dynamic coordination. Future iterations should therefore prioritize stronger alignment between training objectives and technological format, for example by adopting interactive VR or branching narrative scenarios to foster reciprocal exchanges and refine empathic responses in real time (Hadjipanayi et al. 2024; Liao, 2025; Yeh and Meng 2025). Second, empathy development is typically gradual, making it difficult to capture short-term gains with immediate VAS assessments (Winter et al. 2020). Whereas anger control and social communication can elicit more immediate changes, empathy often requires multiple sessions to yield measurable improvements (Patel et al. 2019; Bas-Sarmiento et al. 2020). Enhancing scenario design and instructional cues may also provide participants with clearer opportunities to practice and internalize empathic reactions. Third, the VAS itself may be insufficient to capture the multifaceted nature of empathy, as it was originally developed to measure the intensity of subjective states such as pain (Raudenská and Javůrková, 2017; Wewers and Lowe 1990). More sensitive questionnaires, qualitative measures, or in-VR assessments—for example, incorporating decision-based tasks that prompt participants to select appropriate empathic reactions, or analyzing participants' spoken responses within the VR environment—would likely offer more ecologically valid indicators of empathic engagement. Taken together, these refinements will guide the design of our planned randomized controlled trial (RCT), where longer-term training and improved assessment strategies will be systematically evaluated.

The current study has several limitations, along with recommendations for future research. First, the use of 360-degree video, while feasible and immersive, lacked interactivity, limiting opportunities for role-based decision-making and behavioral execution. This misalignment was particularly evident in the empathy module and may have contributed to its limited improvement. Future iterations should adopt more interactive VR formats to enhance engagement and skill transfer. Second, reliance on the VAS as the sole outcome measure, although appropriate for capturing immediate state-level responses, restricted the assessment of broader social and emotional functioning. Incorporating validated questionnaires, behavioral indicators, and physiological signals (e.g., HRV, EDA) will strengthen construct validity. Third, a notable limitation in the social communication training was the higher frequency of incomplete or random responses compared with the other modules. This may reflect the greater cognitive and linguistic demands of these tasks—such as sustaining conversation, considering peer perspectives, and inhibiting self-centered responses—relative to the more structured and affectively salient empathy and anger control tasks. To improve data quality and reduce attrition, future iterations will refine task instructions and add interactive feedback features to sustain engagement. Finally, the small sample size and within-subject design without a control group limit both the generalizability and statistical power of the findings. Because final sample sizes in some analyses fell below the target of 30, the study may also have been underpowered to detect smaller effects. Moving forward, a larger randomized controlled trial (RCT) using an enhanced version of the program will be essential to establish its effectiveness in comparison with established interventions for social skill impairments.

In summary, this preliminary study demonstrates the acceptability and feasibility of a newly developed VR-based SST program that integrates both knowledge- and emotion-based training strategies. By combining cognitive understanding with contextual transfer, the program leverages 360-degree video to enhance presence and immersion, while the embedded VAS allows immediate in-situ self-evaluation. The main findings indicate concurrent validity for selected modules, with significant improvements in social communication and particularly strong effects in anger control training, where the "I-message" strategy proved most effective. Collectively, these results highlight the program's potential as a valuable tool for enhancing social cognition and skills during the critical developmental period of youth.

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Data availability The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Declarations

Conflict of interest The authors declare no competing interests.

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