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Design and Application of Children's English Learning Aids Supported by Augmented Reality Technology Based on Smart Textiles

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Article

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ABSTRACT

This study aims to design and apply an interactive learning aid based on intelligent textiles to enhance children's English learning effectiveness. The core of the system is a wearable textile vest fabricated from flexible conductive fibers. This smart garment integrates pressure and temperature sensors to provide tactile feedback and is combined with augmented reality (AR) technology to create an immersive learning experience. To validate the efficacy of this textile-based interface, a three-month comparative experiment was conducted to evaluate students in an experimental group (using the device) and a control group (using traditional aids) across five dimensions, including English achievement and learning interest. Results demonstrated the significant effectiveness of the smart textile aid: the experimental group's average English score increased from 68.2 to 82.5, significantly higher than the control group's 71.4 ($p < 0.001$). Their scores in learning interest, concentration, and language application ability were also significantly better than those of the control group ($p < 0.001$). The conclusion confirms that combining AR technology with an interactive intelligent textile system can effectively improve children's learning outcomes. The wearable textile aid received high recognition for its ease of use and interest, but user feedback indicated that its portability (weight) needs optimization, pointing to a direction for future lightweight garment design.

KEYWORDS

intelligent textiles, wearable textiles, textile sensors, educational technology, augmented reality

INTRODUCTION

Under the wave of digital transformation of education, traditional teaching aids have been unable to meet children's diversified learning needs [1]. With their softness, wearability, and functional integration, intelligent textiles have the advantages of immersive interaction and visualization with augmented reality (AR) technology, thereby bringing new opportunities for educational innovation [2]. At present, children's English learning field is in urgent need of more attractive and effective teaching tools [3]. This study focuses on the integration of the two and explores the design of teaching aids for children's English learning, aiming at providing a new path for optimizing teaching mode and improving the learning effect.

Many scholars have explored topics related to intelligent textile research from different dimensions and achieved fruitful results. Zhang et al. [4] focused on computer-aided design and intelligent algorithm, and proposed an innovative path of personalized textile design, achieving precise and customizable textile design by using an optimization algorithm and promoting the promoting the intelligent development of textile design. Angelova et al. [5] paid attention to the knitting manufacturing process, studied the application of intelligent automation technology in this process, and improved the manufacturing efficiency and quality of complex textiles through advanced software integration and structure optimization. Zheng et al. [6] studied bionic technology, developed a bionic textile sensing system suitable for humanoid robots, realized the intelligent texture recognition function, and expanded the application boundary of intelligent textiles in the robotics field. Zhang et al. [7] comprehensively reviewed the application of MXene materials in functional and intelligent textile manufacturing, and discussed its preparation technology, structural characteristics, and performance advantages in detail, providing theoretical guidance for the development of intelligent textiles based on MXene. Dang et al. [8] focused on material innovation, developed multifunctional conductive coatings derived from biological substances, and endowed smart textiles with excellent electromagnetic shielding and photothermal conversion performance, which are suitable for wearable smart textiles and skin bioelectronics. However, the existing research mainly focuses on industry, robotics, materials science, and other directions, and has not yet combined the characteristics of smart textiles with educational scenarios, especially in the field of children's English learning. Research on children's English teaching research has been productive. Juan [9] discussed the application of total response teaching method in children's English teaching in depth and analyzed the role of this teaching method in promoting children's interest and participation in learning through practical cases. John [10] evaluated teachers' teaching practice and studied the relationship between it and the acquisition of English reading and writing skills of primary school children to provide a basis for optimizing teaching practice. Lu and Li [11] compared the similarities and differences between children's mother tongue acquisition and foreign adults' Chinese acquisition, and provided enlightenment for international language teaching from the perspective of language acquisition laws. Fu and Yang [12] focused on the use of teaching resources and studied the effective use of English teaching videos for young children who have a bilingual background. However, most of these studies focused on traditional teaching modes, teaching methods, and teaching resources, lacking integration with emerging technologies, and did not explore the use of cutting-edge technology to develop innovative teaching aids to improve children's English learning effect [13]. Moreover, for new teaching tools and methods, research to verify the practical application effect through rigorous experimental design is lacking, and scientifically evaluating their real impact on children's English learning is difficult.

On the basis of this background, this study is of great innovation value and necessity. It is innovative because this study pioneers the integration of smart textiles and AR technology to design children's English learning aids, breaking the limitations of traditional teaching aids and creating a new interactive experience and learning model for children's English learning. At the same time, a scientific experimental evaluation system is constructed, and the application effect of teaching aids is quantitatively analyzed through multidimensional indicators to fill the gaps in relevant empirical research. This research can effectively compensate for the lack of integration of technology and education, provide teaching aids with more scientific and technological content and practical value for children's English teaching, help innovate the educational model, promote the improvement of children's English teaching quality, and provide a theoretical and practical basis for the expansion and application of smart textiles in the field of education.

MATERIALS AND METHODS

Experimental Subject

Students from two parallel classes in the same grade were recruited. Based on the most recent English mid-term and final exam scores, students were stratified into high (top 30%), medium (middle 40%), and low (bottom 30%) achievement strata. Within each stratum, students were randomly allocated (1:1) to the experimental or control group using block randomization to ensure equal group sizes (n=35 per group) and balanced baseline proficiency. Baseline equivalence was assessed for age, sex, vocabulary and grammar scores, and logical reasoning ability measured by Raven's Standard Progressive Matrices, with no significant between-group differences ($p>0.05$). The study was approved by the Ethics Committee (No. 20250605), and written parental consent was obtained.

Materials

In the experimental group, smart textiles were used to create a wearable vest made from flexible conductive fibers. This vest integrates pressure and temperature sensors to provide tactile feedback and environmental awareness. For the AR technology component, the mobile app is developed on the basis of the EasyAR Sense Pro SDK. This platform offers a suite of advanced features, including 3D object tracking, which allows for the dynamic recognition of various real-world 3D objects relevant to English learning materials. It can simultaneously identify and track multiple 3D models, with no strict limit on the physical size of the target objects. The planar image tracking function enables students to scan specific patterns on the vest, like an apple pattern. Once scanned, it triggers the display of 3D English word models, English situational animations, and other content, such as a dynamic 3D apple model accompanied by pronunciation and sentence explanations. In the situational dialogue simulation module, students wear the vest in a simulated setting (such as a virtual supermarket) and engage in English conversations with virtual characters through voice interaction. The SDK also supports cloud recognition, providing an extensive library of learning resources that can be accessed on the fly. Additionally, it has a content and interaction support system that uses H.264 hardware decoding for smooth video playback, even for transparent videos, enhancing the overall immersive experience. The vest vibrates to remind students of key vocabulary and grammar points in their dialogues [14]. The teaching aids include a built-in learning progress tracking system that records students' word learning and conversation practice in real time, along with their accuracy rates. In the control group, the primary school's current English textbook is used, with word cards featuring a combination of text and images, including spelling, pronunciation, and simple definitions. Ordinary point reading pens offer basic word reading and text reading functions, suitable for simple listening practice, but lack interactive and situational simulation features. Table 1 shows the functional differences between the two groups of different teaching tools.

Table 1. Comparison of functional differences between AR teaching tools and traditional teaching tools for intelligent textiles

Functional dimension	Intelligent textile AR teaching tools (Experimental group)	Traditional teaching tools (Control group)
Interactivity	Supports 3D model triggering, virtual situational dialogue (such as virtual supermarket scene and virtual character voice interaction), and multimodal interactive experience	Only through the reading pen to realize the basic words and text reading, the interactive form is single, and no contextual interaction occurs
Feedback mechanism	Integrated pressure and temperature sensors provide instant tactile feedback by vibrating the vest to alert key words and grammar points in a conversation	No active feedback mechanism is available, and only repeated pronunciation through the reading pen lacks dynamic hints for the learning process
Scenario simulation	Immersive virtual scenes (such as shopping, daily conversation, etc.) are built, and students can practice English application in the simulated environment	It relies on textbooks, pictures, and word cards; does not include virtual situation simulation; and mainly presents static knowledge
Learn to track	Built-in learning progress tracking system, real-time recording of word learning, dialogue practice and accuracy, support data learning analysis	No learning data tracking function is available, so it is impossible to record the learning progress and accuracy, and it relies on teachers' manual inspection
Multisensory experience	Combined with AR visual presentation (3D model, animation) and intelligent textile tactile feedback (vibration reminder), multisensory collaborative learning is realized	Information is transmitted only through vision (picture and text) and hearing (point reading pronunciation), without the participation of other senses such as touch
Function scalability	3D content can be updated and virtual scenes expanded through an app, and functions and content can be iterated and upgraded	The function is fixed, relying on the content of textbooks and word cards, and cannot expand new scenarios or update interactive forms

Methods

The experimental method adopts a three-month cycle design that covers the entire teaching process of a full semester. This three-month cycle aligns with the conventional planning phases of most educational stages, better fitting the quarterly-based teaching arrangements within semesters while fully coordinating with the instructional progress of textbook units. Through this design, we can systematically track students' knowledge absorption and application throughout their learning cycle during this phase. Additionally, this duration is sufficient to observe the phased impact of AR teaching tools on students' learning interests, habits, and academic performance while also avoiding excessive interference from other factors (such as semester changes and holidays) during a longer period. Figure 1 illustrates the teaching tasks at different stages within the experimental period.

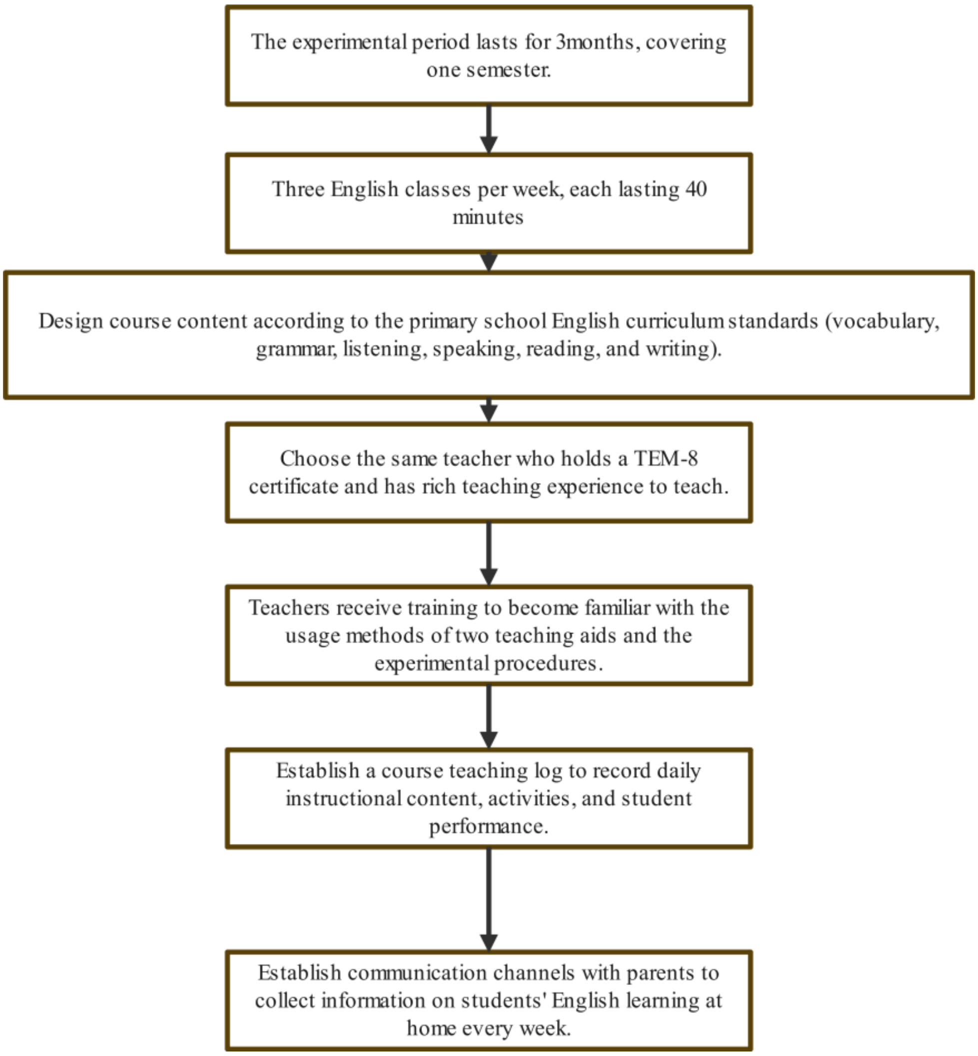

Figure 1. Experimental process and task design

After the completion of the instructional design, the indicators need to be evaluated to determine the effectiveness of the use of teaching aids. A total of five indicators are selected for evaluation in this study. Table 2 shows the evaluation dimensions, specific indicators, and calculation methods.

Table 2. Evaluation dimensions and indicators of teaching tool application effect

Dimensions	Indicators	Computational method
English language exam scores	Total score of the test paper	The third-party standardized English test paper recognized by the education department was used to test before and after the experiment. The full mark of the test paper is 100, including listening (30), vocabulary grammar (30), reading comprehension (20), and writing (20) [15]. The mean and standard deviation of the total test scores of the experimental group and the control group were calculated by SPSS software, and the significant difference between the two groups was analyzed by independent samples t-test to evaluate the overall change in English knowledge.
	Type analysis of wrong questions	After the examination, students' wrong questions are classified and sorted into listening comprehension errors, vocabulary and grammar misuse, reading logic deviation, writing structure confusion, and so on.
Interest in learning	Questionnaire score	A five-point Likert scale of 15 questions (1 = very different, 5 = very agree) is designed, questions are developed from the dimensions of learning attitude, motivation, and enthusiasm for participation, such as "I like taking English classes" and "I am willing to take the initiative to learn English words." The scores of all the questions are totaled, the total score of each student is calculated, the average score of the experimental group and the control group is determined, and the differences between the groups through independent samples t-test are compared to quantify the change in learning interest.
	Record of classroom participation	Trained observers use the Classroom Participation Observation Scale and use narrative recording method to describe students' specific performances in classroom group discussion, role-playing, and question interaction, such as "actively proposing innovative ideas" and

	behavior	"actively organizing group discussion," to refine the typical behavior patterns of students' classroom participation and qualitatively evaluate their learning interests [16].
Study concentration	Eye tracker data	Using Tobii Pro X3-120 eye tracker, the gaze duration and saccade frequency of students during their study were recorded. The fixation time refers to the continuous fixation time of students on learning materials (such as word cards and screen content) in seconds. Scanning frequency refers to the number of gaze shifts per unit time. The average gaze duration and saccade frequency of the two groups of students under the same learning task were calculated, and the differences between the two groups were analyzed by independent samples t-test to quantify the concentration level.
	Description of classroom concentration state	Observers record students' concentration (attentive listening, active interaction, slight distraction, and serious distraction) every five minutes, and the situational description method is used to record students' specific behaviors of distraction, such as "frequently fiddling with stationery" and "whispering to classmates," as well as their performance during concentration, such as "staring at the screen and reading words," and concentration is analyzed qualitatively from the perspective of behavioral situation.
Language application ability	Situational dialogue score	Four themes are set, including shopping and asking for directions, and students are instructed to randomly select a theme to engage in one-on-one conversations with the teacher. The teacher scores on the basis of the Oral Expression Scoring Scale, evaluating pronunciation and intonation (20 points), vocabulary usage (30 points), grammatical accuracy (30 points), and content coherence (20 points), with a total score of 100 points [17]. The average scores of both groups are calculated, and the differences between the groups are compared using an independent samples t-test to quantify language application skills.
	Content analysis of short essay writing	Students are required to write an 80–100-word essay. After independent scoring by two teachers, the average score is taken. Excellent and exemplary essays are analyzed in depth, focusing on content depth, logical structure, and language features. With the use of case analysis, students' language organization and application skills are evaluated qualitatively, such as analyzing how complex sentence structures and advanced vocabulary are used to

		express viewpoints.
Satisfaction with teaching aids	Survey dimension scores	A five-point Likert scale is designed with 20 questions covering dimensions of usability, entertainment value, functionality, and portability. After key dimensions are extracted through factor analysis, the average score for each dimension is calculated.
	Open-ended feedback	At the end of the questionnaire, open-ended questions were set up, such as "What do you think is the most attractive part of this teaching aid?" and "How do you want to improve the teaching aid?" Content analysis was used to code and classify students' answers, and high-frequency keywords and typical suggestions were extracted [18].

Statistical analysis was performed by using SPSS26.0. The count data were expressed as % and χ^2 test; the measurement data were expressed as ($\overline{x} \pm s$) and t-test. The difference in the results was statistically significant at $p < 0.05$.

RESULT

English Test Scores

As shown in Figure 2, the data indicate no statistically significant difference in the average scores of the two groups before the experiment (t = 0.82, p = 0.41). However, after the experiment, the scores of the experimental group improved significantly, showing a statistically significant difference compared with the control group (t = 5.13, $p < 0.001$). The analysis of error types revealed that before the experiment, both groups had a high proportion of errors in listening comprehension (about 35%) and vocabulary and grammar misuse (about 40%). After the experiment, the experimental group's errors in listening comprehension decreased to 18%, and those in vocabulary and grammar misuse decreased to 22%. By contrast, the control group's errors in listening comprehension were 29%, and those in vocabulary and grammar misuse were 33%. The chi-square test showed that the differences in listening comprehension errors between the two groups were statistically significant ($\chi^2 = 6.23$, $p < 0.05$), and the differences in vocabulary and grammar misuse errors were also statistically significant ($\chi^2 = 5.89$, $p < 0.05$). The teacher team found that the experimental group made significant progress in using complex sentence grammar and capturing listening details, while the improvement in the control group was relatively slow.

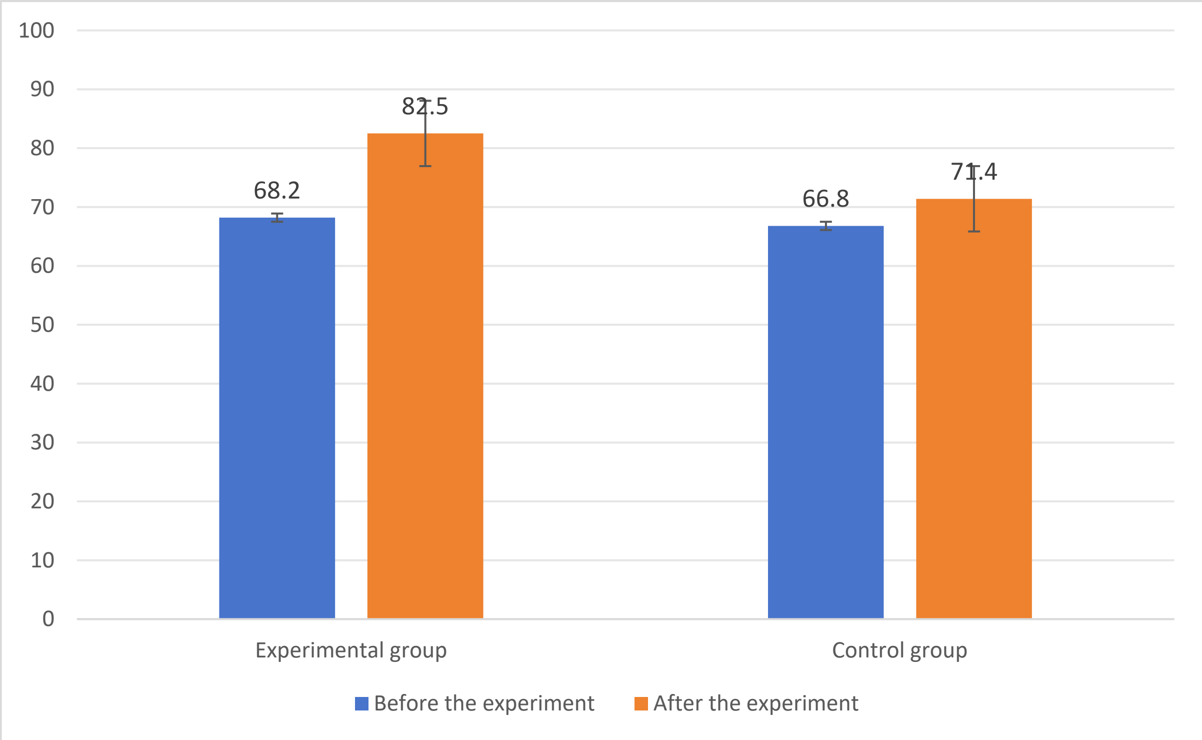

Figure 2. Data on English test scores of students from both groups before and after the experiment

Interest in Learning

Figure 3 shows no statistically significant difference in the pre-experiment questionnaire scores measuring students' learning interest between the two groups ($t = 0.65$, $p = 0.52$). After the experiment, the experimental group's questionnaire scores were significantly higher than those of the control group, with statistical significance ($t = 7.89$, $p < 0.001$). Before the experiment, both groups had low frequencies of active participation in group discussions, averaging less than two times per discussion. After the experiment, the experimental group averaged 4.2 active participations per discussion, while the control group only averaged 2.1 times. A t-test showed significant differences between the two groups ($t = 5.34$, $p < 0.01$), indicating that the experimental intervention effectively improved the experimental group's active participation in group discussions. After the experiment, 65% of the students in the experimental group actively designed scenarios during role-playing, such as adding haggling details in an English shopping scenario. By contrast, only 23% of the students in the control group did so, mostly following fixed scripts. A chi-square test indicated that the difference in the proportion of students actively designing scenarios between the two groups was statistically significant ($\chi^2 = 18.76$, $p < 0.001$).

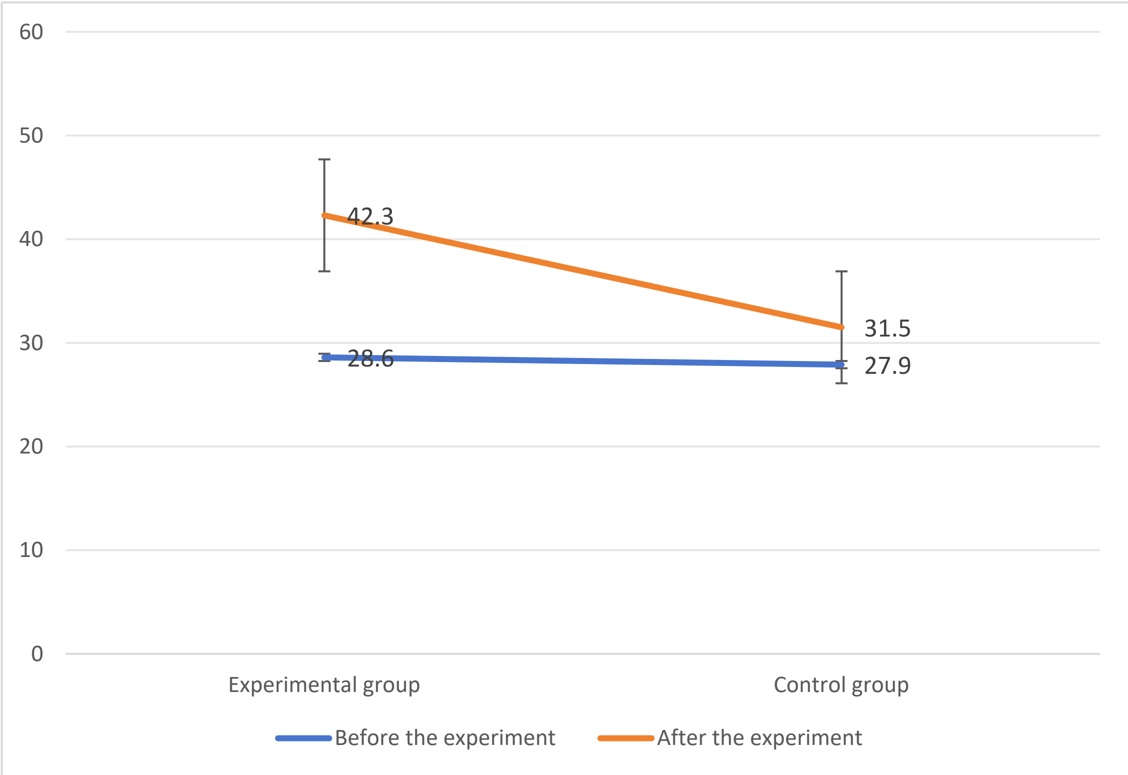

Figure 3. Questionnaire scores of students' interest in learning before and after the experiment

Students' Concentration

Figure 4 data shows no significant differences in the average fixation duration (t = 0.62, p = 0.54) and scanning frequency (t = 0.78, p = 0.44) between the two groups before the experiment. This finding indicates that the baseline performance of these visual attention indicators in both groups was comparable prior to experimental intervention, establishing a solid foundation for the validity of subsequent experimental results. After the experiment, compared with that of the control group, the average gaze duration of the experimental group increased more significantly (t = 6.32, $p < 0.001$), and the saccade frequency decreased more prominently (t = 5.87, $p < 0.001$). Both differences were statistically significant, indicating obvious changes in the experimental group's visual attention patterns after the intervention. After the experiment, the students in the experimental group spent 75% of the time listening attentively, with typical behavior such as staring at the screen to follow AR animation and read words. In the control group, 52% of the time was spent listening, and frequent stationery fiddling took about 18% of class time. Chi-square test showed significant differences:

$\chi^2 = 8.32$, $p < 0.01$ for attentive listening and $\chi^2 = 7.91$, $p < 0.01$ for stationery fiddling.

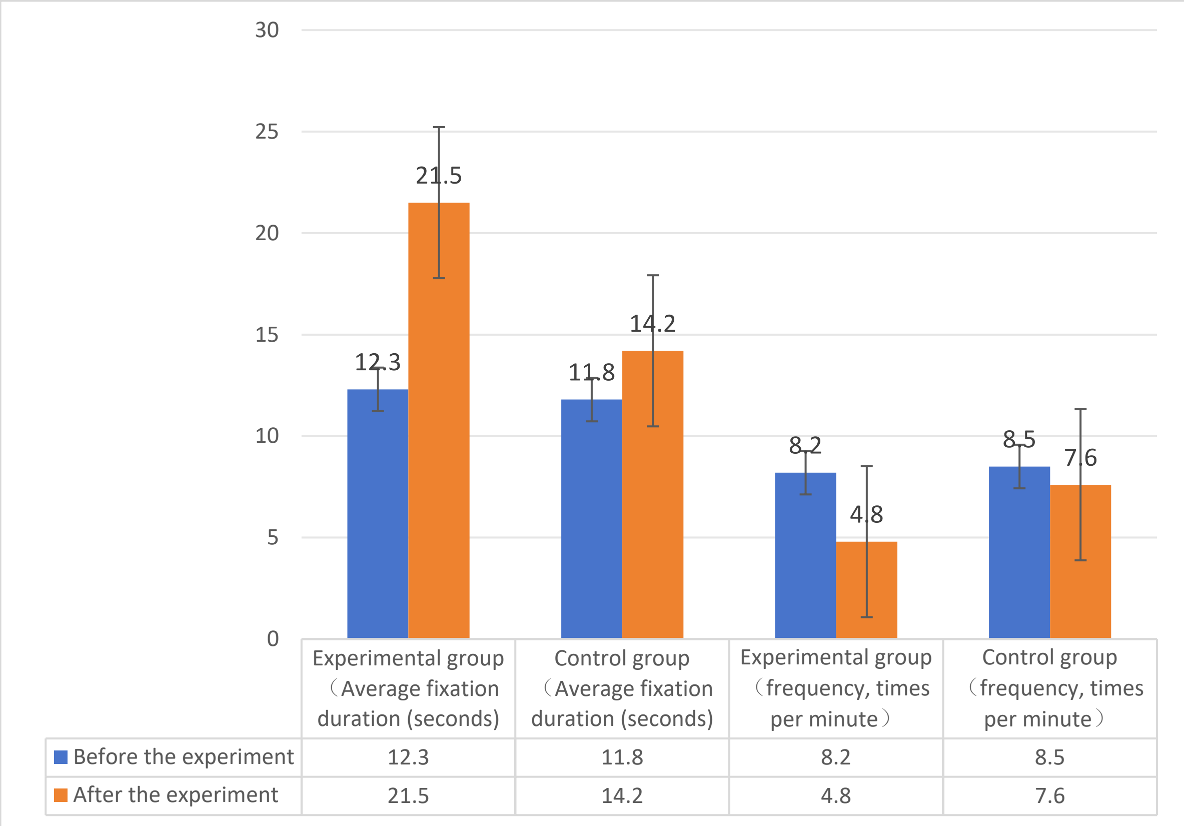

Figure 4. Average duration and scan frequency

Language Application Ability

The data in Figure 5 indicate that the pre-experiment scenario dialogue scores of the two experimental groups were not statistically significant compared with those of the control group (t = 0.93, $p = 0.36$). However, after the experiment, the experimental group's score in this area significantly surpassed that of the control group, with a statistically significant difference (t = 6.78, $p < 0.001$). After the experiment, 45% of the students in the experimental group used complex sentence structures, such as attributive and adverbial clauses to express their views, while only 19% of the control group did so ($\chi^2 = 12.36$, $p < 0.01$). In terms of vocabulary richness, the number of words used by the observation group was (6.8 ± 1.4) and that of the control group was (2.5 ± 0.4). The difference between the two groups was statistically significant (t = 16.156, $p < 0.001$).

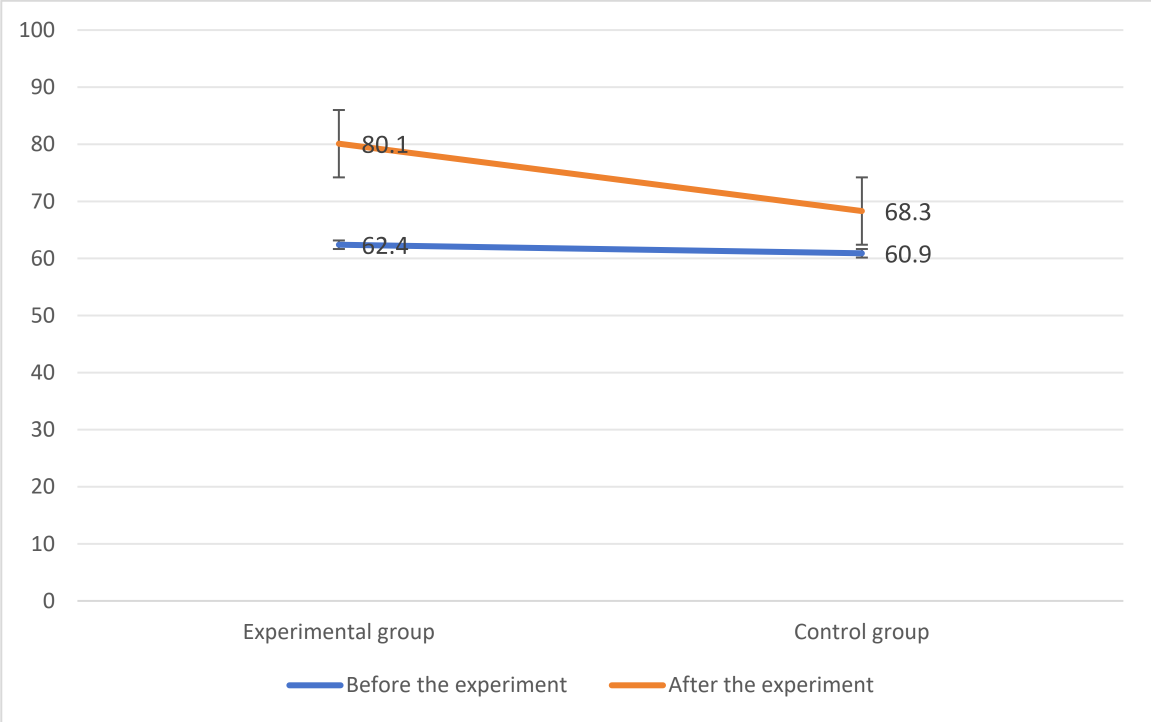

Figure 5. Scores of situational dialogues for students from both groups before and after the experiment

Satisfaction with Teaching Aids

Figure 6 presents the satisfaction scores for teaching aids before and after the student experiment. The results show that no significant differences exist in the four specific dimensions of usability, interest, functionality, and convenience before the experiment (t = 1.23,1.15,1.31,0.98; p = 0.22,0.25,0.19,0.33). However, after the experiment, the experimental group showed a statistically significant increase in these dimensions compared with the control group (t = 7.89,8.32,7.65,4.56; $p < 0.001$). Before the experiment, both the experimental and control groups expressed unfamiliarity with traditional and new teaching aids, with mostly neutral feedback. After the experiment, 78% of the students in the experimental group noted that “AR animations make word learning more engaging,” and 65% suggested adding more interactive games. With regard to portability, some students commented that “the smart textile vest is a bit heavy” and hoped that it is lighter. By contrast, the control group students found traditional teaching aids to be “limited in use” and “lacking novelty,” with only 12% believing that the teaching aids significantly helped their learning. This finding highlights the significant advantages of new teaching aids in enhancing satisfaction.

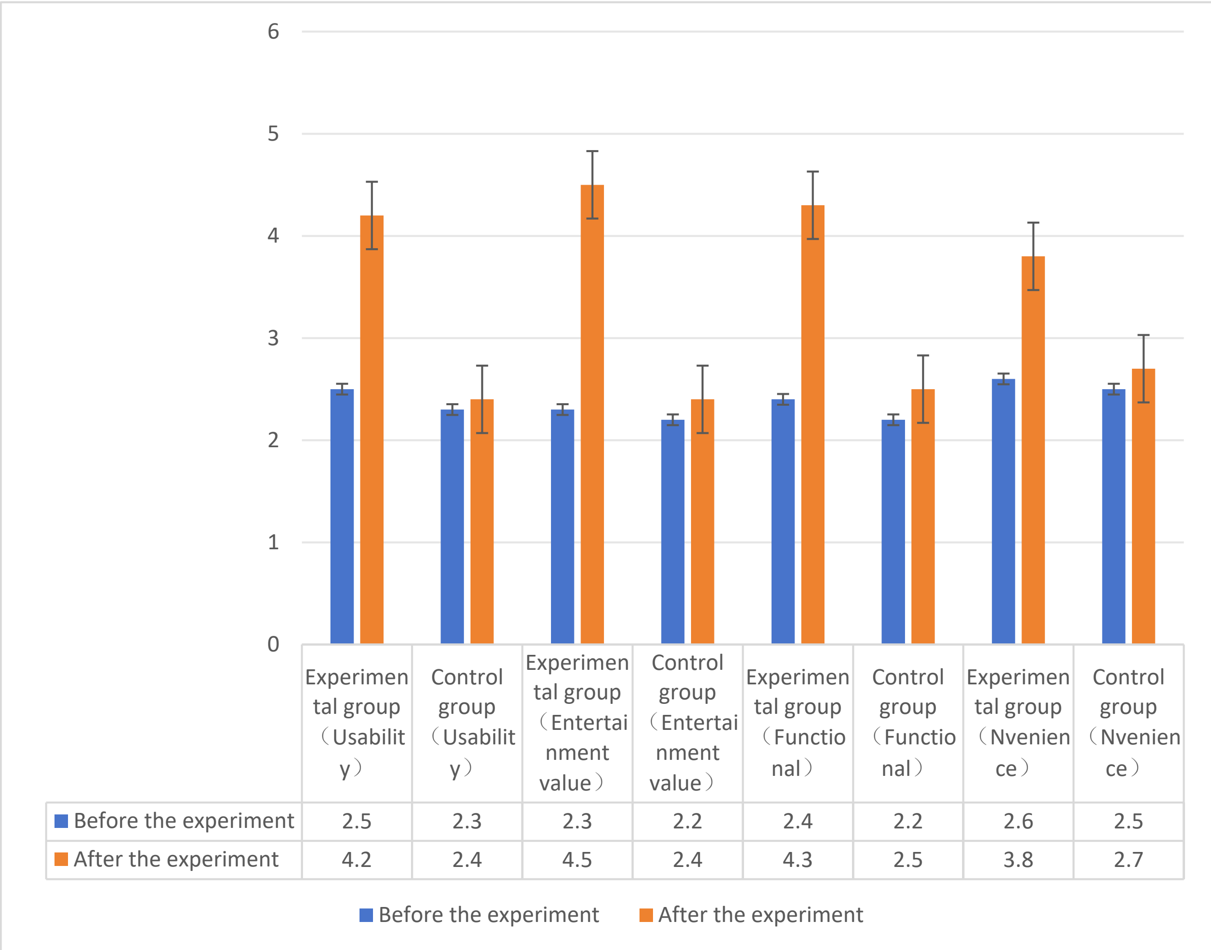

Figure 6. Satisfaction ratings of students from both groups before and after the experiment with teaching aids

DISCUSSION

New Teaching Aids Significantly Promote Knowledge Mastery

Experiments show that AR teaching aids based on smart textiles can significantly improve children's English knowledge. The average total score of the experimental group in the English test reached 82.5, far exceeding the control group's 71.4. The rate of wrong questions in listening decreased from 35% to 18%, and the rate of wrong questions in vocabulary and grammar decreased from 40% to 22%, both of which were better than those in the control group. AR technology is a new type of human–computer interaction technology that has emerged in recent years. It can truly realize the seamless integration of virtual information and real environment through the comprehensive application of object recognition, dynamic tracking, and virtual reality [19]. Further analysis is needed to explore the differences in AR usage behaviors between high-scoring and low-scoring students, such as whether significant variations exist in terms of interaction frequency with smart textiles or preference for dynamic knowledge visualization.

Innovative Design Stimulates Learning Enthusiasm

The new teaching aid has a remarkable effect on stimulating learning interest. The score of learning interest questionnaire in the experimental group increased from 28.6 to 42.3, which was significantly higher than that in the control group (31.5). In the classroom, the proportion of the experimental group actively participating in the discussion and designing the plot reached 65%, far exceeding the control group's 23%. Gamification scenes and instant rewards meet children's psychological needs, while traditional teaching aids have difficulty mobilizing their enthusiasm because they are considered boring [20]. However, the potential Hawthorne effect may also have a certain impact on students' learning motivation and interest enhancement. Moreover, a topic that is worth investigating is whether high-scoring and low-scoring students exhibit distinct behaviors in engaging with AR teaching aids in terms of interest, such as differences in the time spent exploring gamification scenes or the frequency of interaction with instant rewards.

Immersive Experience Enhances Concentration

The new teaching aids greatly improve learning concentration. In the experimental group, the average fixation time was extended from 12.3 seconds to 21.5 seconds, the scanning frequency was reduced to 4.8 times/minute, and the proportion of concentrated listening time was 75%, which was significantly better than that in the control group. The wearing characteristics of smart textiles reduce interference, and the immersive scene created by AR is highly attractive. Traditional teaching aids have difficulty maintaining concentration due to lack of immersion. Additionally, future research could explore how high-scoring and low-scoring students differ in their AR usage behaviors related to concentration, for example, whether high-scoring students sustain longer fixation times or if low-scoring students show more variability in their scanning frequencies during AR-based learning sessions.

Scenario Simulation Helps Improve Language Application Ability

The new teaching aids have obvious advantages in the cultivation of language application ability. The experimental group's score in situational dialogue increased from 62.4 to 80.1, the proportion of complex sentence patterns used in short writing reached 45%, and the amount of advanced vocabulary used was 6.8, far exceeding that of the control group. Real scene simulation and writing guidance can effectively improve students' language practice ability. However, traditional teaching aids have difficult meeting the demand because of the lack of situation and guidance [21]. Additionally, an aspect that needs to be explored is the differences in AR usage behaviors between high-scoring and low-scoring students, such as whether high-scoring students show more active participation in real-scene simulations or have a higher frequency of using writing guidance functions than low-scoring students.

The Recognition Function Has been Improved

The survey on satisfaction with teaching aids shows that the experimental group gave high ratings on its ease of use (4.2 points), interest (4.5 points), and functionality (4.3 points) but gave its portability a rating of only 3.8 points, and the students remarked that the vest is heavy. Although the traditional teaching aid has only a single function, it has superior portability [22]. With the rapid development of information technology, AR/VR technology, as an emerging teaching method, is gradually being integrated into English teaching in primary schools [23]. Further analysis is needed on whether high-scoring and low-scoring students differ in AR usage behaviors related to satisfaction, such as whether high-scoring students are more tolerant of portability issues or if low-scoring students show stronger preferences for functional richness over device weight.

LIMITATIONS

Sample limitations: This study included only two classes from the same grade in a primary school in a specific city, resulting in a small and narrow sample size. This situation makes it difficult to fully represent children from different regions and backgrounds, potentially leading to sample bias and affecting the generalizability of the conclusions.

Short experimental period: The experimental period is three months, covering a more complete teaching process. However, this duration is insufficient for evaluating the long-term impact of the AR educational tool on children's English learning. It does not provide enough time to observe the tool's long-term effects on building children's English knowledge systems and their continuous language development.

Insufficient control of interference factors: Despite efforts to control variables during the experiment, factors such as students' extracurricular English learning and differences in family tutoring are difficult to fully control, which may interfere with the experimental results. Additionally, the AR educational tool's performance is influenced by technical stability and equipment compatibility, potentially leading to data discrepancies. During the experiment, the AR devices encountered a 15% failure rate stemming from software crashes and hardware failures, with such issues occurring approximately three times per week on average; each failure affected around eight students, and the duration of each failure, from detection to resolution, averaged 40 minutes, disrupting the learning process for the involved students during that period. Although immediate on-site repairs and device replacements were carried out to minimize disruptions, these incidents still affected the continuity of the experiment and the consistency of data collection.

Future Research

In view of the limitations of the current study, future research needs to be improved from the following aspects:

Expand the sample scope: Future studies can select children from multiple regions and schools across different grades as experimental subjects, covering students from urban and rural areas with varying levels of English education, to increase the diversity and representativeness of the sample, thereby enhancing the generalizability of the research findings.

Extend the experimental period: The experimental period should be extended to one to two years, conducting long-term tracking observations on students' English learning development after using the AR teaching aids for smart textiles. This approach can enable the comprehensive assessment of the long-term impact of these aids on children's interest, ability, and performance in English learning, exploring their sustained role in children's English learning careers [24].

Optimize experimental design and control variables: The experimental design can be optimized by regularly collecting home learning records and conducting parent interviews to strengthen tracking management of extracurricular learning, thereby reducing interference from external factors. Collaboration with technical teams is needed to enhance the performance of smart textile AR teaching aids, improving equipment stability and compatibility to ensure reliable experimental data. Diversified assessment methods such as dynamic learning tracking and growth portfolios can be introduced to comprehensively monitor students' academic progress [25].

Integrate AR teaching tools into existing courses: First, AR content should be mapped to curriculum standards by aligning core functions (e.g., vocabulary AR cards, situational dialogue simulators) with textbook units, ensuring each AR module corresponds to specific learning objectives. Second, teachers should be trained to integrate 5-to-8-minute AR activities into lesson plans, such as using AR to preview new words before a unit or reinforce dialogues after practice. Finally, the teachers in the two classes should have similar teaching ability, training status, and teaching progress levels to ensure that the two sets of data can be compared.

CONCLUSIONS

This study successfully designed and validated the application of AR technology-supported children's English learning aids based on smart textiles. The experiment demonstrated that these aids significantly outperform traditional tools in enhancing children's English academic performance, interest, concentration, and language application skills, echoing Yang Yabin's (2017) finding in his ADDIE model-based study that AR resources effectively boost primary school English learning effectiveness [26]. The immersive and interactive learning environment created by the aids not only stimulates children's initiative and enthusiasm for learning but also aligns with Yang Yuping's (2023) proposal on AR-based experiential learning activities in primary school English, which emphasizes the role of AR in fostering interactive and engaging learning scenarios [27]. In terms of user satisfaction, the aids were highly praised for their ease of use, fun, and functionality, although their portability requires improvement. This issue presents a direction for future optimization that builds on existing research foundations. This study provides innovative design ideas and practical evidence for children's English teaching, confirming the feasibility and value of integrating smart textiles with AR technology in education—a path that, as research progresses and aids are optimized, is expected to further innovate children's English teaching methods and enhance educational quality, consistent with the academic explorations of Yang Yabin and Yang Yuping.

Availability of Data and Materials

The datasets used and/or analysed during the current study were available from the corresponding author on reasonable request.

Author Contributions

Feng Liu and Fengxia Gao designed the study; all authors conducted the study; Fengxia Gao and Feng Liu collected and analyzed the data. Fengxia Gao and Feng Liu participated in drafting the manuscript, and all authors contributed to critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work, took public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or completeness of any part of the work were appropriately investigated and resolved.

Ethics Approval and Consent to Participate

This survey was conducted in compliance with Ethics Committee of Xinjiang University with the ethics number 20250605. Participants were informed of the study's purpose and data usage prior to participation, and responses were collected anonymously. No personally identifiable information was stored.

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Not applicable.

Conflict of Interest

The authors declare no conflict of interest.

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