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# COMPUTER ASSISTED LEARNING TO IMPROVE EARLY NUMERACY SKILLS AMONG PRESCHOOL CHILDREN WITH HEARING LOSS: AN INTERVENTION STUDY

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***Abstract:*** Early numeracy skills are a vital basis for later mathematical learning and general academic success. Differences in access to language, opportunity to communicate, and exposure to instructional situations may create additional challenges to learning numerical ideas for preschool children who are deaf or hard of hearing. The present study investigated the effectiveness of a Computer Assisted Learning (CAL) program, the Computer Assisted Learning in Kannada for Early Literacy and Early Numeracy (CAL-KELEN) program, in developing early numeracy abilities among Kannada speaking preschool children with hearing loss. A concurrent mixed-method, two-group pre-test post-test intervention design was used. Sixty-four preschool children with hearing loss (32 children in the CAL group and 32 children in the traditional flash-card group) participated in the study. The researcher-developed Test for Examining Early Numeracy Skills in Kannada (TEN-K) was used to test early numeracy. The evaluation included non-numerical comparative measurements, identification and sequencing of numbers, counting and comparison of numbers, operations with numbers, shape concept, money concept and time concept. As the TEN-K scores did not fulfil the normalcy assumption, non-parametric analyses were used. The two groups were not significantly different at baseline (Mann-Whitney U = 497.50, p =0.845). Post-test scores were significantly higher in the CAL group (Median M = 61.00) than in the control group (Median M= 51.00) after intervention. The difference between the groups was statistically significant (U = 985.50, p <0 .001) and the effect size was quite big (r = 0.85). The CAL group increased from M = 26.00 to M = 60.44, whereas the control group increased from M = 26.53 to M = 49.94. Domain-wise results were very high for number recognition and sequencing, counting and comparison, and understanding of operations, shape, money, and time concepts. Qualitative observations also showed enhanced attention, motivation, independence, confidence, and transfer of numerical concepts to the real-life contexts. Analyses for age groups revealed substantial differences in numeracy performance at post-test, with older preschool children generally performing better. The results support the efficacy of a developmentally appropriate, multimodal, and linguistically relevant computer assisted learning program as a supplemental strategy to fostering early numeracy in preschool children with hearing loss.

***Index Terms*** **-** Early numeracy, computer assisted learning, preschool children, hearing loss, Kannada, mathematics, CAL-KELEN.

## I. INTRODUCTION

Learning basic numeracy skills is a key part of the early years of life. Preschool children learn things like numbers, counting, how much, comparing numbers, arranging numbers, simple math operations, shapes, measurement, money and time. Further formal teaching in mathematics requires these skills. Longitudinal studies have found that early math abilities are one of the most effective indicators of success in school. Duncan et al. (2007) reviewed six longitudinal data sets and concluded that children's skills in arithmetic, reading, and attention at school entry were the strongest predictors of eventual academic achievement. Early math skills were very strong predictors.

Early numeracy is not one aptitude, but a many-faceted complex of talents. Number symbols, counting, amount, magnitude, link between numbers, sequencing, and operations are introduced to preschoolers. Informal numeracy is described as counting, relations, and arithmetic operations (Purpura & Lonigan, 2013). These are different but related aspects of mathematical development in early infancy. Similarly, work on preschool numeracy assessment has highlighted the benefit of assessing a range of underlying numerical abilities rather than a single measure of counting or number recognition. The Preschool Early Numeracy Scales were designed by Purpura and Lonigan (2015) to be a multidimensional test of early number skills.

Children with hearing loss may need unique educational techniques to support their understanding of early academic concepts. Language access problems and diminished opportunities for incidental learning might affect vocabulary and conceptual knowledge development, attention to spoken information, and academic preparedness. For many young students, visual communication is the main mode of learning and verbal explanations, a staple of traditional teaching, may not offer sufficient access to learning. Easterbrooks and Stephenson (2012) in their study advocated for the use of accessible, evidence-based educational techniques for deaf and hard of hearing children.

Technology-mediated instruction is one possible solution to these educational problems. Computer assisted learning may include images, animation, text, speech, repetition, interaction and quick feedback. These traits may be especially essential for preschool children with hearing loss, as visual information may be an important pathway of conceptual acquisition and residual auditory information may be processed as appropriate.

The conceptual basis for multimedia learning is consistent with Mayer’s (2009) Cognitive Theory of Multimedia Learning. According to Mayer (2001) appropriate combinations of words and pictures can allow the learner to build meaningful mental representations of the knowledge. Similarly, Paivio’s (1986) Dual Coding Theory suggests that learning and memory consists of verbal and non-verbal representational systems. Young children can use pictures to connect concrete numbers with symbolic number representations in early math.

Technology-supported early numeracy training can be properly based on Piaget and Bruner's developmental theories (Linder, 2008). Bruner (1966) claimed that development takes place in the form of enactive, iconic and symbolic representation. Piaget stressed the importance of children constructing their own knowledge via interaction with things and experiences. These digital learning environments can be integrated by delivering visual items, pictorial representations and numerical symbols which can be handled in the same learning process.

Research has revealed that technology can be supportive for early maths learning. For example, Clements and Sarama (2007) examined the Building Blocks preschool mathematics curriculum, which incorporated research-based technology-enhanced mathematics materials, and found that children in the intervention group made significantly greater gains in mathematics than children in the comparison group. However, results of computer-based early numeracy programs have not proven consistently useful. Aunio and Mononen (2018) discovered that the computer-game educational group improved in a study with low-performing preschool children, although the between-group differences were not statistically significant. The findings imply that effectiveness of digital learning could depend on developmental suitability, instructional design, content, length of time and the group for which the technology is built.

This is especially relevant for Indian preschool children with hearing loss, for whom the availability of technology-supported instructional resources in regional languages is relatively limited. CAL-KELEN is a computer aided instruction program in Kannada, offering visual and interactive learning experiences for early reading and numeracy skills development. The numeracy component was developed on developmentally appropriate concepts employing concepts in Kannada language and locally applicable occurrences. In this study we explicitly assess the efficacy of this technique to improve preschool children with hearing loss early numeracy skills.

## II. Need of The Study

Although early mathematics development has been studied in depth at the international level, very less research exists on technology-supported early numeracy education for preschool children with hearing loss, especially within Indian regional-language settings. Existing digital mathematics programs have usually been built for students with typical hearing and in languages such as English. Hence, their direct relevance to children with hearing loss who talk Kannada cannot be presumed per se.

Accessible learning for children with hearing loss requires consideration of visual attention, language comprehension, communication modality, repetition, feedback and opportunity for autonomous practice. A computer software can provide repeated practice in arithmetic topics and cut down on long verbal explanations. Interactive activities can also allow youngsters to interact, have rapid feedback and redo tasks as per their learning needs.

Thus, the present study was designed to fill an essential research vacuum by investigating whether a Kannada-language computer assisted learning program may be used to enhance early numeracy abilities among preschool-age children with hearing loss, in comparison to a traditional flash-card strategy.

## III. Objectives

1. To evaluate the efficacy of Computer Assisted Learning (CAL) in enhancing early numeracy abilities in Kannada speaking preschoolers with hearing loss.
2. To explore differences in early numeracy performance after intervention between children with cochlear implants and children with Behind-the-Ear (BTE) hearing aids.
3. To explore differential effect in early numeracy performance following intervention by preschool age group.
4. To investigate qualitative evidence of children's engagement, motivation, independence, confidence and application of numeracy ideas after CAL intervention.

## IV. Hypothesis

The principal research hypothesis was:

**H1:** Preschool children with hearing loss exposed to the Computer Assisted Learning (CAL) programme would demonstrate better early numeracy skills than children exposed to the conventional flash-card method.

The corresponding null hypothesis was:

**$H_0$:** There would be no significant difference in early numeracy skills between preschool children with hearing loss exposed to the Computer Assisted Learning programme and those exposed to the conventional flash-card method.

## V. Method

### Research Design

A concurrent mixed-methods approach including quantitative and qualitative data was used in the study. The quantitative part employed a two-group pre-test post-test intervention design with an experimental group receiving Computer Assisted Learning and a control group receiving conventional flash-card instruction. Qualitative data was collected by way of classroom observations, video recordings, field notes, investigator observations and parent input. The original study classified the combination of these sources as mostly convergent triangulation.

**Participants**

The study included 64 preschool children with hearing loss. The sample was divided into an experimental CAL group (n = 32) and a control group that used traditional - flash-card teaching (n = 32). The two groups performed similarly at baseline on early numeracy. The age distribution of each group was 5 children aged 3–4 years, 10 children aged 4.1–5 years, and 17 children aged 5.1–6 years. Thus, the oldest age group was the most represented. The sample included children with different hearing amplification devices. In each instructional group, the subgroup analyses reported 19 children with BTE hearing aids and 13 children using cochlear implants. Aid-related analyses were performed to evaluate if CAL efficacy changed across amplification types.

**Intervention**

The intervention was the Computer Assisted Learning-Kannada Early Literacy and Early Numeracy (CAL-KELEN) program. The program combined multimedia and interactive learning aspects such as visuals, animation, spoken language where appropriate, text, interactive tasks and quick feedback. The early numeracy component was intended to promote the developmentally appropriate numerical concepts in Kannada.

The conventional instructional condition used flash-card-based teaching. Thus, the principal distinction between the groups was the mode of instructional delivery: interactive computer-assisted multimedia learning in the experimental group and conventional flash-card instruction in the control group. Each group underwent intervention for 45 minutes per session, 5 days per week, for a duration of 3 months, for a total of 45 intervention sessions. The instruction was given in small groups of eight children, which allowed for active participation, interaction and individual attention. The experimental group comprised 32 children with hearing loss, divided into four groups of eight. The control group also comprised 32 children, divided into four groups of 8 children. The CAL environment offered the opportunity for repeated practice and fast corrective feedback. Over the course of the intervention children were seen to independently complete more arithmetic activities.

**Instrument**

Early numeracy was measured using a researcher-developed Test for Examining Early Numeracy Skills in Kannada (TEN-K). The evaluation was structured to test several key domains of early numeracy. The TEN-K included the following domains:

1. Non-numerical comparative measurements
2. Identifying and sequencing numbers
3. Counting and comparing numbers
4. Operations with numbers
5. Shape concept
6. Money concept
7. Time concept

These domains offer a wide lens of early numeracy instead than restricting examination to number recognition or rote counting.

**Qualitative Data Collection**

Qualitative information was acquired through systematic observations of the classrooms, video recordings of intervention sessions, field notes, observations by investigators, and input from parents. The data were utilized to analyze children's attention, motivation, involvement, independence, confidence, problem solving, and transfer of numerical learning to everyday contexts. Parent feedback was collected using a researcher-developed rating scale on aspects such as interest and motivation, attention and engagement, understanding of instructions, learning new concepts, recall and retention, independent practice, confidence, numeracy improvement, and overall effectiveness of CAL.

## VI. Statistical Analysis

Descriptive statistics included means, medians, standard deviations, and measures of distribution. The Shapiro–Wilk test, histograms, and Q–Q plots were used to assess normality. The TEN-K pre-test scores showed significant deviation from normality ($W = 0.960$, $p = .038$), while post-test scores also deviated significantly from normality ($W = 0.864$, $p < .001$). Consequently, non-parametric statistical tests were used.

The Mann–Whitney U test was used to compare independent groups. The Wilcoxon signed-rank test was used for within-group pre-test post-test comparisons. The Kruskal–Wallis H test was used to compare numeracy performance across three age groups, followed by pairwise Mann–Whitney U tests with Bonferroni correction when appropriate.

Effect sizes were calculated to determine the practical magnitude of observed differences.

## VII. Results

### TEN-K Pre-test and Post-test Performance

Descriptive statistics revealed a significant amount of improvement in both groups however the amount of improvement was significantly more in the CAL group.

**Table 1**

*Pre-test and Post-test TEN-K Scores of Experimental and Control Groups*

| Group | Test | n | M | SD | Median |
|---|---|---|---|---|---|
| CAL | Pre-test | 32 | 26.00 | 10.01 | 27.00 |
| CAL | Post-test | 32 | 60.44 | 1.29 | 61.00 |
| Flash card | Pre-test | 32 | 26.53 | 8.98 | 26.50 |
| Flash card | Post-test | 32 | 49.94 | 3.87 | 51.00 |

The groups were well matched at baseline. Mean pre-test scores for CAL group and control group were 26.00 and 26.53 respectively while median pre-test scores for CAL group and control group were 27.00 and 26.50 respectively. CAL group mean was 60.44 after intervention and control group mean was 49.94; The post-test standard deviation was also much reduced in the CAL group ($SD = 1.29$) than in the control group ($SD = 3.87$), indicating more consistent performance among children taking CAL.

The CAL group had a mean gain of 34.44 points while the flash card group had a mean gain of 23.41 points. So, the CAL group demonstrated approximately 11 more points of mean improvement than control group.

### Between-Group Comparison

The Mann–Whitney U test demonstrated no statistically significant baseline difference between the groups. The pre-test comparison yielded $U = 497.50$, $p = 0.845$, with a negligible effect size ($r = 0.03$). This supports the comparability of the groups at baseline.

Following intervention, the difference was statistically significant. The CAL group had a median of 61.00 compared with 51.00 in the control group. The Mann–Whitney U test yielded $U = 985.50$, $p < 0.001$, with an effect size of $r = 0.85$, representing a very large practical effect.

**Table 2**

*Mann–Whitney U Test Comparing TEN-K Scores*

| Variable | CAL Median | Control Median | U | p | Effect size (r) |
|---|---|---|---|---|---|
| Pre-test | 27.00 | 26.50 | 497.50 | 0.845 | .03 |
| Post-test | 61.00 | 51.00 | 985.50 | < 0.001 | .85 |

The null hypothesis was therefore rejected. The findings indicated that children who received CAL demonstrated significantly better post-intervention early numeracy performance than children who received conventional flash-card instruction.

### Within-Group Improvement

The Wilcoxon signed-rank test showed a statistically significant improvement in TEN-K scores in the experimental group ($Z = -4.86$, $p < 0.001$). The source analysis also reported significant pre-test post-test improvement for children receiving the conventional flash-card intervention. Nevertheless, the magnitude of improvement was greater in the CAL group.

The findings therefore suggest that conventional instructional practice was associated with improvement in early numeracy, but computer-assisted instruction produced substantially greater gains.

### Domain-Wise Performance

The TEN-K domain-level analysis revealed improvement across all major areas in the CAL group.

**Table 3**

*Domain-Wise TEN-K Mean Scores*

| Early numeracy domain | CAL Pre-test M | CAL Post-test M | Control Pre-test M | Control Post-test M |
|---|---|---|---|---|
| Non-numerical comparative measurements | 5.72 | 8.00 | 5.81 | 8.00 |
| Identifying and sequencing numbers | 14.62 | 22.88 | 14.72 | 20.56 |
| Count and compare numbers | 5.38 | 13.56 | 5.72 | 9.88 |
| Operations with numbers | 0.00 | 4.00 | 0.00 | 2.75 |
| Shape concept | 0.09 | 4.00 | 0.09 | 4.00 |
| Money concept | 0.09 | 4.00 | 0.09 | 2.06 |
| Time concept | 0.09 | 4.00 | 0.09 | 2.69 |

The largest numerical gains in the CAL group occurred in identifying and sequencing numbers, counting and comparing numbers, and non-numerical comparative measurements. The group also reached the maximum scores in operations with numbers, shape concepts, money concepts, and time concepts.

The CAL group's mean score for identifying and sequencing numbers increased from 14.62 to 22.88, representing an 8.26-point gain. Counting and comparing numbers increased from 5.38 to 13.56, representing an 8.18-point gain. Non-numerical comparative measurements increased from 5.72 to 8.00.

The control group also demonstrated improvement, particularly in number identification and sequencing and counting and comparing numbers, but its post-test means were lower than those of the CAL group in most domains.

**Amplification Device**

A secondary analysis examined whether the effect of CAL differed according to hearing amplification device. The Mann–Whitney U test showed no statistically significant difference between BTE and cochlear implant users in the CAL group at post-test ($U = 107.00$, $p = 0.438$). Similarly, no significant difference was found in the control group ($U = 99.00$, $p =0 .353$). Within-subgroup Wilcoxon analyses showed significant improvement among both BTE and cochlear implant users in the CAL group (BTE: $Z = -3.823$, $p < 0.001$; CI: $Z = -3.180$, $p < 0.001$). Significant improvement was also observed among the corresponding control subgroups. These findings suggest that the effectiveness of CAL was not significantly dependent on the type of amplification device.

**Age-Related Differences**

Age-related analyses indicated significant differences in post-intervention TEN-K scores across the three age groups.

**Table 4**

*TEN-K Scores Across Age Groups*

| Group | Age | n | Pre-test M | Post-test M |
|---|---|---|---|---|
| CAL | 3–4 years | 5 | 18.60 | 57.80 |
| CAL | 4.1–5 years | 10 | 21.30 | 60.70 |
| CAL | 5.1–6 years | 17 | 30.94 | 61.82 |
| Flash card | 3–4 years | 5 | 21.20 | 45.60 |
| Flash card | 4.1–5 years | 10 | 26.50 | 48.30 |
| Flash card | 5.1–6 years | 17 | 28.12 | 51.82 |

The Kruskal–Wallis test showed significant differences across age groups in the CAL group, $\chi^2(2) = 10.52$, $p = .005$, $\eta^2(H) = 0.294$. Significant differences were also observed in the control group, $\chi^2(2) = 11.22$, $p = 0.004$, $\eta^2(H) = 0.318$. Both effect sizes were considered large according to the criteria reported in the source chapter.

Bonferroni-adjusted pairwise comparisons indicated that, in the CAL group, the 5.1–6-year group performed significantly better than the 3–4-year group ($U = 11.00$, $p = 0.003$), whereas the differences between 3–4 and 4.1–5 years and between 4.1–5 and 5.1–6 years were not significant after correction.

The results indicate that developmental age was associated with post-intervention numeracy performance. However, the younger children also demonstrated substantial gains following CAL.

### Qualitative Findings

Qualitative evidence supported the quantitative findings. Children in CAL group had a higher level of attention span, motivation, persistent participation, and desire to repeat arithmetic activities. The quick feedback and audiovisual cues and the dynamic animations appeared to hold the children's attention and to allow them to practice over and over.

The investigator noticed improvements in number recognition, correct counting, number ordering, comparison of quantities, simple addition, form recognition, and understanding of money and time concepts. Children who used CAL were more able to do numeracy activities on their own, and felt more confident about mathematics.

Qualitative data showed demonstrated learning transfer beyond the formal instructional sessions. The children were observed identifying numbers in their environment, counting objects in school routines, and employing numerical ideas in everyday situations. Parents reported that their children had used ideas about arithmetic they had learned recently outside the classroom, and had counted household items voluntarily.

### Parent Feedback

The effectiveness of CAL was further supported by input from parents. On the parent assessment scale devised by the researcher, 90.62% of the parents reported very constant or regular improvement in children's numeracy and overall CAL effectiveness. Likewise, 87.50% reported extremely consistent or regular improvement in interest, motivation, attention, and engagement. Independent practice and confidence were also highly commended by parents. All of the parents rated the assessed areas as noticed at least sometimes. These findings give further evidence that the impacts of CAL extended beyond test performance to children’s participation, confidence and independent learning behaviors.

## VIII. Discussion

The main outcome of this study was that Computer-Assisted Learning was much more successful than conventional flash-card instruction in enhancing the early numeracy skills of preschool children with hearing loss. Improvement was observed in both the groups, but the CAL group reported a significantly higher improvement in TEN-K scores. The post-test between-group difference was significant and had a very large effect size ($r = 0.85$). The baseline analysis indicated no significant difference between groups, which lends support to the view that the observed post-test difference was related to the instructional condition and not large pre-existing variations in numeracy skill.

The size of the effect is especially striking because early numeracy is multidimensional and requires the progressive coordination of number symbols, quantities, relations, sequencing, and operations. The most important improvements in the present investigation were found in the identification and sequencing of numbers and in the counting and comparison of numbers. These skills are essential foundations for further arithmetic and logical reasoning. Similarly, in early mathematics research, the importance of number knowledge, numerical relations, counting, comparing, and arithmetic in the preschool era is emphasized.

The findings confirm evidence demonstrating technology-enhanced mathematics courses can assist mathematical development in preschool. Clements and Sarama (2007) observed considerably better gains in mathematical achievement for preschool children who received the Building Blocks intervention, which included research-based technology-enhanced mathematics resources. The present study adds to the body of evidence in a population of preschool children with hearing loss, and significantly, in a Kannada language teaching context.

However, the results should not be interpreted to mean that all computer-based mathematics programs are effective just because they are computer-based. Aunio and Mononen (2018) discovered that children who played an instructional computer game improved in early numeracy, although there were no statistically significant between-group differences. Instructional design is crucial as the fact that their findings are different to those reported above shows. CAL-KELEN is designed for pre-school children with hearing loss and includes visual representation, animation, interactivity, rapid feedback, repetition and Kannada language content. The effectiveness found in the present study may be connected to the technology being aligned with the learning objectives, developmental level, language and accessibility demands of the children.

Results may be further explained by the Cognitive Theory of Multimedia Learning (Mayer, 2009). The CAL-KELEN curriculum included visual information, vocal or auditory reinforcement and interactive tasks. Multimedia theory of learning indicates that good word–picture pairings facilitate meaningful learning. For youngsters with hearing loss, the visual channel may be especially useful because it can offer relatively direct access to representations of numbers, amounts, forms and mathematical connections.

The findings are also compatible with Paivio's (1986) Dual Coding Theory which highlights the role of verbal and non-verbal representational systems in learning and memory. In CAL-KELEN, numerical symbols were regularly linked to visual elements, amounts, animations and contextual instances. Such associations may have helped children to link abstract symbols to meaningful quantities.

A further useful interpretation can be made from Bruner's (1966) theory of representation. The CAL curriculum was developed to help children go from visual, interactive models to symbolic number representations. This may have been especially valuable for preschool children who were still developing the ability to interpret abstract mathematical symbols. According to Bruner the right kind of portrayal helps children in shaping their concepts.

Qualitative findings further contribute to understanding the methods through which CAL might have facilitated learning. Children were more independent in their counting, number recognition and use of mathematical ideas. Children translated counting and arithmetic knowledge to household and everyday situations, parents also stated. This transfer is pedagogically crucial as authentic numeracy development entails the application of numerical knowledge in real-world settings and not only the reproduction of results in organized testing.

The present findings also have significance for children with hearing loss. The CAL program decreased dependency on one learning mode. Children with both BTE hearing aids and cochlear implants exhibited considerable improvement. The post-test comparison did not demonstrate significant difference between amplification groups. This shows that the visual and interactive nature of CAL may have helped learning despite variations in hearing technology.

Age disparities were also found. Younger preschool children scored lower in numeracy after the intervention than older children. This is consistent with the developmental character of early numeracy. Normally With development youngsters develop increasingly advanced skills of counting, comparing, sequencing and arithmetic. The older children also may have had more linguistic experience, attention, working-memory capacity, and familiarity with instructional processes. However, the younger CAL group also revealed a significant rise from pretest mean of 18.60 to post-test mean of 57.80. Thus, it seems that the developmental stage is a factor in the amount and rapidity of performance rather than a factor that negates the possible advantages of CAL.

The findings are of special relevance to multi-lingual and regional language education in India. The CAL-KELEN program was designed specifically for Kannada-speaking children, the numeracy component included Kannada language content and settings relevant to the local environment. This language and cultural relevance may decrease unneeded cognitive load and allow the youngsters to focus on the mathematical subject being taught. The significance of early mathematics learning in culturally and linguistically appropriate contexts is of special relevance to the Indian preschool setting.

## IX. Conclusion

The present study shows strong evidence that Computer-Assisted Learning can be an effective way to improve early numeracy abilities among Kannada speaking preschool children with hearing loss. CAL youngsters improved far more than would regular flash-card children. The CAL group increased from a mean TEN-K score of 26.00 at pretest to 60.44 at post-test while the control group increased from 26.53 to 49.94. Post-test difference was statistically significant with a very large effect size ($U = 985.50$, $p < .001$, $r = 0.85$). The advances were in a number of areas of early numeracy including number recognition and sequencing, counting and comparison, operations, shapes, money and time. Qualitative studies also demonstrated that students paid more attention, were more motivated, were more independent, had more confidence and used numerical concepts in everyday circumstances. The lack of major differences between BTE and cochlear implant users shows that the benefits of CAL were not reliant on the kind of amplification device. Age disparities were noted with older preschool children generally showing stronger numeracy skills after the intervention. However, younger children also demonstrated significant improvement. Overall, the results imply that a developmentally appropriate, graphically supported, interactive, and Kannada-language computer-assisted learning application can be a useful supplementary method to early numeracy training for preschool children with hearing loss. The results suggest continuing development and evaluation of accessible regional-language educational technology for use in early intervention and preschool education.

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