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Game-based learning for effective Indian sign language acquisition: A tool for hearing-impaired and hearing individuals

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Abstract
An interactive word search game that teaches Indian Sign Language (ISL) vocabulary has been developed for both hearing-impaired and hearing communities. Using the game-based learning (GBL) paradigm, the game consists of visual and interactive components, such as windows containing clickable word lists, images, and sign language videos, to enhance engagement and stimulation compliant with learner needs. A detailed literature review places the current work within the context of existing GBL-based research on sign language. Meanwhile, an empirical study involving 50 participants from diverse backgrounds was conducted over a period of four weeks to determine the game's effectiveness. The evaluation results revealed a high retention rate of ISL vocabulary among all participants: the hearing-impaired group learned an average of 9.8 to 15.2 new signs on average, and the hearing group learned an average of 9.8 to 10.5 signs, indicating that the results were statistically significant; concurrently, participants were highly engaged, giving the highest points, 4.3 to 4.5, on the 5-point Likert scale for enjoyment level. This result confirms that GBL is effective for sign language. The inclusive design of the game promotes peer learning that bridges the communication divide between hearing and hearing-impaired communities toward inclusive education. This study paves the way for accessible educational technology and provides valuable insights for both educators and developers catering to diverse learners.

Keywords: Game-based learning, Indian sign language, hearing-impaired, inclusive education, sign language acquisition

1. Introduction

1.1 Sign Language and Indian Sign Language

Sign language is a visual-gestural language for communication used by hearing-impaired individuals, having its grammar and syntax different from those of spoken languages. Indian Sign Language (ISL) is the primary sign language used by the Indian deaf community and recognized as a separate language with various linguistic features. This study is dedicated to ISL to develop a game-based learning tool for signing education of both the hearing-impaired and hearing people.

1.2 Hearing Impairment and Educational Challenges

Hearing impairment causes great disruption in communication and education and, most often, leads to social isolation and reduced access to mainstream educational resources [20]. According to the World Health Organization, approximately 63 million people in India suffer from significant hearing loss, with a fairly high number of children and young adults requiring specialized tools in education [21]. Hearing-impaired people must learn sign language, while the traditional method of teaching may sometimes not be entirely conducive to their visually or kinesthetically oriented methods of learning [12]. With no common and stimulating tools available for ISL learning to date, there is a definitive demand to devise and develop techniques to assist this population.

1.3 Role of Sign Language in Communication and Education

Sign languages, including ISL, are complete languages with their own grammar and syntax and are used by hearing-impaired individuals to socialize, educate, and work in society [20].

Being skilled with sign language also grants hearing-impaired individuals the ability to communicate and gain access to opportunities [7]. Furthermore, teaching sign language to hearing individuals creates an inclusive environment, enabling hearing-impaired and hearing communities to engage in meaningful interactions [19]. Hence, the teaching of sign language to both groups shall serve to achieve effective and equitable means of communication.

1.4 Game-Based Learning

Game-based learning (GBL) utilizes the entertaining and interactive aspects of games to intensify educational accomplishment [3, 4, 5]. GBL has been demonstrated to increase motivation, retention, and practical applications in numerous domains, including general education [2, 18] and language learning [11]. For hearing-impaired learners especially, the visual and interactive GBL is appropriate for sign language acquisition [6, 15, 16, 17]. Instances such as MatLIBRAS Racing [14] and MemoSign [16] prove the efficiency of GBL in sign language teaching, showing considerably better vocabulary retention and user engagement.

1.5 Research Objectives and Questions

The goal of this study is to design and test an interactive word search game aimed at teaching ISL to hearing-impaired and hearing individuals. The objectives are as follows:

- To design a visually stimulating game with interactive elements to aid the acquisition of ISL vocabulary.
- To determine the effectiveness of learning through the game with sign language skills and engagement.
- To investigate the potential of the game for promoting inclusive education and communication.

Some of the main research questions are

- How effective is the game in acquiring ISL vocabulary for hearing-impaired and hearing individuals?
- Does the game increase engagement and motivation in contrast with the traditional ways?
- What are the larger implications of GBL concerning sign language education in various dimensions?

1.6 Benefits of Learning Indian Sign Language for Hearing Individuals

The learning of ISL creates empathy among hearing individuals, facilitating better communication with hearing-impaired individuals [19]. In an inclusive educational setting, hearing students with the ability to communicate in ISL can work alongside their hearing-impaired peers, furthering the goal of social inclusion [7]. It also provides career opportunities to applicants who must communicate with hearing-impaired persons, such as in teaching and healthcare [12]. Through GBL integration, this study aims to make learning ISL appealing and accessible to all learners while furthering social inclusion.

2. Literature review

2.1 Overview of Game-Based Learning

Game-based learning (GBL) essentially refers to a teaching strategy that uses interactive gaming to enhance learning outcomes by making the process of education more engaging and dynamic [3, 4, 5]. Unlike traditional teaching strategies, GBL involves active participation by means of trial and error followed by immediate feedback that enhances motivation, retention of newly acquired knowledge, and actual application of the knowledge in different domains, including the language domain [1, 9]. From a GBL standpoint, hearing-impaired students benefit significantly from the emphasis on visual and kinesthetic aspects that resonate with their learning styles [6, 15, 16, 17]. Research states that the interactive nature of GBL makes it a strong method for teaching complex skills such as sign language, while also being more fun and engaging than traditional classroom methods [1].

2.2 Game-Based Learning for Hearing-impaired Individuals

Hearing-impaired persons uniquely face barriers to communication and education, relying on visual cues and sign language for communication [20]. The traditional methods that might have an auditory base are less effective for hearing-impaired learners [12]. GBL tries to work around this by using visual and interactive elements like animations, videos, and gamified challenges to teach sign languages [1, 14, 16]. A systematic review on games for hearing-impaired students supports GBL's potential in facilitating engaging learning environments that are accessible to hearing-impaired learners and addressing barriers to education itself [13]. By creating these immersive learning environments, GBL increases engagement while simultaneously building one of the key skills that its learners need in order to communicate for social and educational integration [7, 15].

2.2.1 Studies on Teaching Sign Language Through Games

Several studies on GBL for teaching sign language have revealed important insights related to the development of tools for Indian Sign Language (ISL):

MatLIBRAS Racing: This game teaches Brazilian Sign Language (BSL) numbers within a 2D racing setting for both children (7 to 12 years) and adults. Players solve math problems to speed up; BSL signs are displayed in tandem with Arabic numbers at first, followed by signs only once the player has given six correct answers. Made with Unity, the game was designed for the visual audience and was made touch-ready for accessibility. As per research carried out on students, 71.1% learned 5 or more signs, 89.5% found the game motivating, and 97.4% rated it as a beneficial tool [14].

Intelligent Game-Based System for ASL: This system uses the Kinect sensor for the 3D trajectory capture of American Sign Language (ASL) movements and provides immediate feedback to the user via a Unity-based interface. It consists of a practicing mode and a testing mode and provides feedback on correct and incorrect signs. This study showed that the game-based group obtained better post-test scores ($p<0.05$) than the traditional face-to-face group for the five vocabularies (e.g., bear, lion), which means better learning outcomes [15].

Memo Sign: A memory match game utilizing SignWriting was rated 100% easy to use by hearing-impaired learners, who reported that it helped reinforce vocabulary [16].

Inclusive Glossary of Mathematical Terms (GIM): GIM is a tangible game that teaches mathematics and Portuguese Sign Language (LGP) to hearing-impaired, and hearing children (aged 3 to 8). Using physical cards with QR codes and digital videos, it works as a memory game combined with an inclusive glossary. According to case studies conducted with 120 GIM cases, it was found that GIM could assist the acquisition of LGP, especially for hearing-impaired learners, and foster an atmosphere for peer learning [7].

The analyses illustrate GBL's capability to make sign language engaging and inspiring, especially through designs that are visual and interactive based on the hearing-impaired learners' needs.

2.2.2 Key Outcomes from the Past GBL Studies

Several benefits of using GBL for sign language acquisition have been gathered from the studies in the review:

- **Sign retention improvement:** MatLIBRAS Racing claimed that over 70% of its players could correctly recall BSL signs, while the Kinect system for ASL showed statistically significant improvement in post-test results [14, 15]. GIM has been shown to improve vocabulary retention in LGP, especially for hearing-impaired children [7].
- **Engagement and Motivation**: The competitive and interactive nature of the tasks, such as racing in MatLIBRAS or scoring in the Kinect system, fostered motivation, with 89.5% of participants in the MatLIBRAS study considering it motivating [14, 15]. GIM's tangible interface proved very engaging to young learners [7].
- **Inclusive Learning Context**: GIM provided evidence that GBL could afford an inclusive environment in which hearing-impaired and hearing people learn side-by-side, fostering social inclusion with awareness of diversity [7].
- **Instant Feedback:** Such feedback was of paramount importance for the skill development of learners, as the Kinect system acknowledged mistakes immediately and allowed learners to rectify themselves [15].

All these benefits underscore the value that GBL brings to sign language education while making it accessible, interesting, and effective for a diverse range of learners.

2.3 Accessibility Challenges and Solutions in Game Design

Designing GBL tools for hearing-impaired learner's calls for specific accessibility challenges:

- **Visual Feedback:** Hearing-impaired learners infer from visual information with respect to clear visual feedback. The Kinect-based ASL game had lights for right and wrong signs as visual cues to reinforce learning [15].
- **Avoiding Sounds:** Games cannot give instructions through sound but have rather to use visual, or possibly haptic, feedback and instructions. MatLIBRAS Racing was an example that consisted entirely of visual elements [14].
- **Customizable Interfaces**: These set-ups allow for adjustments of text sizes and high-contrast visuals to address different visual abilities, in line with accessibility guidelines [8, 10].
- **Inclusive Design**: Games like GIM are designed to allow peer learning opportunities between hearing-impaired and hearing persons to be more inclusive [7].

The aforementioned solutions grant GBL tools the ability to be accessible yet remain relevant for hearing-impaired learners.

2.4 Gaps in the Literature

Though there has been a surge in the build-up of research on GBL for sign language, very few studies concentrate on Indian Sign Language (ISL). Most researchers have proposed typifications for most other sign languages, like BSL, ASL, and LGP [1, 7, 14, 15]. A much-needed inquiry into the adaptation of GBL techniques for the unique grammar and vocabulary of ISL, evaluating its applicability in an Indian setup, is of the essence. The collaboration may have to involve ISL experts to ensure accuracy in representation, as has been done for some sign language games [15]. This study intends to address the identified gaps through the design and evaluation of a GBL tool for the acquisition of ISL.

3. Approach USED

3.1 The Developed Game: Description

The developed game is a web-based word search game designed to teach Indian Sign Language (ISL) vocabulary to both hearing-impaired and hearing students. It uses GBL teaching techniques to keep the learning environment interesting and easily accessible by hearing-impaired learners with visual and kinesthetic preferences [17]. Words from selected categories were hidden in the 15x15 grid horizontally, vertically, or diagonally. Players chose a category, such as "Classroom Objects" or "Fruits," and interacted with the word list given. Once a player clicked on a word, a picture of that particular object along with a brief video showing the sign in ISL were immediately shown for instant visual reinforcement that enhances vocabulary retention [1, 14, 16].

We designed the game using vanilla JavaScript (ES6) and HTML5 Canvas to render the grid so that users would be able to play the game using a number of devices, such as desktops, tablets, and smartphones. The interface is also built with high-contrast colors, big font sizes, and keyboard navigation to provide access to users with visual or motor impairments, following the accessibility guidelines for hearing-impaired learners [8, 10]. The design focused on user friendliness and could, therefore, be used by children, adults, and individuals varying in tech familiarity.

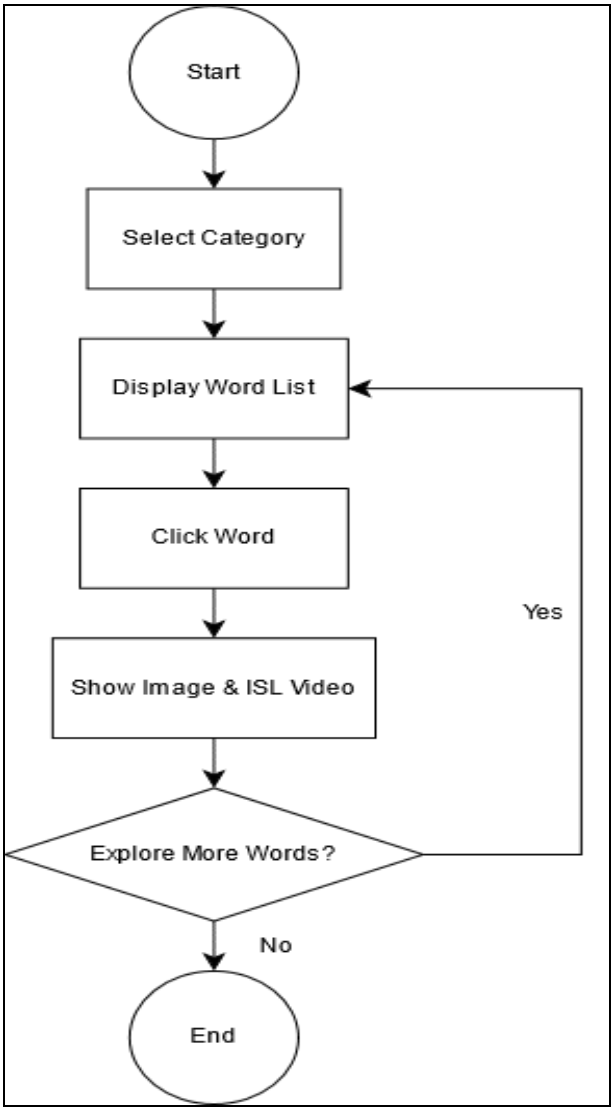

Fig 1: Game Logic Flowchart, depicting the game logic for the ISL Word Search Game.

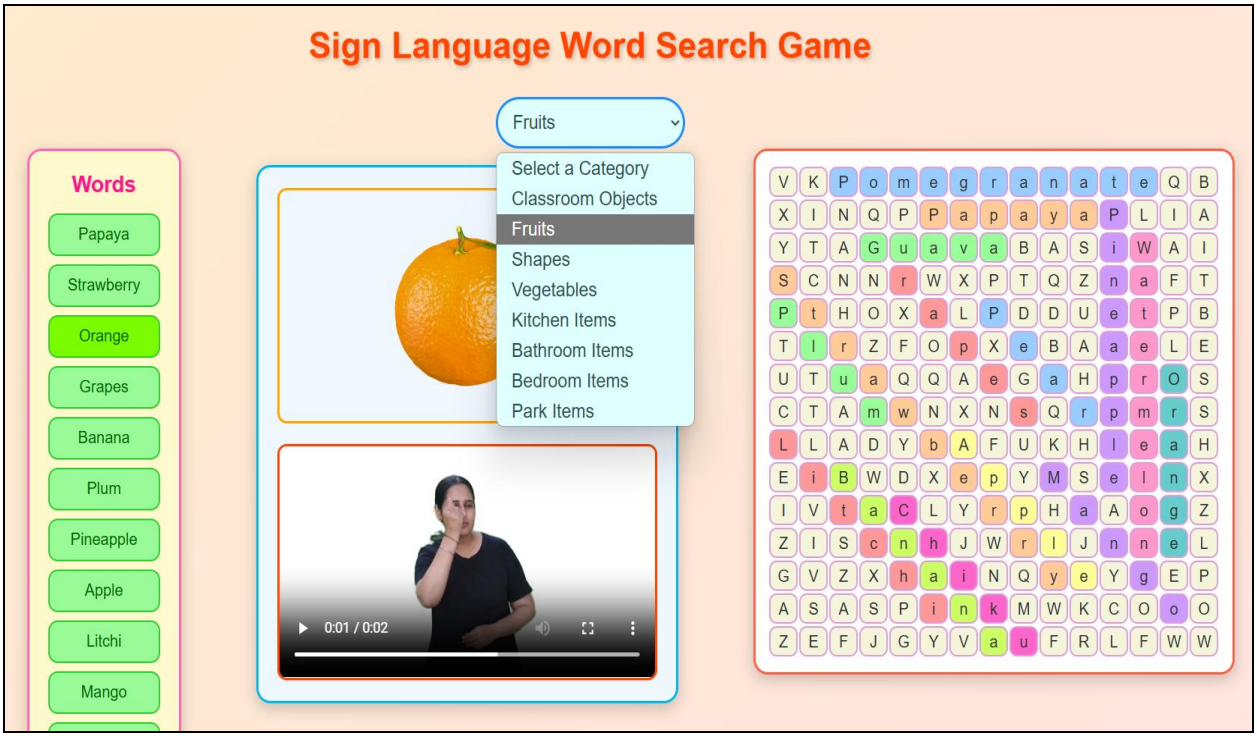

Fig 2: Game Interface, includes the word search grid, word list, and visual feedback area.

3.1.1 Game Design and Features

The game incorporates several features that enhance the effective learning of ISL:

- **Word Search Grid:** A grid of 15x15 boxes hides words that players are expected to search for actively; hence spelling and word recognition are reinforced, emulating the interactive features of MemoSign [16].
- **Clickable Word List:** Players get the chance to click on any of the words provided in the sidebar list to see images and videos of ISL signs relevant to that word. This is a form of immediate feedback found in a Kinect-based ASL system [15].
- **Sign Language Videos**: A short video is displayed to demonstrate the ISL sign for each word, providing an opportunity to practice the accurate sign gestures, which has proven to be an effective method in previous studies [14, 15].
- **Images**: High-quality images are used for each word to strengthen visual association and retention, as with the use of visual aids in GIM [7].
- **Randomization**: The words in the word list as well as those on the grid will be shuffled in every session so that players get to practice in new settings each time, thereby helping to keep up the interest [1].

Elements of game design and interactive feedback in this game align with digital game-based language learning principles that motivate learners and increase learner engagement [11]. This provides the learner an interactive and visual experience that fits right in with the principles of game-based learning, which emphasize engagement and immediate feedback [3, 4].

Algorithm for ISL Word-Search Generation

Ensuring that the game remains functional and educative required the development of an algorithm that generated word search grids dynamically for the ISL learning game. The algorithm provided places selected ISL vocabulary words in a 15x15 grid in random directions (horizontal, vertical, or diagonal) without conflicting overlaps.

Algorithm: ISL Word-Search Generation

Input

- Grid Size: 15 × 15 (rows = 15 and columns = 15)
- Word List: List of ISL vocabulary words, for instance, ["Chair", "Desk", "Backpack",...]
- Allowed Directions: Horizontal, Vertical, Diagonal (Forward Slash / and Backslash \)

Output

- Grid: A 15×15 matrix containing the words and filler letters
- Word Positions: A list of tuples giving the starting row, column, and direction for each word.

Steps

1. Initial grid: Initialize a 15×15 matrix filled with a placeholder character such as underscore (_).

2. Place Each Word

For each word in Word List:

a. Randomly choose a direction from Allowed Directions.

b. Randomly select a starting position (row, column) such that the word actually fits into the grid:

- Horizontal: column + word.length - 1 < 15
- Vertical: row + word.length - 1 < 1
- Diagonal (\): row + word.length - 1 < 15 and column + word.length - 1 < 15
- Diagonal (/): row + word.length - 1 < 15 and column - word.length + 1 >= 0

c. Check whether the word can be placed at the position:

- If all target cells are either empty (_) or already contain the correct letter, proceed.
- If there is a conflict, try a new random position and direction.

d. If valid, place the word by putting cells with its letters.

e. If invalid, repeat steps 2a-2c up to 100 attempts. If still unsuccessful, skip the word.

3. **Fill-up remaining cells:** Fill up any empty (_) cells with random letters (A-Z) to complete the puzzle.

4. Return the Final Grid and Word Positions that can then be used in the game interface.

The algorithm allows letter overlaps if they match, thus making the puzzle more challenging. It dynamically generates grids from one session to another for replayability.

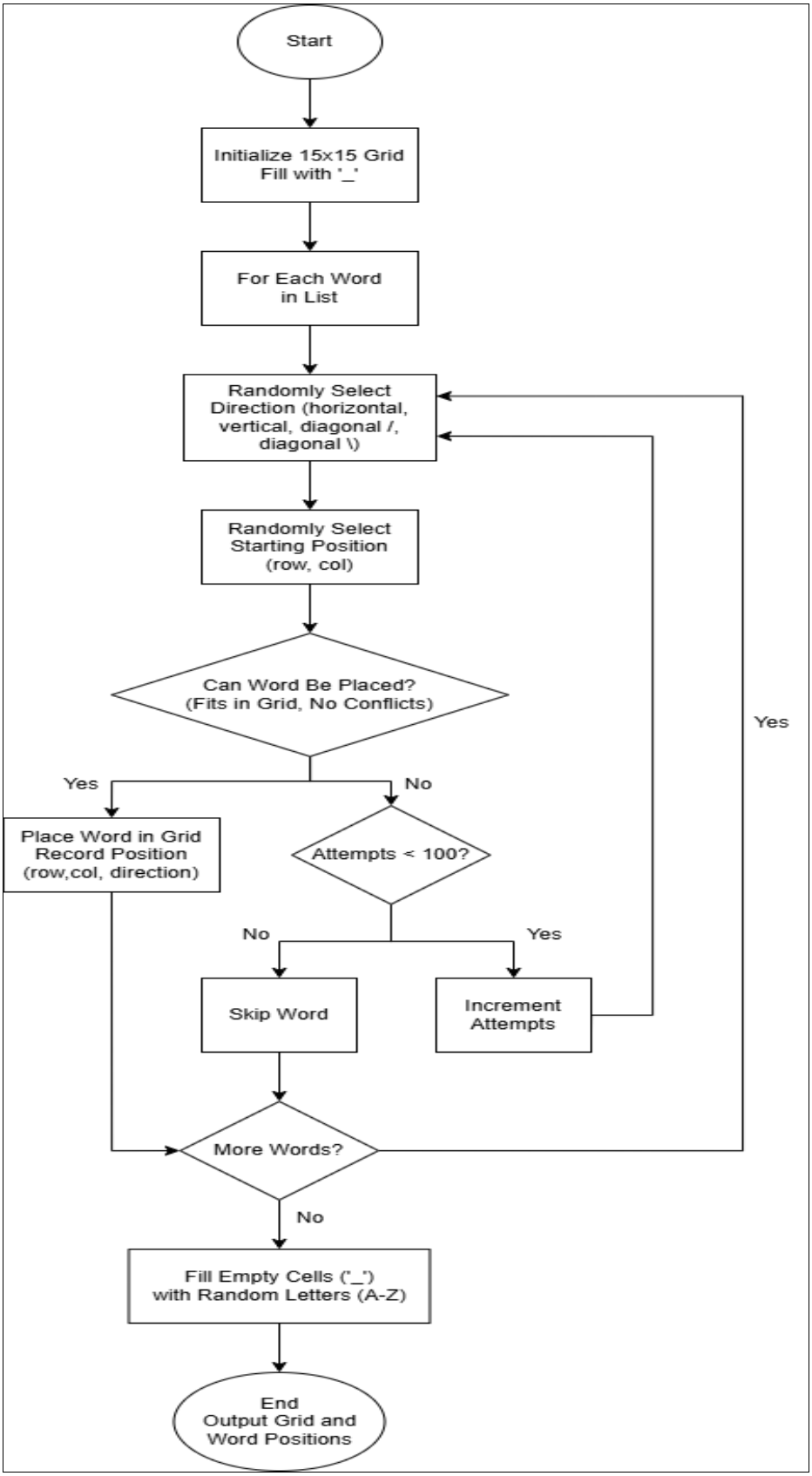

Fig 3: Algorithm for ISL Word-Search Generation

The algorithm ensures that each word is placed randomly in one of the three directions with a check to prevent conflicts. It encourages replayability by means of unique grids generated each session and allows interactive features such as highlighting the words that have been found, thus inciting and facilitating gameplay as per GBL principles.

3.12. Categories and Listed Words

There are eight categories within the game, each containing 11-21 words related to everyday contexts to ensure practicality.

Table 1: Categories and Listed Words

Category	Words
Classroom Objects	Chair, Desk, Bag pack, Eraser, Globe, Notebook, Scissors, Blackboard, Book, Calculator, Chalk, Compass, Glue, Marker, Pen, Ruler, Whiteboard
Fruits	Banana, Orange, Litchi, Grapes, Guava, Pomegranate, Apple, Pineapple, Papaya, Strawberry, Pear, Mango, Watermelon, Plum
Shapes	Circle, Rectangle, Triangle, Square, Oval, Diamond, Heart, Hexagon, Trapezium, Parallelogram, Cone, Cylinder, Cube, Pentagon, Arrow, Cross
Vegetables	Onion, Garlic, Lemon, Ginger, Radish, Cucumber, Carrot, Bottle Gourd, Capsicum, Arbi, Pumpkin, Potato, Mushroom, Bitter Gourd, Cauliflower, Coriander, Tomato, Brinjal, Cabbage, Peas, Lady Finger
Kitchen Items	Refrigerator, Microwave, Stove, Bowl, Spoon, Fork, Juicer, Mixer, Cauldron, Rolling, Sink, Glass, Cylinder Gas, Plate, Kitchen Towel, Rolling Board
Bathroom Items	Mug, Toilet Brush, Towel, Shampoo, Soap, Bucket, Commode, Hair Dryer, Tooth Paste, Shower, Razor
Bedroom Items	Bed, Pillow, Bedsheet, A.C., Heater, Curtains, Almirah, Mirror, Clock, Lamp, Mattress, Fan, Dressing Table, Drawer, Study Table, Iron Board, T.V., Blanket
Park Items	Ground, Plants, Birds, Flowers, Yoga, Exercise, Walk, Slides, Benches, Swings, Fountains, Trees

In these categories, a wide range of vocabulary is covered to put this game into perspective for daily communication and educational settings.

3.1.3 Visual Elements and Interactivity in the Game

This game is designed for the needs of visual and kinesthetic learners within the hearing-impaired individuals:

- **Visual Feedback:** By clicking on a word, an image and ISL sign video are displayed, with vocabulary therefore reinforced by visual association, which is supported by visual learning research for the hearing-impaired [17].
- **Interactive Grid:** Solving the word search grid through interaction stimulates active participation, further immersing learners in engagement through movement learning or problem-solving, similar to MatLIBRAS Racing [14].
- **Engagement through Design:** The interface is fun due to varied animations; besides that, everything is made in high-contrast colors with simple controls that ensure accessibility and pure joy for everyone [8].

These elements support the GBL principle of visual and interactive learning to make the game more effective for ISL acquisition [1, 9].

3.2 Evaluation Methods

The efficacy of the game was evaluated using a mixed-methods approach, which utilized both quantitative and qualitative data to determine the learning outcomes and engagement.

3.2.1 User Testing with Hearing-impaired Individuals

This major evaluation was specifically designed for hearing-impaired individuals, including children and adults, to ensure that the game comprehensively catered to the learning needs of the target audience.

- **Selection of Participants:** Participants were solicited from schools for the deaf, and community centers. The sample size consisted of 30 individuals, spanning an age range of 5 to 60 years, and possessing differing levels of proficiency in Indian Sign Language (ISL), in order to judge how effective the game would be for a broad range of learners.
- **Procedure for Testing:** The participants were divided into two groups: those with knowledge of ISL and those without (n=15 each). The groups were given the game to use. Pre- and post-tests measured the acquisition of ISL vocabulary.

3.2.2 Data Collection and Analysis Methods

Quantitative Data: Pre- and post-test scores were compared using paired t-tests to assess any statistically significant improvement in ISL vocabulary achievement. Survey results were quantified to identify trending answers to satisfaction and engagement conceptions, using descriptive statistics.

Qualitative Data: Interview transcripts and observation notes were analyzed thematically through coding to develop recurring themes, such as favorite features, issues of usability, and perceived benefits in learning, following qualitative methods in GBL research.

The inclusiveness of the game was further assessed by a second evaluation involving 20 hearing individuals (e.g., students, educators), who tested the learning of ISL with feedback. This secondary evaluation thus ensured the applicability of the game for both hearing-impaired and hearing parties, thus contributing to inclusion in education.

Table 2: Evaluation Components and Purposes

Evaluation Component	Method	Purpose
Pre/Post-Tests	Standardized vocabulary tests for ISL	To measure vocabulary acquisition
Surveys	Likert scale questionnaires	To measure usersatisfaction and engagement
Observations	Researcher notes during gameplay	To identify usability and interaction patterns
Interviews	Semi-structured with participants	To gather qualitative feedback on the learning experience

This methodology provides a full assessment into the effectiveness of the game, thus imparting robust findings to ISL education.

4. Results

4.1 Learning Outcomes

The interactive word search game's effectiveness in enhancing Indian Sign Language vocabulary acquisition was assessed through pre- and post-tests administered to hearing-impaired and hearing participants. The results indicate significant improvements in vocabulary among all groups, thus implying that the game is truly effective in teaching ISL.

For the hearing-impaired participants who had prior knowledge of ISL (n=15), the mean vocabulary score was 20.5 (SD=5.2) in the pre-test and 30.3 (SD=4.8) in the post-test, with a mean difference of 9.8 words ($p<0.001$). The hearing-impaired participants without prior knowledge of ISL (n=15) started with a mean pre-test score of 0 and achieved a mean post-test score of 15.2 (SD=3.1); they learned an average of 15.2 new signs ($p<0.001$). Among the hearing participants, those with prior knowledge of ISL (n=10) increased their mean score from 10.3 (SD=2.5) to 20.1 (SD=3.0), a gain of 9.8 words ($p<0.001$). Hearing participants without prior knowledge learned an average of 10.5 new signs (SD=2.8) by the post-test ($p<0.001$). Thus, the results suggest that the game is effective in assisting in ISL vocabulary acquisition, and this is true for hearing-impaired and hearing persons alike, regardless of their prior knowledge, as the hearing-impaired persons prefer visual & interactive teaching methods.

Table 3: Pre/Post Test Vocabulary Scores

Group	N	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Difference	p-value
Hearing-impaired with Prior ISL	15	20.5 (5.2)	30.3 (4.8)	9.8	<0.001
Hearing-impaired without Prior ISL	15	0	15.2 (3.1)	15.2	<0.001
Hearing with Prior ISL	10	10.3 (2.5)	20.1 (3.0)	9.8	<0.001
Hearing without Prior ISL	10	0	10.5 (2.8)	10.5	<0.001

Scores represent the number of ISL signs correctly identified.

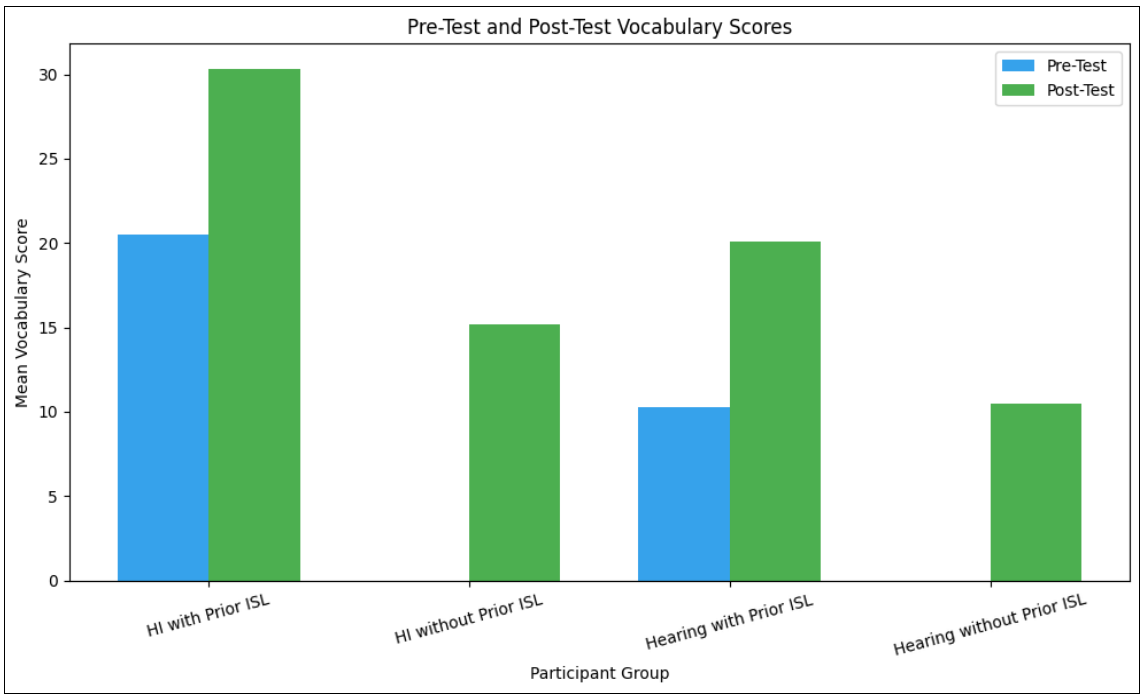

Fig 4: Learning Progress Pre-test and post-test vocabulary scores by participant group showing major improvements.

4.2 Levels of Engagement and Motivation

The post-game surveys revealed high engagement and satisfaction levels among participants. On a 5-point Likert scale (1=Strongly Disagree, 5=Strongly Agree), the mean rating for the statement "The game was enjoyable" was 4.5 for hearing-impaired participants and 4.3 for hearing participants. The mean ratings for "The game helped me learn ISL effectively" were 4.2 and 4.0, respectively. Considering such ratings, it appears that the participants scored the game highly as an engaging and learning experience.

Table 4: Survey Results on Engagement and Satisfaction

Statement	Hearing-impaired (Mean)	Hearing (Mean)
The game was enjoyable	4.5	4.3
The game helped me learn ISL effectively	4.2	4.0

This table illustrates the average ratings on a 5-point Likert scale (1=Strongly Disagree, 5=Strongly Agree) for engagement and learning effectiveness, as perceived by both hearing-impaired and hearing participants.

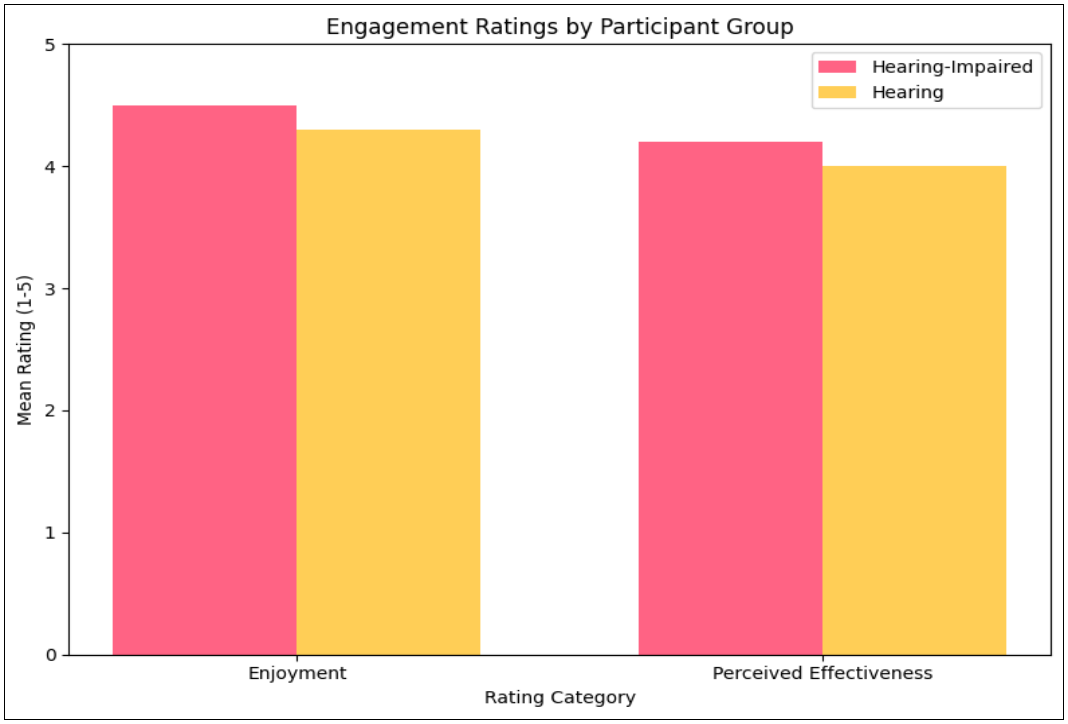

Fig 5: Engagement Ratings

Engagement ratings for enjoyment and effectiveness by participant group

Interviews and observations gave qualitative data for a more intense insight into user experiences. Participants praised the visual and dynamic components of the game, especially the sign language videos and word search grid. One hearing-impaired participant commented, "I really enjoyed learning new signs through the game. The videos helped me understand how to make the signs correctly." A hearing participant had this to say: "Playing this game made me more aware of how important sign language is, and I feel more confident communicating with my hearing-impaired friends." These remarks speak to the ability of the game to cultivate both engagement and confidence in ISL learning.

We held open interviews with 20 participants, and followed transcription by arbitrarily coding the data on recurring themes such as the ones below: visual appeal, usability, and learning experience (for summary, see Table 5).

Table 5: Summary of Qualitative Feedback

Theme	Example Quote
Visual Appeal	"I enjoyed learning some new signs from the videos."
Usability	"The grid was somewhat difficult at first but seemed to ease with practice."
Learning Experience	"This game gave me confidence in relating to my hearing-impaired friends."

Some participants suggested improvements for the game such as the addition of more categories or further difficulty levels to keep interest in the long term, implying that the players wanted to keep engaged with the game. Only a handful of hearing-impaired individuals found the 15x15 grid difficult to manage at first, but most of them said that it got easier to use with practice, indicating that the learning curve for this game is not steep.

5. Discussion

- The interactive word search has proven to be very useful in building Indian Sign Language vocabulary for both hearing-impaired and hearing individuals. Significant benefits were seen in participants with no prior knowledge of ISL.
- The competitiveness and interactivity of the word search grid, similar to gamification in student response systems (GSRSs), promoted concentration and enjoyment in younger demographics, a benefit that gamification has been proven to foster in learning contexts.
- Teachers could integrate this game into curricula to help promote inclusive education as an environment in which hearing-impaired and hearing students' study ISL alongside one another.
- The game can be the fun, interactive bridge to communication barriers between hearing and hearing-impaired students.
- This becomes particularly salient in school and workplace environments and community centers, wherein hearing and hearing-impaired people do interact.

The game allows the fun and easy learning of ISL and thus aids in removing communication barriers, as supported in research for inclusive communication practices.

6. Conclusion

This study has shown an interactive word search game to be an effective tool in the acquisition of ISL vocabulary for both hearing-impaired persons and hearing persons. Based on the evaluation, significant gains were made in vocabulary retention: the hearing-impaired participants with no ISL

knowledge learned 15.2 new signs on average, in comparison with 9.8 signs learned by those with prior knowledge. The hearing participants learned 10.5 signs and 9.8 signs, respectively. The prominent learning results show the usefulness of the game for ISL as an introductory learning tool, more so for a beginner, and this aligns with previous GBL results for sign language. High engagement was mentioned, with average enjoyment ratings of 4.5 and 4.3 by hearing-impaired and hearing participants, respectively.

7. Future work

- Carry out long-term assessments to evaluate sustained ISL retention and fluency.
- Include new categories in the game, for example, emotions and professions, and incorporate higher levels for students of varying proficiency.
- Use artificial intelligence and machine learning to provide instant feedback on sign accuracy, based on the latest ISL recognition technology.

Thus, by promoting game-based learning for Indian Sign Language, this study empowers hearing-impaired persons and cultivates societies that accommodate shared communication. The engaging and accessible nature of the game opens doors to the education field, thereby creating a platform for further equitable opportunities and the elimination of communication barriers for learners with varied needs.

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