A systematic literature review of serious games teaching sign language

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Abstract

Over 450 million people worldwide suffer from hearing loss, relying on over 200 sign languages for communication. Serious games offer a solution to teach sign language, bridging communication barriers. This systematic literature review examined 414 articles, identifying 42 serious games targeting 19 sign languages. Evaluations generally support their effectiveness in engaging and educating learners of all ages, both hearing impaired and non-impaired.

This study aids game developers in selecting suitable technologies and approaches for developing and evaluating sign language teaching games. Serious games emerge as valuable tools in enhancing communication between hearing impaired and non-impaired individuals.

Keywords: Games; Teaching/learning strategies; Improving classroom teaching; Media in education

Introduction

The World Health Organization estimates that globally, 466 million individuals have hearing impairments, including 34 million children (World Health Organization, 2021). For those born deaf, sign language often becomes their primary mode of communication (World Federation of the Deaf, 2021), showcasing linguistic complexity and diversity (Kegl et al., 1999). Sign languages incorporate manual articulation, facial expressions, and body movements for linguistic expression (Liddell, 2003). These elements convey intricate linguistic nuances and grammatical structures (Perniss et al., 2010; Supalla, 2014). Traditional face-to-face teaching methods for sign language present challenges due to limited teacher-to-student ratios. Interactive tutoring systems and digital serious games offer dynamic learning environments (Clark et al., 2016), enhancing engagement and motivation (Sailer & Homner, 2020; Susi & Johannesson, n.d.). They facilitate sign language acquisition and mastery (Dehghanzadeh et al., 2021), catering to individual learning needs. Sign language games bridge communication gaps between deaf and hearing individuals, promoting inclusivity and understanding (Dehghanzadeh et al., 2021).

This review aims to assist in developing effective serious games for sign language education, highlighting design considerations and impact on learning. We analyze 63 papers, describing 42 games for 19 sign languages.

Related work

While literature on sign language recognition, sign language itself, and serious games exists, a specific focus on their intersection, namely serious games for sign language teaching, remains scarce. Costa, Marcelino, Neves, and Sousa (Costa et al., 2019) conducted a review, but only a few projects aligned with this study's focus. Other reviews by Wadhawan and Kumar (Wadhawan & Kumar, 2019), Cheok, Omar, and Jaward (Cheok et al., 2019), and Boyle et al. (Boyle et al., 2016) primarily concentrate on different aspects, such as sign language recognition systems or general serious games efficacy. Meta-reviews by Clark, Tanner-Smith, & Killingsworth (Clark et al., 2016) and Sailer & Hommer (Sailer & Homner, 2020) also fail to address this specific niche.

This literature review aims to fill this gap by scrutinizing serious games developed for teaching sign language. Through systematic analysis, we categorize these games, assess their effectiveness, features, and integration of sign recognition systems. Given the dearth of reviews in this area, our study offers timely insights for researchers, practitioners, and game developers, promoting inclusive education and communication for individuals with hearing impairments and their communities.

Method

The following research questions guided the methodology, including data collection and analysis:

RQ0. What serious games exist for teaching sign language?

RQ1. What technological and methodological approaches do the games take to teach sign language?

RQ2. What target users are the games being developed for?

RQ3. How are these games being evaluated, and what do those evaluations say regarding their effectiveness?

The selection process for this review was divided into two phases. In the first phase, a search was conducted across scientific databases to identify relevant articles. In the second phase, we analyzed games mentioned in those articles. The main features used to categorize games were chosen before the literature search, based on research questions. For RQ1, the first and second authors independently wrote short descriptions of approaches found in selected games to cluster them into categories. They then coded all selected studies independently with an average agreement of 94.3% (technological methods) and 90.8% (methodological approaches) respectively, as measured using Jaccard coefficient, finally merging their results to generate the consensus version reported in this paper.

Throughout the research process, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Selcuk, 2019) were followed. While other systematic review methodologies exist, PRISMA is both well-known and familiar to the authors. Figure 1 provides an overview of the research process.

Phase 1: Literature search and analysis

Databases searched

We searched through the 8 following databases during March 2024: The Association for Computing Machinery (ACM) Digital Library, Education Resources Information Center (ERIC), SAGE, Taylor & Francis, IEEE Xplore, Science Direct (Elsevier), ProQuest, and Springer.

Search queries

The search queries used in this study were designed to focus specifically on games related to sign language. The inclusion of the keyword “sign language” was crucial to ensure that the search results were relevant to the topic of interest. Additionally, to encompass a range of game-like applications, a selection of keywords related to gaming was chosen, including "game," "videogame," "app," "gamification," "simulation," and "virtual environment."

The resulting query used to search within the title and, when available, the abstract of all papers was as follows:

> ("sign language" OR "sign languages") AND
> ("game" OR "videogame" OR "app" OR "gamification" OR "simulation" OR "virtual environment")

The inclusion of both "sign language" and "sign languages" addresses potential plural-handling limitations in certain systems, ensuring that relevant results are not missed due to false negatives. No additional filters or restrictions were applied during the search process, allowing for a comprehensive exploration of the literature. By employing this search query, the study aimed to gather a wide range of articles and studies specifically focusing on serious games related to sign language.

Research selection

The following inclusion and exclusion criteria further define the scope of our review:

Inclusion criteria

Peer-reviewed publications in English, from any date, describing or referred to a playable digital game with the aim of teaching sign language

Exclusion criteria

- Non-peer-reviewed publications.
- Publications where a full text in English or Portuguese was unavailable.
- Publications containing only a description of a possible game.
- Publications containing a game either to teach content using sign language, but not teaching sign language itself; or to teach sign language without the use of any technology.
- Publications about sign language translation and detection that only mention games in passing (as in “this method could be used for making a game”, but not actually describing or referring to existing games).

After removing duplicate results, we went through the title and abstract of the remaining publications, applying the above inclusion and exclusion criteria. In the next phase, we analyzed the full text of those papers, and classified each serious game mentioned in the papers, including technologies, mechanics, required peripherals, and evaluations describing their results and/or effectiveness.

During this more extensive reading, we removed several articles matching one or more of our exclusion criteria.

Phase 2: Analysis of the resulting games

Game selection

Several games were reported in more than one paper. This is the case with multi-year projects that describe different versions or aspects of a single game. Of the 63 articles selected in phase 1, 42 unique projects were found, of which 17 are unnamed. We reference unnamed projects as "NN – First Author Name".

Game analysis

Based on the final list of serious games, we analyzed each of the projects in greater depth, gathering:

- Name
- Year of first publication
- Targeted sign language
- Game characteristics
- Game mechanics
- Platform
- Technology used
- Type of game
- Information on how it was evaluated
- Type of evaluation
- Number of users
- Evaluation method
- Results
- Publications

Results

Papers identified in research

The papers described in this research were collected as described in Section 3.1.2. In our first round of searching, 414 non-duplicate papers were found.

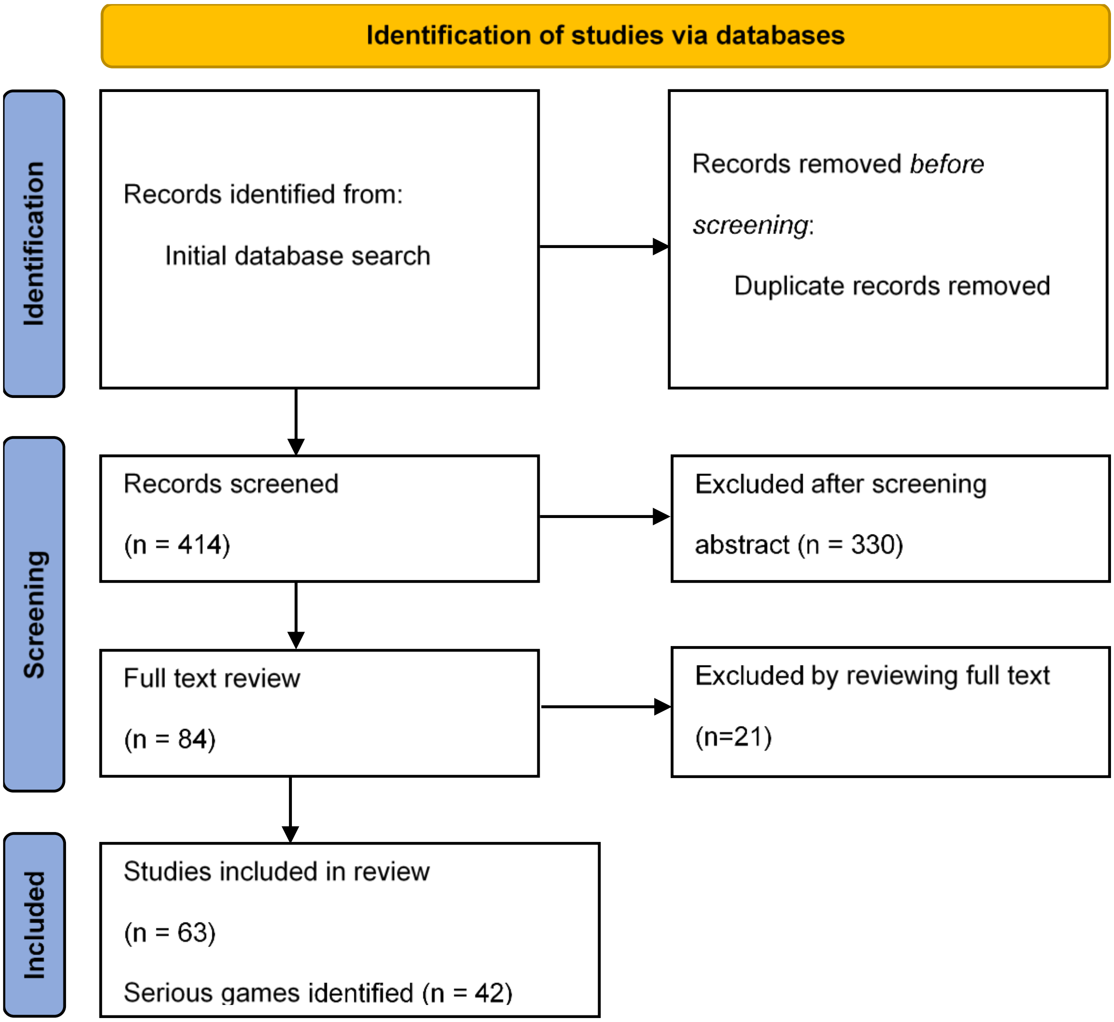

Figure 1. Summary of the review process, which followed PRISMA guidelines.

Selected papers

After applying inclusion and exclusion criteria to 414 initial candidates, only 84 papers remained. Most focused on automated sign language translation, with games mentioned as potential applications. Some articles discussed games for teaching subjects such as math using sign language, and were excluded for not teaching sign language itself.

Analyzing the full text of these 84 papers, we excluded 21 due to unplayable or conceptual projects, or “games” which lacked any gamification elements. This left us with a final set of 63 publications. The number of selected publications per year exhibits moderate growth over time ($R2 = 0.206$). Table 1 and Figure 3 display the distribution of papers across databases. Note that our search process accounted for duplicates across databases, ensuring accurate selection.

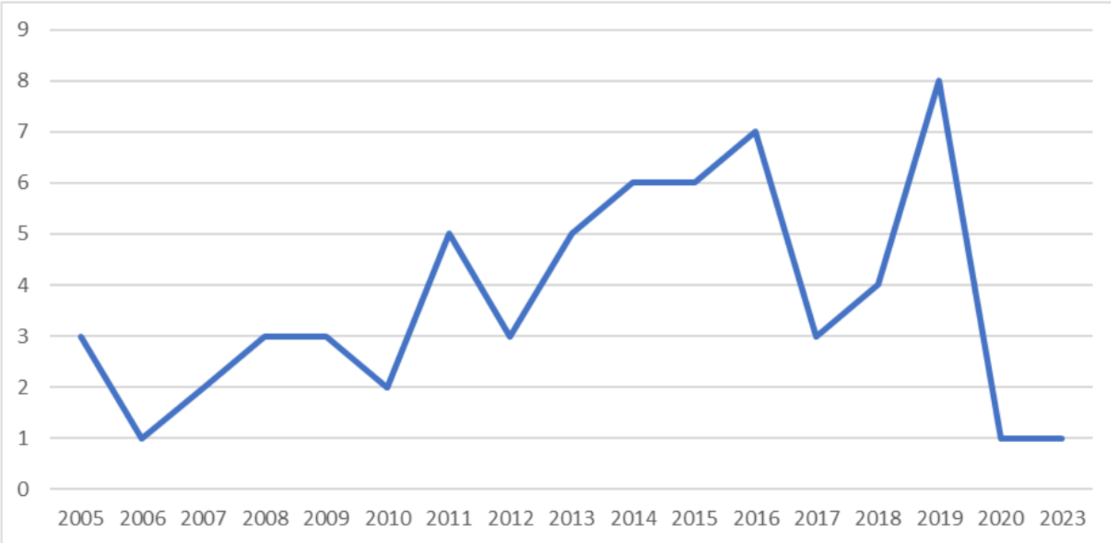

Figure 2. Number of publications related to serious games for teaching sign language and meeting inclusion criteria. The linear trend shows moderate growth over time, with a dip after 2020 that may be due to the effects of the COVID-19 pandemic.

Table 1. Number of publications identified in search and meeting inclusion criteria.

Database	# papers found	# papers included
ACM	39	19
ERIC	52	3
SAGE	2	0
Taylor & Francis	46	1
IEEE Xplore	83	15
Science Direct (Elsevier)	7	2
ProQuest	110	0
Springer Link	75	12
Papers obtained by references	-	11
Total	414	62

Selected games

After analyzing the full text of the 63 publications selected in phase 1 (available in supplementary materials), we extracted a set of actual games for analysis in phase 2. Some of these games appeared in multiple articles by the same authors, which is common when projects can last several years with papers describing incremental advances in different facets. This led to a final set of 42 games, approaching 19 sign languages in total.

From this final list of serious games, we extracted the data mentioned in Section 3.2.2; the results are shown in Table 2, where the "sign languages" column provides an overview of the specific sign languages targeted by each game. The acronyms used for each sign language can be found in Table 3, along with a count of the number of games that target it. Figure 4 sorts those counts by popularity. Taken together, Tables 2 and 3 allow us to answer RQ0:

RQ0. What serious games exist for teaching sign language?

Table 2. Main attributes of games found during phase 2 of the review. Full references for each game are available in supplementary material. NN-FirstAuthor used for games without official name. Note that target audiences were often not described.

Resource name	Year	Sign language	Platform	Technology	Game mechanics	Target audience
CopyCat	2005	ASL	PC	Colored Gloves	Imitation	Children
Auslan Children	2005	AUSLAN	PC	Pointer-only	Imitation	Children
NN – Y. Oh	2008	KSL	PC	Camera	Tetris	-
iSign Bear	2008	ASL	Teddy Bear	Interactive Teddy Bear; RFID Cards	Interactive Story	Children
PlayWare	2008	ASL	Teddy Bear; PC	Interactive Teddy Bear; RFID Cards	Interactive Story	Children
SignTutor	2009	TSL	PC	Camera	Imitation	Students
Teach Yourself Auslan	2011	AUSLAN	PC	Pointer-only	Quiz	-
Hangman Game	2011	LIBRAS	PC	Camera	Hangman	-
Nao's Tale	2011	TSL; ASL	Humanoid Robot; PC	Humanoid Robot; Kinect	Imitation; Quiz	Children; Adults
Sign My World	2012	AUSLAN	PC	Pointer-only	Imitation	Children
NN – T. Ritchings	2012	ArSL	PC	Data Glove	Imitation	Adults
iSpy-uSign	2013	TSL; ASL	Humanoid Robot; PC	Humanoid Robot; Kinect	Imitation; Quiz	Children
Luz, Camera, Libras!	2013	LIBRAS	Mobile	App	Imitation; Quiz	Teens; Adults
NN – L. Santos	2013	LIBRAS	PC	Camera; AR Cards	Memory	-
Robostar Sign Game	2014	TSL	PC	Pointer-only	Quiz	Children; Adults
NN – A. Krastev	2014	ISG	PC	Pointer-only	Quiz	Children
Virtual Sign Game	2014	PSL	PC	Data Gloves; Kinect	Adventure; Imitation; Memory	Teens; Adults
Kinect-sign	2014	PSL	PC	Kinect	Quiz	Teens; Adults
iSign	2015	TSL	Humanoid Robot; PC	Humanoid Robot; Kinect	Imitation	Children
NN – F. Soares (1)	2015	PSL	PC	Kinect	Interactive Story	Children
NN – F. Soares (2)	2016	PSL	PC	Leap Motion	Hangman	Children
SmartSignPlay	2016	ASL	Mobile	App	Interactive Story; Quiz	Children
NN – K. Silanon	2016	ThSL	PC	Pointer-only	Memory; Hangman; Quiz	Children
MemoSign	2016	ASL; TSE	PC	Pointer-only	Memory	Children
NN – M. Garcia	2016	FSL	Mobile	App	Quiz	Adults
GyGSLA	2016	PSL	Mobile	Data Gloves	Imitation	Adults
NN – M. Parreno	2017	ECS	PC	Leap Motion	Hangman; Tic Tac Toe	Children
NN – T. Kamnardsiri	2017	ASL	PC	Kinect	Quiz	Children
LeSigla	2017	ECS	PC	Leap Motion	Imitation	Children

NN – M. Zikky	2018	SIBI	PC	Leap Motion	Imitation	Children
FingerSpelling	2018	IPSL	PC	Camera	Imitation	Children
MatLIBRAS Racing	2018	LIBRAS	PC	Pointer-only	Quiz	Children
iLearnPSL	2018	PSL	PC	Leap Motion	Quiz	Children
NN – J. Schioppo	2019	ASL	PC; VR	Leap Motion; HTC VR	Imitation	Adults
i-Sign	2019	BIM	Mobile	App	Quiz	Children
Signum Battle	2019	BSL	PC	Leap Motion	Adventure; Imitation	Adults
NN – J. Mihaljevic	2019	HZJ	PC	Pointer-only	Quiz	Children; Teens
Libras Game	2019	LIBRAS	PC	Pointer-only	Memory	Children
NN – D. Rivas	2019	ECS	PC	Leap Motion	Imitation	Children
NN – A. Gordillo	2019	LSM	Mobile	Camera; AR Cards	Imitation; Quiz	Children
NN – A. Gediel	2019	LIBRAS	PC	Pointer-only	Quiz	Adults
NN – A. Mazhari	2022	ISL	VR	Oculus Quest 2	Racing	Children

Table 3. Number of games by sign language, sorted by number of games and then by language.

Sign Language Taught	# games
American Sign Language (ASL)	9
Brazilian Sign Language (LIBRAS)	6
Portuguese Sign Language (PSL)	6
Turkish Sign Language (TSL)	5
Australian Sign Language (AUSLAN)	3
Ecuadorian Sign Language (ECS)	3
Arabic Sign Language (ArSL)	1
British Sign Language (BSL)	1
Croatian Sign Language (HZJ)	1
Filipino Sign Language (FSL)	1
Indian Sign Language (IPSL)	1
Indonesian Sign Language (SIBI)	1

Table 4. Number of games using each interaction technology.

Technology Used	# games
Pointer (mouse, touch)	15
Leap Motion	8
Kinect	7
Camera	6
Humanoid Robot	3
Data Gloves	3
Interactive Teddy Bear	2
AR Cards	2
VR	2

Technologies and mechanics of sign language games

This subsection analyses technologies used for playing serious games to learn sign language, along with the different genres and game mechanics used for teaching. For this section, technology refers to the set of peripherals that players can use to interact with a game. The game mechanics focus on the gameplay, covering aspects such as the use of interactive stories, adventure games or quizzes. Collectively, we use this categorization to answer RQ1:

RQ1. What technological and methodological approaches do the games take to teach sign language?

Game technologies

As detailed in Table 2, and summarized in Table 4, we identified a total of 11 unique interaction technologies among the 42 games, with some games making use of multiple. Due to the complexity of recognizing sign language to provide relevant feedback to players, some games rely on recent techniques from automatic sign language recognition and translation, while traditional pointer-based interaction is still among the most popular choices:

Pointer-only (n=15): low-cost technology that uses a computer mouse or a touchscreen for interaction in quiz-based games, such as Teach Yourself Auslan, Robostar Sign Game, and NN – A. Krastev.

Leap Motion (n=8): a camera-equipped device which recognizes hand movements in real-time. Can effectively recognize simple gestures, which is enough for a basic teaching game (Potter et al., 2013). Examples include NN – F. Soares, NN – M. Parreno, and Signum Battle.

Cameras (n=6) and Kinect (n=7): allow players to interact with gestures. While the depth-perception of Kinect devices can detect body movements, it cannot accurately read finger data, which is very important for sign language recognition. Therefore, both Kinect and regular cameras require post-processing to interpret user interaction, typically achieved by using pre-trained machine-learning models. Games such as Luz, Camera, Libras! and Kinect-sign have used a "Wizard of Oz" system instead of machine learning, where a human (hidden from the player) evaluates the gestures and simulates a translation algorithm by providing feedback.

Humanoid Robot (n=3): robots that simulate sign language vocabulary, used in games such as iSpy-uSign and iSign.

Data Gloves (n=3): gloves containing sensors to track hand movements, as used in NN – T. Ritchings, Virtual Sign Game, and GyGSLA.

Interactive Teddy Bear (n=2): teddy bears with embedded screens or speakers for interacting with children, combined with RFID readers to recognize certain objects, seen in iSign Bear and PlayWare.

AR Cards (n=2): cards that can be displayed in front of cameras, which recognize their patterns and can then present the corresponding gestures using augmented reality, as in NN – L. Santos and NN – A. Gordillo.

VR (n=2): virtual reality headsets that can display a virtual environment for sign language learning, implemented in NN – J. Schioppo and NN – A. Mazhari.

Colored Gloves (n=1): low-technology versions of "Data Gloves", used in CopyCat, with passive gloves that are used in conjunction with a camera or Kinect sensor, allowing visual capture of finger movements and positions.

Game mechanics

Different sign language games use different game mechanics to achieve their goal, which we have classified into 8 categories, as summarized in Table 5. Games with multiple mechanics are counted several times:

Imitation (n=18): Players imitate gestures presented via picture, video, avatar, humanoid robot, etc., which are evaluated to show progress. Examples include SignTutor, NN – M. Zikky, and LeSigla.

Quiz (n=17): Players select the correct meaning of a gesture or vice versa from a set of options, seen in MemoSign, SmartSignPlay, and iLearnPSL.

Memory (n=5): Players find pairs of cards with signs and their corresponding meanings from a shuffled grid of face-down cards, as used in NN – L. Santos and Libras Game.

Interactive Story (n=4): Players interact with a story by signing a specific word or showing a related card, such as in iSign Bear and PlayWare.

Hangman (n=4): Players guess a word by signing letters, as seen in NN – F. Soares and NN – K. Silanon. If the word contains a letter, it is revealed; otherwise, a failure is recorded, too many of which lead to a loss.

Adventure (n=2): Players use traditional controllers or mouse and keyboard to control a character, interacting with other characters via sign language, such as in Virtual Sign Game and Signum Battle.

Racing (n=1), Tetris (n=1), Tic Tac Toe (n=1): Players use signs to choose a lane and overtake cars in an infinite road game (MatLIBRAS Racing); or sign the correct falling letters to make them disappear (NN – Y. Oh.); or sign numbers between 1 and 9 to play tic-tac-toe (NN – M. Parreno.)

Table 5. Number of games making use of each mechanic.

Mechanics Used	# games
Imitation	18
Quiz	17
Memory	5
Interactive Story	4
Hangman	4
Adventure	2
Racing	1
Tetris	1
Tic Tac Toe	1

Table 6. Number of games per target user group.

Target Users	# games
Children	28
Adults	10
Teens	4
Undefined	5

Target users of sign language games

This subsection seeks to answer RQ2:

RQ2. What target users are the games being developed for?

We identified 3 main targets: children (up to 12 years old), teens (12 to 18 years old), and adults. Table 6 illustrates the distribution of games per target group, counting games that target several groups multiple times. Games categorized as "Undefined" did not contain any description of their target users.

While most of the games are developed for a younger audience, there are also some projects geared for adults. Games that target both younger and older audiences, such as Nao's Tale and Virtual Sign Game, tend to have difficulty adjustments or include multiple mechanics that can cater to both simple and complex learning needs. Of the 42 games, only 6 are exclusively for adults. Four of these games require advanced devices such as Leap Motion, Data Gloves, or VR headsets.

Evaluation of sign language games

Not all projects included in this literature review contain information on how their resulting games were tested and validated, or their relative effectiveness for teaching their respective sign language. In total, 15 projects had no mention of experimental evaluation. This section studies the evaluation process of serious games to teach sign language and addresses RQ3:

RQ3. How are the serious games being evaluated?

According to the papers identified in the literature review, only 26 of the 41 games have any evaluation associated with them. Two of the projects contained evaluations that did not study the game itself but rather the accuracy of the sign language recognition tool contained within the game, which we consider out of scope for this review. The remaining 24 game evaluations, most of which (14, or 53%) merely report on the general experimental setup and number of players, while leaving out many details necessary to judge the strength and relevance of their claimed results, are summarized in Table 7, and classified into the following 5 categories:

- Measuring engagement via reactions and feedback while playing the game (n=7): Examples include PlayWare, Kinect-sign, and NN – A. Gediel, where observations included players' enthusiasm and time spent on each level.

- Measuring user accuracy and/or difficulty while playing the game (n=6): Studies like Virtual Sign Game and NN – M. Parreno involved tracking player performance to assess how accurately players could replicate signs.

- Single questionnaire after playing the game (n=6): This evaluation method was used by NN – F. Soares, SmartSignPlay, and NN – A. Mazhari, where players were asked to complete a questionnaire to gauge their experience.

- Questionnaire after playing the game, and a follow-up questionnaire (n=3): Projects such as SignTutor and NN – T. Ritchings involved a follow-up assessment to determine long-term user retention.

- Questionnaires before and after playing the game (n=2): Evaluations conducted by CopyCat and LeSigla included both pre- and post-play assessments to determine improvements in player knowledge.

A full third (34%) of cases only measure engagement, describing only players' reactions while playing, their general enthusiasm at the end of the playthrough, or measuring how much time players spent playing and interacting with each level or word.

The number of users in each experiment is highly variable (see Figure 5), ranging from 3 in NN – T. Ritchings to 230 in NN – J. Mihaljevic. There is a tendency for smaller experiments, in terms of the number of players, in projects that involve complex peripherals and setups. Only 3 experiments exceed 100 participants, with most involving less than 50, and almost 40% staying below 10.

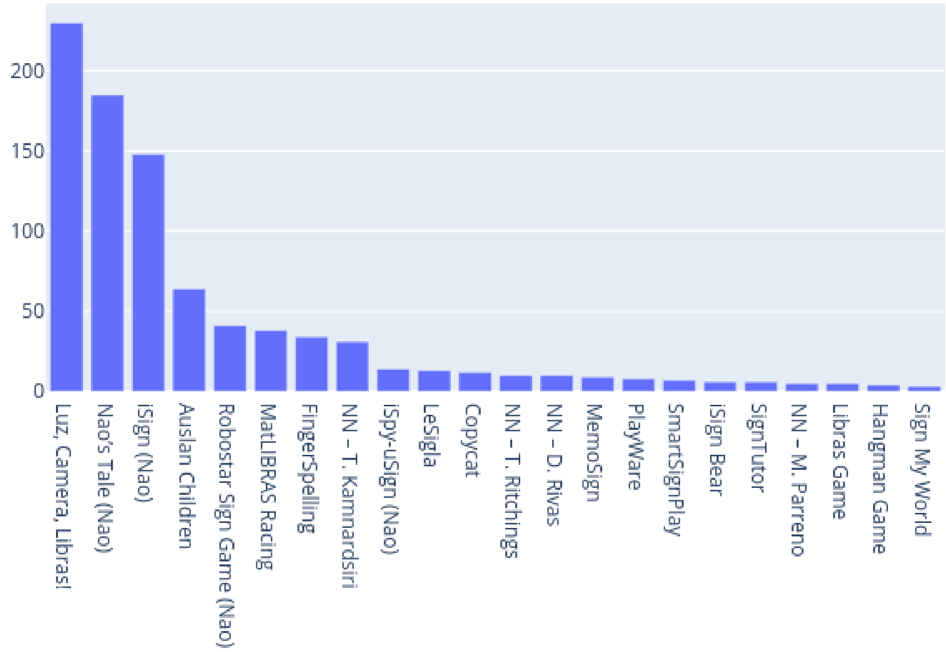

Figure 5. Number of total participants (N) for evaluations in each game.

Researchers studying Auslan children's learning used two types of assessment: receptive and expressive. Receptive assessment measures how well players associate motions with words, while expressive assessment measures how well players can sign a written word or a picture of an object. The researchers found that children performed better on receptive assessment than on expressive assessment.

Although no study makes a direct comparison between male and female groups for experiments, some do mention marked gender-linked preferences, especially with children. Auslan Children presented 3 choices for teaching sign language: a song, an interactive story, and a memory game, with researchers reporting that 9 of 17 girls on their group said that the memory game was their least preferred activity – while only 1 of 11 boys did the same. Instead, most boys selected the story as their least preferred activity. The first place regardless of gender went for the song. The researchers behind Nao's Tale and iSign also reported that boys were more interested in humanoid robots, whereas girls showed less interest in that type of technology.

Only 2 projects conducted follow-up tests or interviews, and only 2 performed multiple sessions. SignTutor divided its study into two sessions, with users becoming more comfortable with the language and the game itself, resulting in a decrease in learning time for 3 gestures from the first to the second session. LeSigla evaluated both hearing-impaired and non-sign-language speakers. Hearing-impaired users achieved higher scores due to their familiarity with the language. NN – D. Rivas included 6 sessions over time, and compared performance of deaf vs. listening users.

The only standardized type of evaluation used was the System Usability Scale (SUS), present in two projects, *NN – M. Parreno* and *NN – D. Rivas,* which requested participants in their evaluations to fill SUS questionnaires to evaluate game usability.

No Learning Analytics were reported to be implemented in any of these experiments, and as such, no study displayed information acquired during gameplay to measure the learning rates of the users.

Table 7. Evaluation of selected games.

Game	Number of users on evaluation	Detailed results?	Evaluation method	Control Group?
Copycat	12	Yes	Pre-Post Questionnaire	Yes
Auslan Children	64	Yes	Accuracy	No
iSign Bear	6	No	Engagement	No
PlayWare	8	No	Engagement	No
SignTutor	6	No	Post Questionnaire	No
Hangman Game	4	No	Engagement	No
Nao's Tale (Nao)	185	Yes	Accuracy	No
Sign My World	3	No	Engagement	No
NN – T. Ritchings	10	No	Accuracy	No
iSpy-uSign (Nao)	14	No	Post Questionnaire & Follow Up	No
Luz, Camera, Libras!	230	No	Accuracy	No
Robostar Sign Game (Nao)	41	No	Accuracy	No
Kinect-sign	"3 groups"	No	Engagement	No
iSign (Nao)	148	Yes	Post Questionnaire	No
SmartSignPlay	7	Yes	Post Questionnaire	No
MemoSign	9	Yes	Post Questionnaire	No
NN – M. Parreno	5	Yes	Post Questionnaire	Yes
NN – T. Kamnardsiri	31	Yes	Pre-Post Questionnaire	Yes
LeSigla	13	Yes	Accuracy	No
FingerSpelling	34	No	Engagement	No
MatLIBRAS Racing	38	Yes	Post Questionnaire & Follow Up	No
Libras Game	5	No	Engagement	No
NN – D. Rivas	10	No	Post Questionnaire	No
NN – A. Mazhari	5*	No	Post Questionnaire	No

* Targeted at children, but evaluated on adults due to COVID-19

Discussion

Properties and mechanics

Over time, serious games for teaching sign language have advanced, with a growing number of publications indicating increasing interest in their development. Initially focused on Australian and American Sign Languages, recent years have witnessed diversification, covering a broader range of sign languages, including International Sign Language (McKee & Napier, 2002). These advancements reflect the expanding recognition of the importance of sign language.

Ellis and Blashki (Ellis & Blashki, 2007) introduced the concepts of expressive and receptive learning, highlighting a predominant emphasis on expressive learning in game mechanics, which shows promise for effective sign language acquisition. Games like LeSigla and MemoSign have demonstrated the effectiveness of incorporating expressive learning elements, enhancing users' ability to produce signs accurately.

Debates persist regarding the use of avatars versus real individuals as sign language representations, with challenges concerning nonmanual components (Kipp et al., 2011). For example, studies like Kinect-sign have used avatars, which, while effective in demonstrating basic signs, struggle with facial expressions and body language crucial to sign language proficiency. Our study identifies emerging patterns such as diversification of covered sign languages and technological advancements in sign language processing, as seen in the use of Leap Motion for gesture recognition (e.g., NN – F. Soares).

Recent developments include broader sign language coverage, emphasis on expressive learning, and advancements in recognition technologies. Games such as SmartSignPlay have leveraged interactive storytelling to keep young learners engaged, showing how narrative elements can make sign language learning more relatable and immersive.

Target Audience

Most sign language teaching games are designed for children, with games such as iSign Bear and PlayWare specifically catering to this age group. Only a few games target adults and use advanced technologies such as VR headsets and data gloves, for example, NN – J. Schioppo and GyGSLA. These technologies provide more immersive experiences can potentially enhance learning for older users by offering complex interaction opportunities.

Researchers found that children often lack awareness and understanding of deaf individuals and the importance of learning sign language. Increased community awareness and understanding of hearing disabilities could stimulate children's interest in learning sign language. Children may exhibit shyness and resistance due to cultural norms of speech-based societies, emphasizing the need for awareness about hearing disabilities and sign languages in education. Games like NN – M. Parreno have aimed to address this by incorporating friendly, interactive elements that encourage participation without fear of judgment, which helps overcome initial reluctance.

By recognizing the characteristics of its target audience, including cultural influences, serious games can be designed to improve user engagement. For example, MatLIBRAS Racing uses competitive game elements to motivate children to practice sign language, turning learning into a playful challenge rather than a formal educational task.

Validation, Validity & Effectiveness

Many reviewed articles lacked comprehensive evaluations of their serious games. Out of the articles that did include evaluations (see Table 7), over 53% did not describe essential details of their experiments, necessary to interpret the strength of their results; and over 34% only assessed engagement, missing the chance to gain deeper insights into the actual effects of their teaching methods.

Regarding external validity, many of the evaluations included small, relatively uniform sample sizes. This limits the ability to generalize findings to larger and more diverse populations, including different age groups or different learning contexts. Reliance on specific technologies, such as Leap Motion or Kinect, also presents challenges for generalization, as these technologies may not be accessible or feasible in all educational settings.

Internal validity of selected papers is hampered by a lack of control groups in most of the studies. Only 3 studies utilized control groups, making it difficult to determine whether observed gains were due to the intervention or other factors. Additionally, informal methods of gathering user feedback can introduce bias, affecting the reliability of the results. Most evaluations were conducted immediately after gameplay, with no longitudinal follow-up to assess long-term retention of skills or knowledge gained, further limiting the ability to draw definitive conclusions about the effectiveness of the interventions.

Regarding the extent to which studies accurately measured the effectiveness of their respective games in teaching sign language (construct validity), many of the reviewed studies lacked standardized evaluation metrics and relied on subjective measures of engagement or satisfaction. Only two studies, NN – M. Parreno and NN – D. Rivas, used standardized tools such as the System Usability Scale (SUS). Furthermore, many evaluations focused primarily on engagement metrics, such as enthusiasm or time spent interacting with the game, rather than directly assessing learning outcomes or sign language proficiency. The diversity of game mechanics and technologies used across studies introduces further variability.

Most studies used questionnaires to evaluate the effectiveness of learning sign languages through serious games. Positive outcomes were consistently observed across different sign languages and experimental settings. Studies that incorporated control groups provided direct comparisons between traditional teaching methods and technology-based approaches, yielding clearer results. LeSigla introduced a unique aspect to the typical control group setup by comparing the progress of a group of native sign language speakers with that of a group of non-hearing-impaired students (Rivas et al., 2017). The results showed positive outcomes for both groups, with the hearing-impaired group consistently achieving higher scores. This comparison between native and non-native sign language speakers offers an intriguing perspective for other technologies studied in this field, such as the use of humanoid robots, as seen in Nao's Tale.

There is insufficient evidence to determine the most effective technologies and methods to teach sign language through serious games. It is crucial to focus on robust evaluations to enhance the effectiveness and accessibility of serious games, thus fostering inclusivity and communication with the deaf community.

Limitations

The current work, like all systematic literature reviews, has several limitations, starting with the search terms used, the databases selected, and the temporal window in which the research was performed. The articles discussed in this review therefore present a necessarily partial snapshot of empirical research on serious games for teaching sign language, which is representative of the state of the art at the time of writing.

Conclusions

This paper presents a systematic review on serious games for teaching sign language, aiming to identify existing games, their approaches, target groups, and evaluation methods. We identified 62 papers reporting on serious sign language games, extracting 41 games and categorizing them based on sign languages taught, game types, technologies used, target audiences, and evaluation outcomes. Recent articles tend to adopt modern technologies, with many games designed as quizzes due to cost-effectiveness and minimal hardware requirements.

While serious games show promise for authentic learning and engagement (Clark et al., 2016), evaluations generally lack comparability with each other, hindering informed decision-making. Future research should aim to conduct evaluations with larger and more diverse participant groups, implement control groups where feasible, and utilize standardized evaluation metrics to enhance the reliability and validity of findings.

Research gaps include the impact of using real-person videos versus sign language avatars; and the impact on learning retention from different technological and methodological approaches. Future studies should improve evaluations, including the use of game learning analytics for deeper insights into user interactions and learning outcomes.

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