

SignIt! An Android Game for Sign Bilingual Play that collects Labelled Sign Language Data

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Abstract – The Deaf or Hard-of-Hearing (DHH) community constitutes over 430 million people globally, with about 70 million of them using sign language as their primary means of communication. India has around 63 million DHH individuals. The DHH community in India faces several challenges, particularly in learning sign language and English, due to delayed diagnosis, stigma, oralism, and diversity of languages. Digital games for spoken and sign language learning have gained popularity due to their advantages over traditional language learning methods, such as enhanced engagement and socialization, driving increased research and adoption over traditional methods. Thus, we collaborated with *National Institute of Speech and Hearing*, an academic institution for the DHH community, to brainstorm (non-)technological games for English and Indian Sign Language (ISL) learning. Based on our discussions, we developed *SignIt!*, an accessible quiz platform that enables individuals to play sign language-based quizzes either solo or with others, and to create their own quizzes. To assess the game’s usability, we conducted a study with 20 members of the DHH community, followed by interviewing 15 participants. Overall, our participants answered 2160 quiz questions and created 210 questions. The quiz creation resulted in the collection of three hours of labelled real-world sign language data. The interviews revealed novel insights, such as preference for playing competitively with friends, empowerment by their agency to be content creators, and early signs of learning English, sign language, and quiz content by playing and creating quizzes. We plan to open-source and release *SignIt!* to increase its adoption among diverse DHH communities.

Keywords – game, deaf, hard of hearing, multiple-choice question, creation, learning

1. INTRODUCTION

The Deaf or Hard-of-Hearing (DHH) community constitutes over 5%—or 430 million people—of the global population [1]. Due to the inaccessible nature of their environments, this community faces challenges in various facets of their everyday lives, including communication, learning, and play [2, 3]. In particular, learning sign language has been found to be challenging for DHH children, as more than 90% of deaf children are born to hearing parents with no/minimal levels of sign language proficiency [4], thus lacking access to language learning at home from parents.

India is home to about 15% of the world’s DHH population [5]. The DHH community in India faces several additional challenges in learning sign language and English due to various social and cultural factors. For instance, due to the overburdened healthcare system, the average age of diagnosing hearing impairments in India is 24.3 months, and for early intervention is 33.4 months [6]. This delayed diagnosis results in delayed language acquisition, which often leads to poor academic performance and school dropouts [7, 8]. Moreover, DHH children lack access to language learning at home and at school due to the stigma associated with deafness, the exclusive oralism in integrated schools, and the diversity of spoken languages and cultures. For more than 5 million Deaf

children in India, there are only 387 special (DHH-only) schools [9], which often have insufficient qualified sign language teachers and interpreters, as there are less than 500 certified Indian Sign Language (ISL) interpreters in India [10].

To address this complex problem of imparting English and sign language learning, our group at *Microsoft Research India* initiated a research collaboration with *National Institute of Speech and Hearing* (\approx 3 years ago). *National Institute of Speech and Hearing* is an academic institution working on the identification, intervention, rehabilitation and education of individuals with (hearing) disabilities. They provide bilingual education (Bilingual Education is an approach to educate Deaf children using both the sign language of the deaf community and the written/spoken language of the hearing community. It has been recognised as one of the best ways to teach (DHH) children [11, 12, 13]) to their DHH students. As part of this collaboration, two Deaf teachers of *National Institute of Speech and Hearing* (one teaching ISL, and another working with early-stage ISL intervention) visited *Microsoft Research India* for 6 weeks, and 6 DHH students from *National Institute of Speech and Hearing* interned with us (three of them are co-authors of this research paper). We chose to explore play-based solutions since they provide a more

53 fun and engaging learning experience compared to tra-
54 ditional language learning methods [14, 15]. Further,
55 games create a personalized and non-threatening envi-
56 ronment where learners feel safe to socialize and prac-
57 tice without being embarrassed or anxious [16, 17, 18]
58 Our explorations and discussions resulted in the design
59 and development of *SignIt!*, a novel accessible Android-
60 based quiz platform (A preliminary version of the work
61 reported here appeared in [19]).

62 *SignIt!* aims to facilitate learning of ISL and English
63 for DHH players. It enables individuals to play sign
64 language-based quizzes either solo or with others, and to
65 create their own quizzes using the built-in video record-
66 ing feature. Each quiz consists of three or more multiple-
67 choice questions in sign language, with hints containing
68 the English translation of each ISL question and option.
69 Players can alternate between sign language and En-
70 glish while playing, which supports them in learning new
71 words and phrases in both languages. To understand
72 the usability and gameplay of *SignIt!*, we conducted a
73 mixed-method study with 20 participants from the DHH
74 community.

75 Overall, our participants answered 1769 multiple-choice
76 questions playing solo and 391 questions while playing
77 with others, and created 82 quizzes containing 210 ques-
78 tions. The process of quiz creation led to the produc-
79 tion of a substantial volume of Indian Sign Language
80 (ISL) videos, amounting to three hours of content. This
81 content was categorized into two types: *continuous* and
82 *isolated* sign language videos. The continuous sign lan-
83 guage videos were generated when signing a quiz ques-
84 tion. This subset of the dataset comprised 1358 sen-
85 tences, encompassing a vocabulary of 1948 words. Inter-
86 estingly, 390 of these words were signed by at least three
87 different users, indicating a degree of commonality in the
88 signing patterns. On the other hand, the isolated sign
89 language videos were produced when signing an option
90 for a quiz question. This portion of the dataset included
91 751 words, with 95 words being signed by a minimum
92 of three users. The diversity and volume of this dataset
93 underscore its potential utility for future research in ISL
94 recognition and translation. From the semi-structured
95 interviews with 15 participants, we gained novel in-
96 sights. We observed early signs of learning English, sign
97 language, and quiz content in the process of playing and
98 creating quizzes. Despite only 18.1% of questions being
99 played in social mode, our participants preferred playing
100 and competing with others, but they struggled to find a
101 suitable time to play together. Finally, our participants
102 felt empowered with their agency to be content creators
103 and identified venues to promote their created quizzes.

104 While designed for the Indian DHH community, *SignIt!*
105 provide a way to specify the language used for signing
106 and for hint text, making it inclusive for other DHH
107 communities. We are in the process of open-sourcing
108 *SignIt!* to increase its real-world usage. We conclude
109 the paper with key lessons learned to develop game-
110 based learning solutions for the DHH community, with

111 respect to (anti-)privacy, agency, and learning.

112 2. RELATED WORK

113 In this section, we explore prior work on sign language
114 learning games and gamified approaches for sign lan-
115 guage data collection.

116 2.1 Sign Language Learning Games

117 Current estimates show that more than 91% of Amer-
118 ican children aged 8-18 years play almost 110 minutes
119 of (smartphone) video games daily [20]. In spite of the
120 ill effects of excessive gaming, digital games have im-
121 mersive properties, demand active participation, chal-
122 lenges an individual to develop new skills, and provide
123 emotional and social support, which has potential to
124 benefit the learning experience [21, 22]. Due to these
125 reasons, games have been developed for a variety of sign
126 languages across the world, including American SL [23,
127 24], Australian SL [25], Arabic SL [26], Chinese SL [27],
128 Brazilian SL [28], and Indian SL [29]. Based on the in-
129 teraction mechanism, these sign language games can be
130 divided into two broad categories: (1) Learn-by-view:
131 wherein the game shows signing videos/avatars to the
132 player to help them learn new signs [26, 30, 25, 28], and
133 (2) Learn-by-practice: wherein apart from the signing
134 videos/avatars, the game prompts the player to mimic
135 signs with feedback to help them improve the correct-
136 ness of their signing [23, 27, 24, 29].

137 Sign my World [25] is a learn-by-view Australian Sign
138 Language game, to familiarize DHH children with
139 commonly-used nouns and verb signs. The game inter-
140 face has a 2D environment (e.g., a bedroom) containing
141 various interactive objects. On clicking an object, it dis-
142 plays a zoomed image of the object and its name on a
143 flash card, followed by a video of the sign for that ob-
144 ject. This helps children to make associations between
145 the object and the sign. On similar lines, Ada Runner
146 [28] is a Brazilian Sign Language game about traffic ed-
147 ucation to teach children 28 basic traffic-related signs.
148 Ada Runner was only evaluated by educators and there
149 are no reported results of children using the game. Sim-
150 ilar games are also available on Google Play and Apple
151 App Store, such as ASL Bloom (American SL), Ling-
152 vano (British SL), and ISL Journey (Indian SL), offering
153 a structured way to learn sign language from recorded
154 videos. Although learn-by-view can help with learning
155 sign recognition, it remains a challenge of such learn-
156 ers to sign themselves. Learn-by-practice games aim to
157 address that key limitation.

158 CopyCat is a learn-by-practice American Sign Language
159 (ASL) game, which uses gesture recognition to help
160 DHH children practice ASL skills [23]. The game runs
161 on a desktop computer, and uses a video camera and
162 wrist mounted sensors to recognize a limited set of
163 ASL phrases, focusing on the correct repetition of ASL
164 phrases. Although it combines gameplay with sign lan-

165 guage learning, the research work lacks evaluation with
166 end users. SignFind [27] is a recent work that requires
167 the players to wear wrist sensors and sign specific words
168 in Chinese Sign Language to explore a virtual world.
169 Similar to CopyCat, SignFind uses a gesture recogni-
170 tion software running on a desktop/laptop. The Sign-
171 Find paper reports a pilot study with four children on a
172 limited vocabulary. Virtual Sign [31] is a similar game
173 that uses sensor gloves and Microsoft Kinect for learning
174 Portuguese Sign Language. Although learn-by-practice
175 games are better suited for learning, they require ex-
176 pensive hardware like gloves with embedded accelerom-
177 eters [23], pinch gloves [24] and depth cameras [32] for
178 tracking hand gestures, thus limiting their widespread
179 adoption. Moreover, the desktop/laptop requirement
180 restricts the gameplay to a non-mobile setting. Finally,
181 current sign language recognition algorithms are limited
182 to recognizing isolated words. Continuous sign language
183 recognition focuses on recognizing phrases in sign lan-
184 guage. It is ideal for teaching sign language, however is
185 an unsolved problem [33, 34].

2.2 Sign Language Data Collection

187 To counter hardware requirement of learn-by-practice
188 games, recent works have been exploring deep learn-
189 ing techniques for sign language recognition from video
190 feeds recorded using off-the-shelf cameras [35, 36, 29].
191 There are various datasets proposed across the world
192 to facilitate the training of these deep learning models.
193 The ASLLVD dataset [37] is a widely researched col-
194 lection of American Sign Language vocabulary, contain-
195 ing over 3,300 unique signs demonstrated by 1-6 native
196 signers. However, only 48 of these signs have 8 or more
197 videos. All videos in the dataset have a uniform back-
198 ground to facilitate the segmentation of hands and face.
199 The RWTH-Boston-50 [38] is a well-known dataset of 50
200 classes of American Sign Language vocabulary. RWTH-
201 PHOENIX-Weather 2014 [39] is a dataset of German
202 sign language, designed for continuous sign language
203 recognition. It contains over a million frames and 1,081
204 distinct words, recorded from a public television weather
205 broadcast and performed by 9 different signers. IN-
206 CLUDE [35] is an open-source ISL dataset with 0.27
207 million frames, 4,287 videos, and 263 word signs from
208 15 different word categories. These datasets are often
209 recorded in lab settings with homogeneous signers. In
210 an effort to collect real-world sign language data, ac-
211 cessibility researchers are exploring ways to gamify sign
212 language data collection [40]. ASL Sea Battle is a sign
213 language game designed to collect and label real-world
214 sign language videos, while also providing fun and ed-
215 ucation to its users, taking away the drudgery of sign-
216 ing just for data collection. In this game, fluent ASL
217 signers play a modified accessible version of the popular
218 strategy game, Battleship, with hearing individuals on
219 their smartphones. Their user study results suggest that
220 ASL Sea Battle can be used to sustainably collect high-

221 quality sign language video data, fetch accurate labels,
222 and provide players with entertainment, education, and
223 social connections. However, the current game is limited
224 to signing isolated words. Although the paper mentions
225 the possibility of using the game for learning American
226 SL, that aspect has not been explored.

227 To summarize, existing sign language games have
228 limitations—they typically focus on a limited vocabu-
229 lary and lack multiplayer modes that foster social col-
230 laboration and competition. *SignIt!* overcomes these
231 limitations by supporting multiplayer gameplay and en-
232 couraging user-generated content. Empowering players
233 to create sign language content not only allows for di-
234 verse and engaging content for others, but also helps in
235 collecting diverse isolated and continuous sign language
236 data.

3. THE DESIGN OF *SIGNIT!*

238 During our brainstorming sessions with two teachers
239 and six students from *National Institute of Speech*
240 *and Hearing*, we came to know that they use Ka-
241 hoot! (<https://kahoot.com/>) a popular online game-
242 based learning platform with 1.6 billion users that en-
243 gages students through interactive quizzes in a compet-
244 itive and fun environment [41, 42]. extensively in their
245 classroom teaching. However, they struggle with Ka-
246 hoot! as it primarily relies on text-based quizzes and
247 lacks support for sign language quiz creation. Hence,
248 we decided to co-design a sign language-based quiz plat-
249 form, *SignIt!* with the goal of facilitating ISL and En-
250 glish learning in a fun and engaging manner. It enables
251 players to play sign language-based quizzes in three
252 modes—individual, group, and live. Moreover, it al-
253 lows users to create their own quizzes using the built-in
254 video recording feature. We paid attention to design
255 visually appealing graphics and ensuring scalability to
256 accommodate a large user base.

257 Below we describe the key elements of *SignIt!*.

3.1 Quiz Play

259 The home screen of the *SignIt!* app provides a list of
260 quizzes in different categories that the player can choose
261 to play (Figure 1a). On selecting a quiz, it shows rele-
262 vant details of the quiz (like number of questions, quiz
263 creator, and highest score) and provides option to play
264 that quiz as a single player or with others in the ‘Live’
265 mode (Figure 1b). On starting a quiz in any of the
266 modes, the player lands on the question screen (Fig-
267 ure 1c). This screen presents a question at the top along
268 with two to four answer options below it. Both the ques-
269 tion and options appear as sign language videos by de-
270 fault. The question video gets automatically played once
271 the question screen loads. A user can play any video by
272 tapping on the corresponding play button. Each option
273 has three buttons—a radio button (on its top right) to
274 select that option as an answer, a play button (on its

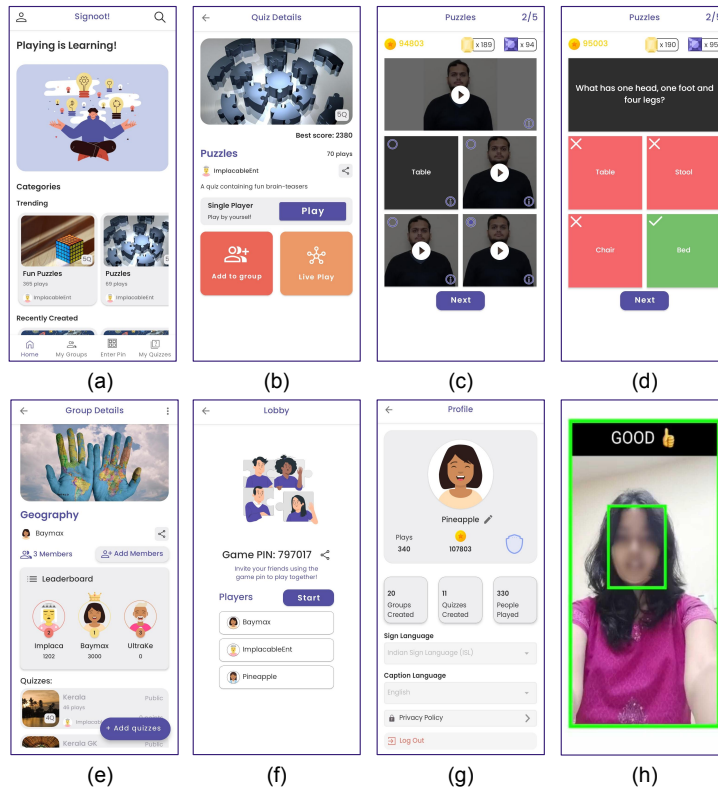


Fig. 1 – Screenshots of *SignIt!* (a) Home screen (b) Quiz Details screen (c) Question screen (d) Answer Analysis screen (e) Group details screen (f) Game lobby screen for live mode (g) User profile screen (h) Video recording interface

center), and a hint button (on its bottom left) to toggle the visibility of the corresponding English translation. The radio button and the hint button gets enabled only after watching the sign language video of that option once. After selecting an answer and clicking the ‘Next’ button, the answer screen (Figure 1d) shows the question text and option texts, along with the correct option highlighted in green and the incorrect options highlighted in red. Clicking the ‘Next’ button on the answer screen takes the player to the score screen, which displays their answer’s correctness, the points scored for the current question, and their total score for the quiz.

Each question is worth 1000 points. Players receive no points for answering a question incorrectly. If a player takes more than 20 seconds to answer a question, twice the number of extra seconds ($((timeTaken - 20) * 2)$) are deducted from their score, up to a maximum deduction of 300 points. Using a hint incurs a penalty of 40 points; however, once a hint is used for any video, there is no further reduction for using it again. On finishing a quiz, the player is awarded virtual coins equivalent to their total score divided by 10, rounded to the nearest integer. The total coin count is visible in the top left corner of the question screen (Figure 1c as 94803 coins). Apart from coins, players can also earn badges, e.g., ‘10 Correct Answers in a Row’, ‘Quiz created with 5+ questions’. In case the user is struggling to answer a question, *SignIt!*

offers two power-ups—a golden power-up costing 500 coins that removes half of the incorrect options, and a purple power-up costing 1000 coins that removes all incorrect options. Both the power-ups are visible in the top right corner of the question screen (Figure 1c as 189 available golden power-up and 94 available blue power-up).

Similar to Kahoot!, *SignIt!* supports three quiz play modes namely individual mode, group mode and live mode. These modes are detailed below:

Individual mode: Individual mode allows a player to play quizzes alone. A player can play the same quiz multiple times. While Kahoot! has a timer for each question in the individual mode, we decided not to impose a time limit as previous research revealed negative impact of timer in Kahoot! [41] such as stress, reduced reflection, and rushed guesses. Additionally, we allow players to watch the sign language question/option video multiple times, considering different sign language proficiency levels.

Group mode: In *SignIt!*, players can create groups and add other *SignIt!* players in their created groups. The group creator can add quizzes to their groups by clicking the ‘Add to group’ button in the quiz details screen (Figure 1e). Groups serve as a way to bring players and quizzes together, adding an element of competition among players. Similar to the individual mode, group

329 quizzes do not have a timer and can be played asyn-
330 chronously. The group leaderboard showcases the cu-
331 mulative points earned by each group member by play-
332 ing quizzes shared in that group (Figure 1e), fostering a
333 competitive environment wherein players strive to top
334 the leaderboard.

335 **Live mode:** Live mode allows multiple players to par-
336 ticipate in a synchronous quiz. Players can start a Live
337 mode game by selecting a quiz and choosing the ‘Live
338 mode’ option. This creates a lobby with a randomly
339 generated six-digit game PIN (Figure 1f), which can
340 be shared with other players to invite them to join the
341 game. The quiz host (the player who started the quiz)
342 also participates and the questions with options get dis-
343 played on all participating players’ devices. To ensure
344 a fair leaderboard across different questions, the same
345 question appears on everyone’s screen at the same time.

346 3.2 Create Quiz

347 Apart from playing sign language quizzes, *SignIt!* en-
348 ables players to create quizzes on their areas of interest
349 and expertise, which they can then share with other
350 *SignIt!* players. While Kahoot! allows players to add
351 a video to the question, it doesn’t provide a way to in-
352 clude videos for the answer options. In addition, the
353 translated text of the question needs to be added as
354 subtitles in the video. We believe that a sign language
355 question with visible text has limited opportunities for
356 learning sign language. In *SignIt!*, players can create
357 their own quizzes by adding the quiz name, quiz image
358 (optional), quiz description (optional), associated tags
359 (optional), signing language (ISL, ASL, etc.), caption
360 text language, and a list of questions with multiple op-
361 tions. To obtain licensed cover images for quizzes, we
362 utilize the Pixabay Image search API. In order to make
363 a quiz public to all players on *SignIt!*, it must contain a
364 minimum of three questions, with each question having
365 two or more options. As a reward for creating a pub-
366 lic quiz, the player earns 1000 coins multiplied by the
367 number of questions in the quiz.

368 The create question screen has a similar layout as Fig-
369 ure 1c with placeholders for the question and four op-
370 tions. The user needs to tap on each of these place-
371 holders to add the video and the corresponding cap-
372 tion. To create a valid question, the user must add
373 the question, at least 2 options, and mark the correct
374 answer among the options. After recording the video
375 for a question/option, the placeholder is replaced with
376 the sign language video along with the upload status
377 of the video and an option to edit it. From our DHH
378 co-authors, we received feedback that creating questions
379 is “*time-consuming*” and “*challenging*”. To address this
380 concern, we added a ‘Find question’ feature, which al-
381 lows players to quickly select questions from OpenTriv-
382 iaDB [43], an open-source trivia questions database.
383 As the OpenTriviaDB have multiple-choice questions
384 in text, the player still needs to add the correspond-

385 ing sign language videos. However, on internal test-
386 ing, we noticed that none of the DHH students from
387 *National Institute of Speech and Hearing* utilized ques-
388 tions from OpenTriviaDB, mainly because the questions
389 catered to a “*Western audience*”. For instance, a typi-
390 cal question would be “*Who wrote the play ‘Angels in
391 America’?*”. As a result, we developed our own repos-
392 itory of multiple-choice questions encompassing topics
393 such as Bollywood, sports, and Indian politics, ensuring
394 a more relevant and engaging experience for our players.

395 **Recording Videos:** The video recording interface
396 (Figure 1h) provides players with feedback such as
397 ‘Move closer’, ‘Move left’, and ‘Multiple Faces’ to ensure
398 that they are positioned correctly in the video frame
399 for optimal visibility of their upper body. The feed-
400 back guides the user until they are well-positioned, after
401 which a three-second countdown starts and the record-
402 ing begins. During recording, the top right corner of
403 the screen displays the time elapsed since the recording
404 started, and the bottom part shows a ‘Stop Recording’
405 button. The duration of question videos is limited to
406 30 seconds, while option videos are limited to 15 sec-
407 onds. Either the user presses the stop recording but-
408 ton or when the maximum time limit is reached, the
409 recording stops and the video is saved. The three DHH
410 co-authors created 11 quizzes on topics such as riddles,
411 computer science, Indian state, etc., to populate an ini-
412 tial set of quizzes for the participants to play on *SignIt!*.

413 3.3 User Profile

414 The user profile screen (Figure 1g) displays a variety of
415 statistics, including the number of quizzes played and
416 created, and the frequency of others playing their cre-
417 ated quizzes. It also showcases earned badges and coins.
418 The user can customize their profile avatar and user-
419 name. It also allows players to choose their preferred
420 sign language (ISL as the default) and caption language
421 (English as the default). These preferences automati-
422 cally filters the quizzes displayed on the home screen
423 (Figure 1a), accommodating various language prefer-
424 ences.

425 3.4 Implementation details

426 The *SignIt!* game is an Android application developed
427 in Kotlin, designed to be a production-grade system.
428 The system architecture of *SignIt!* is illustrated in
429 Figure 2. During development, one of the key chal-
430 lenges was managing latencies both during quiz cre-
431 ation and gameplay across various modes. To address
432 it, videos recorded by players are initially stored lo-
433 cally on their devices and then securely uploaded to an
434 Azure blob storage container using a background worker
435 with HTTPS support. Uploaded videos automatically
436 undergo compression and cropping through an Azure
437 serverless function triggered by the blob storage. All
438 video reads/writes are directed through the backend to

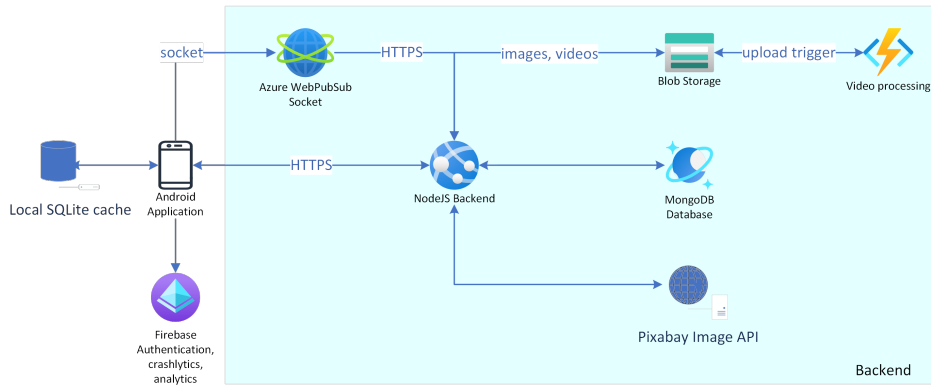


Fig. 2 – Architecture Diagram for *SignIt!*. *SignIt!* app caches data locally on an SQLite database and authenticates users using Firebase. The app connects to the NodeJS backend through HTTPS. For live games, websocket connections are enabled through the Azure WebPubSub service to keep the backend stateless and scalable. Uploaded images and videos are stored in an Azure Blob container. Video uploads to the blob storage trigger an Azure function to center crop and compress videos. Image search is enabled by the backend through a call to the Pixabay Image API.

439 ensure authorized access to the storage containers. For
 440 gameplay in the live mode, a shared state object rep-
 441 resenting the game state is maintained on the backend.
 442 Changes to the state are instantly communicated to rel-
 443 evant clients through web sockets to ensure minimal la-
 444 tencies. To maintain a stateless and scalable backend,
 445 web socket connections for live games are hosted on an
 446 Azure WebPubSub service, which in turn sends events
 447 to the backend via HTTPS. The backend is implemented
 448 as a NodeJS application using the ExpressJS framework.
 449 It is hosted as a web application on Azure App Services
 450 with horizontal scaling enabled. User profile and quiz
 451 metadata is stored on a MongoDB database hosted on
 452 Azure CosmosDB. To ensure optimal performance under
 453 high loads, operations on the application results in
 454 point reads and writes on the database.

455 4. STUDY DESIGN

456 We conducted a mixed-method study with 20 members
 457 of the DHH community to explore the usability, game-
 458 play behavior, social interaction, and learning aspects
 459 of *SignIt!*. It is important to note that we did not for-
 460 mally assess language acquisition but relied on partici-
 461 pant feedback regarding any self-reported learning expe-
 462 riences that arose from their engagement with *SignIt!*.
 463 The study was approved by the Institutional Review
 464 Board at <Anonymous Institute>. During the study,
 465 participants were requested to use *SignIt!* and earn the
 466 five badges corresponding to the five main features of
 467 the game. Once complete, we requested them to fill out
 468 a short survey and optionally participate in a video in-
 469 terview to provide detailed feedback.

470 4.1 Procedure

471 The study was conducted in India from July to Septem-
 472 ber 2022. Due to the aftermath of COVID-19, we con-
 473 ducted the study (including recruitment, *SignIt!* de-

474 ployment, and post-study survey and interview) re-
 475 motely. Participants were recruited via recruitment
 476 emails to the National Institute of Speech and Hearing
 477 (NISH), WinVinaya Foundation, and Enable India (EI),
 478 as well as snowball sampling. To be eligible, participants
 479 needed to have access to an Android smartphone, be 18
 480 years of age or older, and have some level of proficiency
 481 in ISL and English. The study was conducted sequen-
 482 tially in three batches of six, six, and eight participants
 483 respectively. The bugs and challenges reported by each
 484 batch were used to make minor upgrades to the APK
 485 for the subsequent batch.

486 For each batch, once consent was obtained, partici-
 487 pants were added to a WhatsApp group with two of
 488 the co-authors. This group was used to facilitate com-
 489 munication with the participants and also allow mes-
 490 sage exchange among the participants. The *SignIt!*
 491 APK was shared in this group, along with installa-
 492 tion instructions. Within the next 24 hours, a 45-
 493 minute introductory session was conducted over Zoom
 494 video-conferencing tool to provide participants with an
 495 overview of *SignIt!* and the research study and answer
 496 any of their questions. In addition to the participants,
 497 these sessions were attended by two Deaf authors pro-
 498 ficient in ISL and two hearing authors with basic ISL
 499 knowledge. One of the Deaf authors conducted the ses-
 500 sion in ISL. At the end of the session, participants were
 501 requested to earn Level 1 of the first five badges on *Sig-*
 502 *nIt!*, which involved playing five individual quizzes, one
 503 group quiz, and three live quizzes, as well as creating one
 504 group and three quizzes. Two personalised reminders in
 505 English were sent to each participant daily based on
 506 their current usage, encouraging them to continue using
 507 *SignIt!* and earn their next badge. For instance, partici-
 508 pants who primarily played individual quizzes were
 509 sent messages like ‘Hello name! Hope you are having
 510 a great time using *SignIt!* Check out the create group
 511 feature to compete with your friends and try to stay on
 512 top of the leaderboard!’.

Table 1 – Participants Demography, * indicates that the participant was interviewed

P.Id	Sex	Age	City	Education	Occupation	Deafness Level	Deaf Years
P1*	M	22	Trivandrum	Bachelor’s	Student	Mild	22
P2*	F	21	Alappuzha	Bachelor’s	Student	Mild	21
P3*	M	23	Delhi	Bachelor’s	Student	Moderate	23
P4*	F	21	Pathanamthitta	High School	Student	Profound	21
P5*	F	22	Vatanappally	Bachelor’s	Student	Profound	22
P6*	F	21	Delhi	High School	Student	Profound	21
P7*	M	21	Panchkula	Bachelor’s	Student	Mild	21
P8*	M	23	Pune	Bachelor’s	Student	Profound	23
P9*	M	31	Thiruvalla	Bachelor’s	Not employed	Profound	31
P10*	F	22	Thrissur	Bachelor’s	Student	Profound	22
P11*	M	25	Bangalore	Bachelor’s	Working	Profound	25
P12*	M	22	Hyderabad	Bachelor’s	Student	Mild	22
P13*	M	28	Tirunelveli	High School	Working	Profound	28
P14*	F	26	Piduguralla	Bachelor’s	Working	Profound	26
P15*	M	29	Bangalore	Bachelor’s	Working	Profound	29
P16	M	32	Wadakkanchery	Master’s	Working	Profound	32
P17	M	23	Kochi	Bachelor’s	Working	Profound	23
P18	M	26	Biratnagar	Bachelor’s	Working	Profound	26
P19	M	32	Ahmedabad	High School	Working	Profound	30
P20	F	28	Malappuram	Bachelor’s	Working	Profound	22

513 After earning the badges, participants completed an on-
514 line survey and optionally participated in a 45-minute
515 semi-structured interview over a video call. The online
516 survey began with demographic questions, followed by
517 five-point Likert scale questions that rated the ease of
518 using *SignIt!*, the experience of trying its five funda-
519 mental features, and the quality of signing on the app.
520 The survey concluded with questions about the partic-
521 ipants’ prior experience with sign language games and
522 their interest in downloading *SignIt!* if it were publicly
523 released.

524 In the interview, we asked them about their overall ex-
525 perience of using *SignIt!*, their motivation behind using
526 the app, any learnings they gained, challenges faced,
527 and suggestions to improve *SignIt!*. We focused on quiz
528 creation, particularly on identifying and recording quiz
529 questions and options. Moreover, we asked them custom
530 questions based on their play behaviour obtained from
531 the log data, for instance, ‘*Your log file revealed that you*
532 *played the same quiz on “Fun Puzzles” five times in the*
533 *individual mode, why?*. All interviews were conducted
534 in ISL over Zoom by a Deaf author or by hearing au-
535 thors interpreted by ISL interpreters. All the calls were
536 recorded with the consent of the participants. Partici-
537 pants were informed that the data would only be used
538 for research purposes. The participants were requested
539 to uninstall *SignIt!* after their interview. The interviews
540 were transcribed soon after they were conducted by the
541 interviewer, and we use the exact translation when quot-
542 ing participants. Participants were given an INR 700
543 (~10 USD) gift voucher of their preference for partici-
544 pation.

545 4.2 Data Analysis

546 We conducted a mixed-method analysis to systemati-
547 cally analyze the data. Log files from participants’ app
548 usage were quantitatively analyzed to find overall statis-
549 tics including the time spent on the app, number of
550 quizzes started/completed in various modes, number of
551 quizzes shared with other participants, and the number
552 of quizzes created. We also performed thematic analysis
553 to explore the themes that emerged from the interview
554 data for our qualitative analysis. We subjected our in-
555 terview data to open coding and categorized our codes
556 to understand user behaviour. Two authors participated
557 in the coding process and iterated upon the codes un-
558 til a consensus was reached. Over the course of the
559 analysis, they discussed coding plans, developed prelim-
560 inary codebooks, reviewed the codebook, refined/edited
561 codes, and finalized categories and themes. The first-
562 level codes were very specific, such as “motivation to
563 play” and “sharing quizzes”. After several rounds of iter-
564 ation, the codes were condensed into high-level themes,
565 such as “challenges with comprehension”, “learning”,
566 and “collaboration”.

567 4.3 Participants

568 Our study included 20 participants (7 female, 13 male,
569 age=24.9±3.75 years), with 12 participants from Na-
570 tional Institute of Speech and Hearing (NISH), 5 from
571 WinVinaya Foundation, and 3 from Enable India. All
572 participants in this study belonged to the DHH com-
573 munity. In terms of Indian Sign Language (ISL) profi-
574 ciency, 9 participants were experts, 7 were intermediate,

575 and 4 were beginners. Most participants had profound
576 hearing loss (15), with 1 having moderate and 4 having
577 mild loss. They resided in diverse locations across south-
578 ern, western, and northern India, as well as Biratnagar,
579 Nepal. In terms of education, 15 participants held un-
580 dergraduate degrees, 4 had completed high school, and
581 1 had a Master’s degree. Of the 20 participants, 15 (6 fe-
582 male, 9 male, age=23.8±3.14 years) participated in the
583 post-study feedback interview.

584 4.4 Authors’ Positionality

585 Three of the 10 authors are Deaf with ISL as their first
586 language. All other authors are hearing with one au-
587 thor having beginner-level competence in ISL and three
588 others having some familiarity with ISL. The hearing
589 authors are native speakers of four Indian languages
590 and have English as their primary professional language.
591 Three of the authors self-identify as female and the rest
592 as male. All of the hearing authors have prior experi-
593 ence working with and/or conducting studies with peo-
594 ple with disabilities.

595 5. FINDINGS

596 Participants in our study engaged with the *SignIt!*
597 app for an average of 9.2±7.7 days. During this pe-
598 riod, they attempted a total of 1139 quizzes, averaging
599 56.95±40.22 quizzes per participant across all quiz play
600 modes. Moreover, they created a collective total of 210
601 complete quiz questions, with an average of 10.5±8.7
602 quiz questions per participant. The participants dedi-
603 cated a combined time of 86 hours and 31 minutes to
604 using the app. Feedback from the participants revealed
605 that they found the user interface of *SignIt!* to be easy-
606 to-learn, intuitive, and accessible. They highlighted var-
607 ious reasons for using the app, such as passing time,
608 learning English and ISL, exploring the quiz content,
609 connecting with friends, and seeking recognition. These
610 motivations played a significant role in their engagement
611 with *SignIt!*. Below, we report the key findings from our
612 study.

613 5.1 Role of Sign Language

614 *SignIt!* was developed with the goal of creating an ac-
615 cessible game-based learning platform for the DHH com-
616 munity, enabling players to play and create quizzes in
617 sign language. In the post-study interview, when the
618 participants were asked about their overall experience
619 with *SignIt!*, 10 participants appreciated quizzes in sign
620 language. Specifically, participants reported their strug-
621 gles with English (as a second language), which has been
622 well documented in accessibility literature [44, 2]. Al-
623 though English was minimally used across the *SignIt!*
624 app, our participants reported hard-to-understand En-
625 glish in the hints (captions) of quiz questions and in the
626 Find Questions-repository. For quiz creation, six par-
627 ticipants did not choose any questions from the Find

628 Questions-repository, as they found the English to be
629 “*too complicated to understand*”.

630 The novelty and accessibility of sign language-based
631 quizzes helped with the quick adoption and retention
632 of *SignIt!* usage, with participants spending 28.2±13.24
633 minutes on *SignIt!* every day. We observed a large
634 variance in the average daily usage, ranging from 6.8
635 minutes/day by P18 to 59.8 minutes/day by P14. P14
636 stated that she used *SignIt!* because “*I learned some-*
637 *thing new with everything [all quizzes played] ... when I*
638 *finish my work, I’m usually free and have nothing to do,*
639 *so I get bored. That’s when I have no friends around*
640 *also to talk to, so this was a good way to keep in touch*
641 *with my friends and play.*” Three participants compared
642 *SignIt!* to Kahoot! and preferred *SignIt!* as they find it
643 difficult to understand the “*long English sentences*” in
644 Kahoot! quizzes. For instance,

645 “I have used Kahoot! before. In my experi-
646 ence, the long English sentences are confusing
647 and hard to understand... *SignIt!*, wow, this is
648 such a great thing for us. I can easily switch
649 between ISL and English, so easy to use and
650 kept me motivated. I felt good while using this
651 app.” – P3

652 Despite the sign language being more consumable, par-
653 ticipants reported several difficulties in understanding
654 ISL on *SignIt!*, due to regional variations in ISL, the
655 speed of signing, and low video quality. First, the In-
656 dian Sign Language (ISL) is not a *single* language. It
657 has a variety of regional dialects, such as the Bangalore-
658 Chennai-Hyderabad Sign Language, Mumbai-Delhi Sign
659 Language, and Kolkata Sign Language [45, 46], which
660 have different signs for the same English word. In ad-
661 dition, DHH from rural India have minimal exposure
662 to these standardized dialects, as they typically use an
663 organically evolved ‘home signing’ system for communi-
664 cation [47, 48]. Two participants mentioned that some
665 quizzes were signed in Kerala Sign Language (Note:
666 Kerala is a state in India) and they were having dif-
667 ficulty understanding it.

668 “I think the signers are from Kerala... the
669 signing was a little different. So, basically, I
670 didn’t know those signs of the capital cities,
671 so it was difficult for me to understand. If
672 the deaf person could spell it like K-O-C-H-I
673 (finger-spelled) I would understand.” – P15

674 A few participants reported difficulty understanding the
675 quiz question and/or the options due to the use of “*non-*
676 *standard signs*”. One of the participants (P15) during
677 the post-study interview explained to the researchers
678 that “*it is an issue because SignIt! is a non-interactive*
679 *platform*”, i.e., it lacks two-way communication. Typ-
680 ically, when two DHH individuals communicate in dif-
681 ferent regional dialects of ISL, they clarify the mean-
682 ing of their signs and/or ask the other person to finger-

spell it in case of any confusion. Diversity and non-standardization of ISL is a known problem, and the National Education Policy of India, published in July 2020, aims to standardise ISL and create educational resources utilising the standardised form.

Second, participants raised concern about the signer’s speed in the quizzes stating that “*it was too fast to follow*”. This may be due to the time restrictions placed by *SignIt!* on the length of sign language recorded quiz videos—30 seconds for a question, and 15 seconds for each option. These restrictions were added to ensure that the game remains fast-paced. Finally, P5 complained about the lack of video quality, particularly “*hands moving out of the video frame*” while signing, in a few quizzes she played. In spite of providing real-time feedback (like move closer/far, move left/right, multiple faces) to the participants for quiz creation video recordings, we identified a few videos with part of hands/face getting cropped.

5.2 Participants Motivation to Learn

One of the major motivations for our players to use *SignIt!* was learning, specifically acquiring general knowledge from the quiz content, and improving their ISL and English language skills. On average, our participants attempted 32.9 ± 22.2 quizzes (wherein they answered one or more questions), ranging from 3 to 89 quizzes across participants. In the individual mode, participants played an average of 23.5 ± 16.48 quizzes, despite a minimum threshold of 5 quizzes set by researchers, suggesting that participants were intrinsically motivated to play quizzes in *SignIt!*. Participants mentioned a variety of reasons to play quizzes, including “*to learn new things*” (8 participants), “*to compete with friends*” (6), “*it’s fun*” (6), “*to pass time*” (3), and “*to earn badges*” (2). Similar motivations have been reported in previous digital games related studies [49, 50]. Interestingly, P10 stated that she played particular quizzes to help with her exam preparation. From the log data, we found that P10 played 2 mathematics-based quizzes and 11 general knowledge-based quizzes on topics such as geography, sports, and computers. This hints that similar to Kahoot!, *SignIt!* has potential to be used as a learning platform.

To further understand the quiz play behaviour, we grouped the most played quizzes according to their tags. The five most popular tags among our participants were riddles (215 plays, 3 quizzes), geography (127 plays, 8 quizzes), computers (112 plays, 6 quizzes), Deaf culture (109 plays, 3 quizzes), and sports (87 plays, 7 quizzes). An example of a riddle quiz question: *What is always coming but never arrives?*, with the answer being *Tomorrow*. This emphasis on playing riddles shows that fun was the key reason behind playing quizzes, however our participants attempted quizzes related to geography, science and technology, and sports, to learn more about these topics. Two participants also requested ex-

planations of the answers and/or providing more information related to each question-answer pair, to aid in the learning process.

While we did not test the retention of acquired knowledge of our participants, we found anecdotally that several participants (5) recalled learning about popular topics, such as “*I learned how many MLAs are there in India*” – P9. Interestingly, our participants found it hard to remember the finger-spelled answer (compared to signed answers). For instance, “*I learned about who is the father of mathematics? However, there was no sign name for that person. So they (finger) spelled his name. The name was very long so I forgot.*” – P12. We found participants played the same quiz multiple times, mainly to improve their learning, to check their retention of the quiz content, and to increase their highest score. For instance:

“Yes, I played the quiz, but my answers were wrong for some questions. I learned which of my answers were mistakes... I tried again and played the same quiz... That’s how I improved my knowledge.” – P6

In our study, 19 out of 20 participants repeated one or more quizzes. The maximum number of times a quiz was repeated was 7 (by three participants). Out of the 137 instances of a quiz being repeated, the number of correctly answered questions increased in 75.9% of the cases. Kahoot! players have been found to show similar game play behavior of playing quizzes multiple times [51].

In addition to learning from the quiz content, participants reported learning language skills, in particular English words and ISL signs, from the ISL-to-English mappings in questions and options. For instance:

“It [quizzes] helped me learn English... For example, dog’s baby is known as puppy. I was not aware of that. I would think dog baby would be called ‘baby’, but every animal’s children, I mean baby have a different name, that is a good thing I learned.” – P15

For context, in ISL, the word puppy is communicated by signing ‘dog’ followed by ‘small’. Several words and concepts in English lack an equivalent sign in ISL, resulting in such knowledge gap. Apart from vocabulary, participants suggested incorporating quizzes on English grammar topics such as tenses and pronouns, to help them further improve their English.

Three participants mentioned learning sign language from *SignIt!*. They preferred learning from options, as it comprised of words or short phrases, making it easier to learn sign language-to-English mapping. Participants mentioned two main reasons for not being able to learn ISL from quiz questions – the difficulty of matching individual signs with the corresponding English words in the sentence and the fast pace of the signing, making it challenging to follow.

795 Apart from learning by playing quizzes, our participants
796 also gained general knowledge, learned English words
797 and ISL signs, through quiz creation. Four participants
798 mentioned learning “*new facts*” while searching for con-
799 tent for their quizzes. For example,

800 “I am a nature fan and an animal lover. You
801 may think that giraffe have just one stomach
802 like everyone else, but Giraffe has four stom-
803 achs, so that is really, really nice to know...
804 Learning such details about different animals
805 was very cool. I got this information online
806 (while creating an animal quiz).” – P15

807 Other participants provided similar examples of learn-
808 ing about sports, Indian politicians, and multinational
809 companies.

810 5.3 Collaboration within Community

811 Prior work has demonstrated that group play is typically
812 more engaging than individual play because playing in a
813 group fosters competition and collaboration [22]. Even
814 in our study, we discovered that elements of group play
815 such as group quiz and live quiz in *SignIt!* was preferred
816 by our participants. A total of 132 group quizzes and
817 56 live quizzes were played during the study duration.
818 Our participants created 46 groups, with an average of
819 4.7 ± 2.7 members/group, and in total shared 75 quizzes
820 in these groups.

821 Most of our participants were acquainted with each
822 other prior to the study. That might have played a
823 role in their readiness to form groups, and play live
824 and group quizzes. As P14 said: “*I connected with my*
825 *friends, like P13 and P15, using the group mode... It*
826 *was nice to connect with different friends and play. It*
827 *was very simple.*” Our participants used groups as a
828 way to stay connected with each other and as a forum
829 to share and discover quizzes. Three participants stated
830 that they added quizzes on topics that they wanted their
831 friends to learn about. For example:

832 “The group mode is useful because my friends
833 don’t know about these different topics. I
834 either share existing quizzes or my created
835 quizzes with them, so that they will learn from
836 these quizzes... They will gain knowledge after
837 playing quizzes.” – P6

838 Interestingly, 64% (48 out of 75) of the quizzes shared in
839 these groups were created by the group creators them-
840 selves. This indicates that participants created these
841 groups mainly to promote their own quizzes. Aside from
842 sharing quizzes, three participants stated that they en-
843 joyed joining groups to get access to quizzes vetted by
844 others. The log analysis showed that two of these par-
845 ticipants were in approximately 30 groups each, and
846 played at least one quiz in a majority (26 and 23) of
847 their groups. Groups enabled participants to effectively

848 share and consume content, with a sense of belonging
849 to the *SignIt!* community.

850 To create a group in *SignIt!*, participants need to add
851 other *SignIt!* users from their saved contacts. How-
852 ever, once the group is formed, all group members were
853 represented by their randomly generated usernames.
854 While this anonymity protected participants’ privacy,
855 some participants complained that they found it chal-
856 lenging to identify their friends in the group. As a
857 workaround, six participants updated their default ran-
858 dom usernames to their original full names, so that
859 others can identify them. In addition, one participant
860 wanted to upload their headshot instead of the avatar
861 image to further help others. This shows that partic-
862 ipants willingly de-anonymized themselves in order to
863 socialise more effectively. Not only that, participants
864 requested showing online status of their friends on *Sig-*
865 *nIt!*, a feature available in popular social media plat-
866 forms. This was mainly to help them coordinate a time
867 to play live quiz with their friends.

868 “For live quizzes, my friends didn’t have time
869 to play together the quizzes game due to their
870 study or assignment. I could play individual
871 quizzes instead.” – P6

872 Besides playing with other study participants, 5 out of
873 16 participants expressed their willingness to share *Sig-*
874 *nIt!* with their other friends. Interestingly, P9 saw po-
875 tential to connect with DHH individuals across borders:

876 “I think this can be an international game
877 where we can meet deaf people from across the
878 world. It will be more of, like, people can play
879 and share things... they can spend hours in
880 this, play game, socialise and talk about deaf
881 culture of different countries. There’s a lot of
882 possibilities through this app. I want to play
883 with my friends, and also, I want to meet new
884 people here.” – P9

885 To enable meeting new people on *SignIt!*, it needs to
886 display all *SignIt!* players to everyone, instead of just
887 players’ saved contacts.

888 The key reason behind our participants’ enthusiasm
889 for group and live quizzes was the element of compe-
890 tition. Prior research has shown several positive out-
891 comes of competition in game-based learning such as
892 increased intrinsic motivation, greater attention and ex-
893 citement, more collaborative work, and active partici-
894 pation [52, 53, 54, 55]. We observed similar patterns in
895 our study. Our participants stated that the competitive
896 element in live quizzes kept them “*motivated and inter-*
897 *ested*”, with three participants mentioning that at times
898 they got “*bored*” playing individually. Specifically, since
899 the leaderboard was displayed after every question, the
900 players were motivated to perform better by answering
901 correctly and quickly.

902 “I got bored when I was playing individual
903 mode alone. I enjoyed group mode games with

904 other members because there is competition
905 like a fight to win the game.” – P8

906 Similarly, in group mode, participants checked the group
907 leaderboard often—in total, 166 times by 15 partici-
908 pants, 11.1 ± 6.4 times each participant—to view their
909 position and to “*see my friends’ results*”. Log analysis
910 with Kruskal-Wallis test revealed a significant effect of
911 quiz play mode on quiz completion ($\chi_2=7.017$, $p<0.05$).
912 A post-hoc test using Mann-Whitney tests with Bon-
913 ferroni correction showed the proportion of completed
914 group quizzes (83.5%) to be significantly higher than indi-
915 vidual (36.5%) and live (35.2%) quizzes, with $p<0.05$.
916 This may be due to the asynchronous nature of group
917 quiz play, enabling the players to play at their conve-
918 nience, along with facilitating an environment of social
919 competitive play. To further illustrate this competitive
920 behaviour, P1 requested for notifications when a new
921 quiz gets added to any of his groups, because “*I was not*
922 *aware when the member added the quiz, I had to check*
923 *myself. I was one or two days late when I saw there are*
924 *two to three quizzes, I want to get the notification that*
925 *there are quizzes which are ready*”.

926 The motivation to top the leaderboard has negative con-
927 sequences as well. 13 out of the 22 participants tried to
928 game the system. From the log data, we found that in
929 46 instances, our participants played the quiz in indi-
930 vidual mode before attempting it in group mode to gain
931 an unfair advantage and score high. Similar behaviours
932 were observed before initiating and attempting a live
933 quiz as well.

934 5.4 Participants Enthusiasm to Create Con- 935 tent

936 Our participants created 82 quizzes containing 210 valid
937 questions and 46 incomplete questions, with an average
938 of 3.1 ± 1.8 questions per quiz. A majority (14) of our
939 participants rated the quiz creation interface to be easy
940 to learn and use. In particular, P1 commented:

941 “I liked creating quizzes on *SignIt!*. I really
942 liked it a lot. I mean, this is the first time
943 I made a quiz using my own ideas. Earlier I
944 used to think how I can make quiz. So this
945 was something new for me and I learned as
946 well.” – P1

947 In spite of the minimal learning curve of quiz creation,
948 it was the most complex task on *SignIt!*, as it involved
949 identifying quiz questions with a minimum of 2 op-
950 tions, recording sign language videos, and entering cor-
951 responding English text for each question and its op-
952 tions. Our participants reported several motivating fac-
953 tors for quiz creation, including improving their knowl-
954 edge (discussed in Section 5.2), helping the DHH com-
955 munity, earning coins and badges, and acquiring fame.
956 Four participants stated that they created quizzes to
957 “*impart knowledge to Deaf people*” through their quizzes.

958 These participants primarily created quizzes about In-
959 dia (on capitals of cities, languages spoken, and tradi-
960 tional food), world geography, animals, and computers,
961 i.e., on specific topics which they thought was useful for
962 the DHH community to learn about. Interestingly, one
963 participant stated fame as a motivator for quiz creation.
964 The prospect of acquiring ‘fame’ on *SignIt!* meant that
965 when other players will play the quizzes created by our
966 participants, the players will start recognizing the quiz
967 creators through it. For example, P1 stated:

968 “To make a quiz, I need to sign as well. I really
969 like it... I think that it’s going to be great, as
970 it is something made by me, and others will
971 see it... Other people will click and they will
972 see my video. I will automatically become fa-
973 mous.” – P1

974 To quantify fame, we count the number of times a quiz
975 has been played, similar to the concept of views on
976 YouTube. We found that P1 quizzes have been played
977 52 times, compared to the average of 12.8 ± 19.5 plays
978 across other participants.

979 Our participants created an average of 10.5 ± 8.7 valid
980 questions (minimum=0 question, maximum=25 ques-
981 tions). Out of the total 210 valid questions, our partici-
982 pants created 74 using the Find Questions-repository
983 and 136 using external sources (including Google,
984 YouTube, and the National Geographic TV channel).
985 Five participants preferred using the Find Questions
986 repository despite its limited number of questions and
987 categories, due to the convenience and ease offered by
988 it. For instance,

989 “It takes very long to make quizzes on my own
990 because I need to think, I need to research...
991 that’s very difficult. So the easier option and
992 the quicker option was to just sign whatever
993 was already there [in the repository].” – P14

994 Other participants also used the repository when they
995 were “*out of ideas*” for new quizzes. In contrast, five
996 participants did not use this feature at all, mainly be-
997 cause the English text in the repository questions was
998 too difficult to understand, and they wanted to avoid
999 creating duplicate questions on *SignIt!*.

1000 With respect to adding sign language videos to the ques-
1001 tions and corresponding options, multiple participants
1002 praised the video recording interface which effectively
1003 guided them to adjust their distance from the cam-
1004 era. The automated feedback was beneficial for our
1005 participants as they were not accustomed to record-
1006 ing themselves. To improve this interface further, our
1007 participants suggested adding a trim tool to help cut
1008 the end of the recording (wherein the creator taps the
1009 ‘Stop’ button), adding a feature to upload videos from
1010 the gallery, and recording videos horizontally for “*more*
1011 *signing space*”.

1012 The authors manually analyzed the questions created by
1013 our participants to evaluate them on factual correctness

1014 and grammar, and categorize them. Overall, 89.5% of
1015 the questions were factually correct, unambiguous, and
1016 had one correct answer. Out of the remaining ques-
1017 tions, 6.2% had incorrectly marked answers and 4.3%
1018 questions were ambiguous. An example of an ambigu-
1019 ous question from a cricket-based quiz was ‘*Who made 6*
1020 *sixes in 6 balls?*’ wherein two options were correct. An
1021 example of an incorrectly marked answer was “*Which is*
1022 *the most populated country in the world?*” where ‘China’
1023 was marked as the answer, while ‘China’ was the correct
1024 answer at the time the participant created the question,
1025 ‘India’ surpassed it recently and was the correct answer
1026 at the time of analysis. Through this analysis, we found
1027 that questions based on political figures, records, etc.
1028 could become outdated and would need to be updated
1029 by the quiz creator to prevent misinformation. In addi-
1030 tion, 20 questions had minor grammatical errors such as
1031 missing articles, incorrect prepositions, and interchange
1032 of singular and plural verbs, however the questions were
1033 understandable. With respect to category, the most
1034 common questions were about animals (24), cricket (23),
1035 India (23), computers (12), and mathematics (12). Par-
1036 ticipants chose quiz topics based on their personal in-
1037 terests, popular interests, and usefulness of the content
1038 for the DHH community. For instance, “*I’m collecting*
1039 *feedback from Deaf people about their interests. They’re*
1040 *saying they want more questions about MS Office, Excel,*
1041 *Word, Tally, etc. software.*” – P15. Subsequently, P16
1042 created a quiz on Microsoft Excel with five questions on
1043 charts, rows, and keyboard shortcuts.

1044 Participants actively encouraged other participants to
1045 play their quizzes and even advertised them, by adding
1046 their quizzes to groups (discussed in Section 5.3), start-
1047 ing their quizzes in live mode, and sharing links to their
1048 quizzes on their WhatsApp group. Out of the 12 par-
1049 ticipants who shared quiz links, 10 participants shared
1050 their own quizzes an average of 4.3 ± 2.5 times. In addi-
1051 tion, participants mentioned sharing their quizzes in live
1052 and group mode mainly to see how their friends would
1053 perform. As quiz creators, our participants were deeply
1054 invested in how their quizzes were performing in terms
1055 of number of plays on *SignIt!*. Our log analysis showed
1056 that participants played their own quizzes on an average
1057 of 10.7 ± 18.0 times, ranging from 0 to 67 times. Surpris-
1058 ingly, 14 out of 20 participants started their quizzes and
1059 exited them without answering any question, more than
1060 twice. One possible explanation for such behavior could
1061 be to increase their number of quiz plays. Similar behav-
1062 ior has been reported by prior studies exploring content
1063 creation on media platforms such as YouTube [56]

1064 5.5 Collection of Sign Language Video Data

1065 Through our user study, we collected a total of 2,931
1066 sign language videos (total duration of 3 hours and 12
1067 minutes), along with their corresponding English text
1068 labels. These videos were recorded in real-world settings
1069 (e.g., homes, hostels, and workplaces) by signers across

1070 genders and geographical locations, and thus captured
1071 the regional variations of ISL. To facilitate the two fun-
1072 damental machine learning tasks—isolated and continu-
1073 ous sign language recognition, we divided the collected
1074 sign language data into two distinct datasets. While
1075 the isolated sign language dataset comprised of videos
1076 with single-word annotations (from quiz options), the
1077 continuous sign language dataset included videos with
1078 short phrases and sentences (from quiz questions and
1079 options). The isolated sign language dataset consisted of
1080 1573 videos, with 751 unique words such that 95 words
1081 were signed by three or more users. The continuous sign
1082 language dataset included 1358 videos of sentences, with
1083 a vocabulary of 1948 words such that 390 words were
1084 signed by three or more users. The maximum number of
1085 occurrences of the term “false” is observed in 26 isolated
1086 sign language videos, whereas the maximum number of
1087 occurrences of the term “many” is observed in 63 con-
1088 tinuous sign language videos. Detailed statistics of the
1089 datasets can be found in Table 2.

1090 To evaluate the quality of the data collected, the authors
1091 randomly sampled 100 videos from both the isolated
1092 sign language and continuous sign language datasets.
1093 Similar to prior work [40], they employed a certified ISL
1094 interpreter to manually evaluate the accuracy of the En-
1095 glish hints used as labels for the sign language videos on
1096 a five-point Likert scale. The scale ranged from 1-very
1097 inaccurate to 5-very accurate. The authors also manu-
1098 ally reviewed each sign language video to check for video
1099 quality issues.

1100 In the isolated sign language dataset, the annotations
1101 received an average rating of 4.5 ± 0.8 , with 72 videos
1102 rated as very accurate (5). Of the remaining 28 videos,
1103 17 had lower ratings because of regional dialects used
1104 and finger-spelling for common words. The other 9
1105 videos received lower ratings because they were incom-
1106 plete, incorrect, or not clear enough to evaluate. In
1107 terms of video quality, 85 videos had ideal lighting and
1108 placement of the signer. However, seven videos had a
1109 slight lag in the videos, two had stretching artifacts due
1110 to the cropping around signers, four had poor lighting,
1111 and two had low resolution. Based on these issues, there
1112 is a need to improve the recording interface to assist
1113 signers in future iterations.

1114 In the continuous sign language dataset, the annotations
1115 received an average rating of 4.3 ± 1.1 , with 66 videos
1116 rated as very accurate (5). Of the remaining 28 videos,
1117 13 had lower ratings because of regional variations, in-
1118 correct sign language phrasing, and finger-spelling. The
1119 other 15 videos were incomplete or had incorrect signs,
1120 which could be due to the 15-second limit imposed on
1121 signed videos in *SignIt!*. In terms of video quality, 83
1122 videos were of good quality, 10 had low resolution, and
1123 3 had poor lighting. Additionally, 4 videos had blurred
1124 hands due to lag while recording.

Table 2 – Key details of the collected datasets.

Characteristic	Isolated SL Dataset	Continuous SL Dataset
Number of signers	20	20
Number of videos	1573	1358
Vocabulary size	751	1948
Average video length (sec)	3.5±1.4	6.7±3.7
Min./Max. video length (sec)	0.6 / 12.4	0.5 / 26.3
Average words per video	1	5.5±4.4
Total duration	1H 6M	2H 7M
Max. # of videos for a word	26	63
Frame rate, Resolution	30, 512x512	30, 512x512

6. DISCUSSION

SignIt! is an example of co-development of an accessible quiz platform with the DHH community. Our study revealed many issues that detract from learning on *SignIt!*, such as difficulty from long sentences, difficulty recalling names due to lack of corresponding signs in ISL, and regional variations. Additionally, *SignIt!* enables the DHH community to create diverse content. We discuss the challenges with a sign language-based user-generated content platform, such as content moderation, labor of creation, and privacy. Since quiz creation leads to a large amount of labelled sign language data, we discuss the different ways to ensure that the data generated aligns with the requirement of ML models, and guardrails for transferring this generated content for open-source development of ML models. Based on these findings and prior work, we subsequently explore these issues in further detail, how platforms might mitigate these issues and the recommendations for future apps that support user-generated sign language content.

6.1 Learning as a Positive Motivation and Outcome

Our study findings highlight *SignIt!* as a versatile learning tool, that caters to various learning scenarios. The platform is specifically designed to accommodate individuals with different levels of proficiency in ISL and English, allowing for simultaneous learning of both languages. The Indian DHH community exhibits significant diversity in language proficiency in both ISL and English, influenced by factors such as schooling background, age of exposure to sign language, and the presence of local languages in different regions of India. *SignIt!* recognizes and supports this diversity by enabling players to interchangeably leverage their existing knowledge in one language to learn the other, in contrast to general game-based language learning platforms that assume expertise in one language and teach another. Within our study, we observed three distinct learning scenarios.

The first scenario focused on the discovery and learning of new vocabulary in English and ISL while playing

quizzes. Vocabulary learning usually took place from the options of the multiple choice questions since they contained single words or short phrases. For example, P15 encountered an unfamiliar English word – “puppy” and found that animal children have specific names in English. Interestingly, P12 couldn’t remember the name of the father of Mathematics since the name was long and the ISL component was fingerspelled. There are several words and concepts in English that do not contain direct equivalent signs in ISL. In such cases, the words are either conveyed using a combination of words or by finger-spelling. With respect to sign language, P15 faced challenges in comprehending signs for Indian capital cities since the quiz contained an unfamiliar regional variation of ISL. We recommend future sign language learning platforms consider the regional variations in sign languages and have an option to indicate the specific region of the content if available, this would enable users to make informed decisions to engage with the content based on their familiarity or curiosity regarding the specified regional sign language variation. Exposure to regional variations facilitates communication between diverse DHH communities and enriches the learning experience. Therefore, discovering new and diverse vocabulary in both languages while playing quizzes is critical to learning. However, the retention of new vocabulary is a challenge and depends on the frequency with which participants encounter and use the words subsequently. Research shows that repetitive exposure to a certain subject matter promotes learning [57]. Many of our participants also played quizzes multiple times to solidify their understanding and retention of the information. In contrast to options, we found that participants found it challenging to learn from the questions since they contained longer sentences. The differences between English’s Subject-Verb-Object (SVO) structure and ISL’s Subject-Object-Verb (SOV) structure, coupled with the absence of connectives and articles in ISL, made it difficult to establish correspondences between individual words in a sentence. In summary, this scenario portrays instances of unstructured and incidental learning during gameplay.

The second scenario involved participants using *SignIt!*

1209 as a conventional quiz platform to enjoy quizzes in ISL
1210 while occasionally picking up new information. Since
1211 there is a dearth of information present in ISL, partic-
1212 ipants appreciated engaging in diverse content in their
1213 native language (ISL). Interestingly, we found that partic-
1214 ipants created quizzes on useful topics with the goal
1215 of imparting knowledge to the wider DHH community.
1216 They encouraged their friends to learn and used groups
1217 as a forum to share and discover quizzes. While learning
1218 general facts from the quizzes was not the main objec-
1219 tive of *SignIt!*, it was a significant and positive learning
1220 outcome of the app.

1221 The third learning scenario involves learning while
1222 creating quizzes. To create a quiz, our partici-
1223 pants searched for relevant quiz material from external
1224 sources. Moreover, they added suitable sign language
1225 and English translations for the questions and options.
1226 Since this process required our participants to actively
1227 fill in the gaps in their knowledge and spend more time
1228 with the quiz, we believe that it led to a broader and
1229 more comprehensive learning experience compared to
1230 the other scenarios.

1231 6.2 Agency of Content Creation

1232 In our user study, we found that our participants created
1233 a rich and diverse sign language quiz platform contain-
1234 ing almost 3,000 sign language videos that covered fun
1235 topics, educational syllabus-based topics, general use-
1236 ful worldly information, and even Deaf specific topics
1237 such as Deaf culture. This is significant as the amount
1238 of quality content accessible by the Deaf across these
1239 topics is sparse.

1240 Further, our participants not only prioritized accurate
1241 sign language but also took care to provide hints in
1242 simplified English, making the content more accessible
1243 to players with varying levels of language proficiency.
1244 This suggests that *SignIt!* and similar such efforts hold
1245 promise in being a platform where the Deaf community
1246 experiences and exercises the agency to create content
1247 for other members of their community. While the partic-
1248 ipants found the quiz creation interface easy to use,
1249 the process as the quiz creator was time-consuming as
1250 they not only needed to find the quiz content but also
1251 enter the question and four options in both sign lan-
1252 guage and English. We recommend future platforms
1253 support sign language content generation in a way that
1254 reduces the labor of this task. For instance, creating a
1255 Library where quiz creators can add sign language to
1256 text pairs. These pairs may be re-used as necessary (in
1257 the case of *SignIt!*, for re-using across multiple questions
1258 and quizzes). This would reduce the labour of the quiz
1259 creator while also bringing some uniformity to the con-
1260 tent. Since *SignIt!* users were given complete agency
1261 over their creations, the responsibility for ensuring the
1262 correctness of the information presented, as well as the
1263 sign language videos and translations, rested entirely on
1264 them.

1265 In our analysis, we found inaccuracies, ambiguities, and
1266 minor grammatical errors in a small proportion of the
1267 questions. Though these issues did not have any conse-
1268 quences in our study, it is crucial for user-generated sign
1269 language content platforms to have content moderation
1270 before being released publicly to prevent misinformation.
1271 For *SignIt!*, we propose that a content moderation
1272 feature should check each question created and notify
1273 the quiz creator if there are any mistakes. Additionally,
1274 the feature should periodically check all questions in *Sign-
1275 nIt!* to ensure that the facts presented in the quizzes are
1276 up to date. This iterative refinement process may also
1277 hold pedagogic value and may be incorporated as part
1278 of formal educational programs.

1279 While manual content moderation may lead to accurate
1280 content, it may not be scalable. An alternative is to use
1281 machine learning models to evaluate features of videos
1282 such as lighting, hands going out of frame, and other
1283 factors immediately after recording a video to guide the
1284 creator. Machine learning-based grammar checkers may
1285 also be incorporated to verify the correctness and sug-
1286 gest changes to the text entered by the creator. As ma-
1287 chine learning models for auto-recognition of sign lan-
1288 guage [58] get better with the creation of more open data
1289 resources, we hope for more automated feedback on the
1290 signing quality in the future. Crowd-sourcing feedback
1291 from users of the app is also a potential option.

1292 Our study revealed that many participants were driven
1293 by various motivators to create quizzes, including the
1294 desire to learn, share knowledge, earn coins and badges,
1295 and gain fame. This is similar to the notions of fame
1296 in the social media platforms such as TikTok and In-
1297 stagram, where the viral visibility of one’s video is con-
1298 sidered a measure of success of the content creator. A
1299 quantitative measure of ‘fame’ on *SignIt!* is the num-
1300 ber of plays of the quiz. Our participants actively en-
1301 couraged other participants by sharing their quizzes in
1302 groups and hosting live-mode quizzes with their quizzes.
1303 This positive feedback loop must be further enabled to
1304 scale engagement within the community. On the other
1305 hand, some participants did demonstrate concerns with
1306 privacy by sharing their quizzes only with friends in pri-
1307 vate *SignIt!* groups. To empower such participants,
1308 technologies such as augmented reality can be consid-
1309 ered by creating avatars that mimic a person’s actions
1310 and facial expressions with high fidelity while generating
1311 the quizzes.

1312 6.3 Feasibility of data collection

1313 Research on building machine learning tools to recog-
1314 nize sign language is stymied by the lack of open data
1315 resources at the scale required to train modern neural
1316 networks. We demonstrated that *SignIt!* can be a plat-
1317 form for such data collection at scale. In total, 2,936
1318 labelled videos were collected and were manually veri-
1319 fied by ISL experts to be moderate to high quality. We
1320 believe that with greater focus on processes and tech-

1321 nologies to maximize data accuracy, engaging play can
1322 be a successful way to create large datasets for sign lan-
1323 guages.

1324 Our immediate concern is the word distribution in the
1325 data. We found that across the videos, the frequency of
1326 each word was low at a frequency of ≈ 2 for each word.
1327 While this indicates diversity in content, it impedes the
1328 creation of machine learning models which need a large
1329 number of labelled examples for every sign to be clas-
1330 sified. One way to address this is to specifically curate
1331 questions in the Find Questions-repository that have a
1332 desired distribution of words, for instance, multiple oc-
1333 currences of the top 1000 words that a sign language
1334 student may want to be proficient at.

1335 However, it is important to note that privacy and data
1336 governance be strictly followed in such efforts. We re-
1337 ceived consent from participants for the data use. We
1338 are also developing a data processing pipeline that can
1339 anonymize any given video using pose extraction tech-
1340 niques. To handle the data with ethical boundaries, we
1341 are exploring partnering with an academic institution to
1342 host *SignIt!*. This partnership will facilitate the transfer
1343 of sign language data for global efforts in automatic sign
1344 language recognition with open licensing.

1345 6.4 Limitations and Future Work

1346 This study has some limitations that suggest directions
1347 for future work. First, we only recruited 20 participants
1348 for a short-term study, which limits the generalizability
1349 of our findings to a broader population of DHH indi-
1350 viduals. A larger and longer-term study is needed to
1351 examine the usability and engagement with *SignIt!* to
1352 understand its usage in the wild and the potential chal-
1353 lenges or adaptations required for sustained usage. Sec-
1354 ond, we did not conduct a formal learning assessment
1355 to measure the effectiveness of *SignIt!* as a learning
1356 tool. Instead, our study focused on exploring the user
1357 experience and gameplay of DHH individuals using the
1358 app. A future study should evaluate the learning out-
1359 comes achieved by users on *SignIt!* using pre-defined
1360 learning objectives and metrics, such as knowledge re-
1361 tention, language proficiency improvements, and overall
1362 learning gains. Additionally, future research could ex-
1363 plore various avenues for further enhancing *SignIt!* as
1364 an educational tool for diverse demographics. Building
1365 upon the success of Kahoot! in classrooms, evaluating
1366 *SignIt!* as an educational tool for Deaf and Hard-of-
1367 Hearing (DHH) children in classroom settings could be
1368 a valuable next step. This evaluation could involve in-
1369 tegrating *SignIt!* into the formal education curriculum
1370 and assessing its impact on learning outcomes for DHH
1371 students. Moreover, it would be interesting to explore
1372 the potential of *SignIt!* as a learning tool for hear-
1373 ing individuals using sign language, including friends
1374 and family of DHH individuals, as well as sign language
1375 students, which would expand the user base and pro-
1376 mote inclusive language learning. Finally, we hope to

1377 work with DHH communities from different countries
1378 and cultures to understand how *SignIt!* could accom-
1379 modate different sign languages and caption languages,
1380 and address their unique needs and challenges.

1381 7. CONCLUSION

1382 In this work we presented *SignIt!*, an accessible app-
1383 based gaming experience, which was developed as a
1384 result of a deep collaboration with the DHH commu-
1385 nity in India. *SignIt!* enables participants to create
1386 and solve quizzes with questions and multiple-choice op-
1387 tions signed in Indian Sign Language (ISL). Through
1388 a detailed study with DHH participants, we were able
1389 to establish three key findings. First, the app affords
1390 learning opportunities for participants within an engag-
1391 ing setup. Their learning spans multiple domains – the
1392 subject matter covered in the questions, English vocabu-
1393 lary, and ISL signs. Second, the app effectively encour-
1394 ages social collaboration between participants in sharing
1395 and playing quizzes. It also shows early promise to al-
1396 low mixed-ability groups to interact. And third, the app
1397 empowers participants with the agency to be content
1398 creators. The generated content is valuable since it cre-
1399 ates sign language videos on different domains and can
1400 contribute to more accurate machine learning models for
1401 sign language recognition. Given the potential demon-
1402 strated with *SignIt!*, and its generalizability to sign and
1403 text languages, we hope to expand this research by col-
1404 laborating with different organizations and scaling up
1405 real-world usage.

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