An Educational Arabic Sign Language Mobile Application for Children with Hearing Impairment

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Abstract—This research addresses the need for a mobile application to teach Arabic sign language to deaf children in the Arab world. Therefore, the team develop an educational android application to teach deaf children the Arabic sign language using gamification. Also, the research aims to investigate the impact of using a mobile application for Arabic sign language on children's learning performance. To achieve its goals, the research entails two main stages. The first stage focuses on building the mobile application based on the literature review and on searching the Google and Apple stores for similar applications. In the second stage, an experiment is conducted on 10 deaf children—the experimental group adopted the mobile application for the learning process, whereas the control group followed the traditional learning approach. A pre-test and post-test was conducted and the results show that children who used the game-based mobile application performed better in their quiz.

Keywords—educational tool, deaf, Arabic sign language, hearing impairment, mobile application, game-based learning

1 Introduction

Based on a report issued by the World Health Organization (WHO) in 2021, it is estimated that 2.5 billion people will suffer from hearing loss-related problems by 2050. Additionally, approximately one million young adults are in great danger of permanent hearing loss. Such an increase in hearing impairment is due, totally or partially, to a high exposure to harmful noise and unsafe hearing practices in the environment. This increase in the number of people with hearing impairment needs an additional investment in hearing services worldwide [1]. Approximately 22 million people in the Eastern Mediterranean region suffer from impaired hearing. Updated statistics have not been reported on the exact number of deaf people in the Arab countries, but the number is expected to increase in the coming years. Based on the latest figures reported by the World Federation of the Deaf, in 2008 more than 700,000 persons in the Arab world were identified as deaf and hearing impaired [2], [3]. The term 'deaf' is used to describe people with complete or partial hearing loss. The WHO defines disabling hearing impairment in children of more than 30 decibels (dB) and 40 dB in adults [1].

Deaf people face many challenges in blending within their communities and in getting professional opportunities to participate and be involved in their society. The major challenge faced by deaf people is communication—they lack interaction with their community. They need to express their ideas, feelings, and needs to others. Hearing disability has forced deaf people to limit their interaction to a closed group of people who know sign language. This closed group usually includes family members and others who are deaf [4], [5].

Sign language is a non-verbal and non-vocal communication method that involves the movement of two hands, fingers, and facial expressions to communicate. Each gesture in sign language can represent a symbol or a word and expresses a particular message corresponding to natural language [5]. However, sign language has its own structure and does not follow the same grammar used by the spoken language. In addition, there is no unified language for sign language that can be used by deaf people worldwide—each country has developed its own version. For instance, there is Italian sign language (ISL), Chinese sign language (CSL), French sign language (FSL), and Arabic sign language (ArSL), to list a few. Within ArSL, various sign languages have been developed by different countries due to differences in the Arabic dialects [6], [7]. For example, there is Emirati sign language, Jordanian sign language, Tunisian sign language, and Egyptian sign language, to list a few. The ArSL is not unified, although there is a movement to have a unified ArSL [7], [8]. The Council of Arab Ministers of Social Affairs (CAMSA) has compiled the ArSL vocabulary into a dictionary which is currently used on pan-Arab television channels such as Al-Jazeera [5].

ArSL is the academic language used in deaf schools in Arab countries. However, learners with hearing impairment often cannot grasp the needed skills and knowledge as well as their typical-learner peers [9]. Different reasons lead to this issue. First, deaf schools and deaf educational institutions offer limited chances to train and prepare sign language educators. Second, not all families in the Arab world can provide a special teacher to teach their deaf child sign language due to financial costs and time requirements [5]. Subsequently, when a deaf child has a deaf parent, it is much easier for them to learn sign language [21], otherwise, the family needs to provide a special teacher or to enrol the child into classes to learn the sign language; this may not be convenient in terms of location, time, and cost for the family. In addition, the delay in exposing deaf-mute children to sign language at an early age will delay their learning skills and add more challenges to their education, communication, and blending with the community [36], [37]. Thus, it is crucial for those groups of learners to use different methods and assistive technologies to help them acquire the knowledge and skills as do their normal peers [5], [9], [30]. Technology helps to improve the knowledge and improve communication between learners and impaired hearing people [28], [29], [30]. Furthermore, to find a suitable learning method, particularly for those with hearing impairment, it is essential that education providers consider the language and vocabulary used during the learning process. Also, for them to be aware of the required level of assistive technology involvement, as the 'one size fits all' concept is no longer applicable within this changing environment of the education domain [9], [31]. Educators need to think thoroughly when adopting technology that it is aligned with the learning styles of the learners [31].

Various methodologies and applications have been proposed to develop and embed different technologies within the sign language learning process. The aim of these systems is to improve the interaction and learning between the deaf and other people through the daily practice of communication [5], [6], [10], [23], [30], [34]. Many projects have used PC-based or mobile-based applications to enhance communication between people with disabilities [27], [33] and in particular between deaf people and non-deaf people to improve the experience of learning sign languages [30]. Using smart mobile devices in learning is widely adopted among learners of different ages [32]. Some mobile applications have been built to translate from sign language to text or speech and vice versa [36]. Other mobile applications have been used to enhance the learning experience of deaf learners [10], [11], [17], [19], [22], [30]. The rapid development in using emerging technologies such as mobile devices has changed the way learners are interacting or communicating with each other causing a paradigm shift in the learning and the communication process [28], [29]. It is clear that the deaf communities have had minimal attention in terms of advising on the best guidelines to develop mobile applications to facilitate their learning process for sign language [22]. Few mobile applications teach sign language, and the ArSL in particular [10], [37], hence, there is a need to focus on the deaf community in the Arab world and the support systems and applications [10], [34] that facilitate communication and learning.

In this paper, a mobile application is developed to be used by impaired-hearing children to learn the ArSL and to enrich the related literature. The primary stakeholders in this research are the children who need to learn basic ArSL through a more convenient, appealing, and cost-effective approach. The priority of this application is to target children younger than 12 years old—this age is a critical stage for children to build their communication and knowledge skills and to guarantee the correct exposure to sign language [38]. Furthermore, the research focuses on teaching ArSL due to a lack of educational ArSL [10]. The user can learn letters, words, and numbers through a fun and enjoyable approach. The application is based on the requirements collected from a local school, and after screening the available applications in the Google and Apple stores. The application on children's learning will be tested through an experiment.

The rest of this paper is organised as follows: Section II explores the previous work in this domain; Section III presents the research methodology and design and features of the proposed application, while Section IV provides the results and discussion and Section V presents the conclusion.

2 Literature review

Using technologies to learn a new skill and to acquire new knowledge has dominated this era, in particular using mobile and smart devices [29], [30]. Adults and children are substantially interacting with these devices due to their accessibility, ease of use, and ubiquitous feature. Such use and interaction is not limited to a certain age, gender, or geographic location [30], [32]. Unfortunately, there are limited educational applications for children that can provide the needed benefit during their learning process, instead of replacing the role of babysitting applications, and in particular for hearing impaired

children [30]. Thus, there is a need to consider these children's actual needs during the development and design phases of an educational application [22], [32].

Regarding the use of technology in education, researchers are paying attention to how educators can make the learning process more attractive, enjoyable, and interactive for children using these small portable devices. It is apparent that children are using mobile applications naturally and they find it a more fun and interesting way to learn when they are using mobile devices [32]. This has led to the adoption of a game-based learning approach when designing and developing educational applications for children. Several research studies have recognised that a game-based approach can improve the learner's attitude, performance, engagement, and positive learning behaviour [32], [35].

However, few applications have been found that consider the game elements in their design when targeting the hearing impaired community [22], [34]. For instance, [30] suggested a web-based application that used augmented reality to learn Peruvian sign language. The researchers adopted the elements of game-based approach learning where the learner completes various challenges to earn badges and higher scores. The study showed that the learning time reduced using the application while it helped to create awareness and facilitate communication among the deaf children in the Peru community. The evaluation was conducted on deaf individuals aged between 18 and 40 years. When such applications are to be used by children, different perspectives need to be considered in the design [22], [32].

Another study [36], proposed a mobile application that adopts gamification elements. The suggested application targets the Malaysian deaf-mute community as well as those interested in learning Malaysian sign language. The application features are defined based on data collected from the Malaysian community. The researchers believe this application will bridge the communication gap and facilitate learning for deaf-mute children in Malaysia. The researchers focused on defining significant features to include in the educational mobile application for learning the sign language. The application shows scores for the user when he/she is making the correct sign. No other game-elements are adopted in this application such as levels or any other game/quiz. Furthermore, the proposed prototype was validated/evaluated by the deaf community.

Another application was developed for ArSL [17]. The researchers focused on developing a mobile application that would facilitate communication between Arabic sign speakers and non-Arabic sign speakers through real-time translation of sign language to speech and vice versa. The application targets any individual in the Arabic community who has a communication difficulty using ArSL. The application can be considered more as a mediator between the sign language speakers and those who do not speak the language. It is not considered primarily as an educational application—one of its features is a quiz game that allows the user to learn the language through doing the correct sign to match a given word. The researchers developed the application based on the UAE community and it is considered one of the few applications to target the UAE deaf community. Additional Arabic applications can be found in the following section.

2.1 Mobile applications for Arabic sign language

Each sign language has its own characteristics that should be considered when developing an associated mobile application. In particular, the specific nature of ArSL should be considered when using technology to teach ArSL.

ArSL is considered a manual language that involves three elements: the configuration of hands (hand shape), placement/space (position of the hand in relation to the body), and movement (directions and contacts within space). Also, it uses other non-manual features, such as the face, mouth, and tongue expressions and focuses on words, verbs, and adjectives, however, it lacks many of the particles. In spite of that, grammar is not followed as in the spoken and the written Arabic language, but facial expressions or other ways can express the particles and the verb tenses. The expressions, words, and alphabet can be expressed using finger spelling and cued speech as a communication method among people with hearing impairment [6], [18].

Many mobile applications have been developed to teach the various sign languages with most dedicated to teach the American and English versions [6], [20]. As reported [10], few mobile applications have been developed to teach ArSL. For instance, [6] proposed an Arabic alphabet sign language recognition system based on machine learning that can be used to help deaf students to learn the Quran using ArSL. The suggested system can be used to build educational tools for deaf children to understand the meaning of the Holy Quran. However, the application focused on explaining the Holy Quran, not in teaching basic ArSL. Another intelligent system was suggested [5] to translate the ArSL to speech, and speech into ArSL. The proposed system can be used by anyone interested in learning ArSL, and will support IPhone users in the future.

Abdel-Fattah [18] proposed a mobile application for ArSL real-time translation in which a portable Leap Motion Controller is connected to the USB of the mobile phone through an OTG adapter. The controller is used to capture hand movements. The application's features are: training, text translation, voice-to-sign translation, and a game quiz. However, using an external controller can reduce the usability and portability of the system. Another work developed a system that uses smart sensor gloves and is connected to an android mobile application to convert the movement of the hands into ArSL in spoken and written style [20]. The spoken word or sentence can be translated in this system to text.

By analysing the developed mobile applications by [20], [23-24] that targeted people with hearing loss, it has been observed that the applications focus on brief interactions of less than five minutes, and they use simple navigation and graphics. Such applications enable the quick review of information rather than prolonged or deep learning. This makes them better suited for activities such as a status check, games, pictures, a request for just-in-time information, or a student response tool in the classroom [21]. However, few of the mentioned applications adopted the game-based concepts in developing their application of porotypes such as in [30]. In this application some of the game-based elements such as badges were implemented and incorporated.

Generally, the educational mobile applications that have been developed to facilitate learning sign language are considered very few, in spite of the growing attention of the research community to this domain. Still a lot needs to be done. As well as screening

the work that had focused on academia [1–11], [13], [17-25], [34], [36–48], the authors searched the Google and Apple stores using keywords such as 'sign language applications', and 'learn sign language application' with approximately 40 applications retrieved. These applications vary in terms of the number of supported words, language focus, ratings, using games, and targeted age. The authors, noticed that most of the retrieved applications were targeting the American Sign Language. Even when keywords such as 'Arabic sign language', 'learn Arabic sign language', and ' تلعم لغة الاشارة"العربية', only 11 applications that focus on the Arabic sign language were retrieved out of 40 applications. The 11 applications were reviewed and assessed based on the criteria in Table 1—only two applications were included. The next section presents the mobile application for sign language in particular the ArSL.

Table 1. Exclusion and Inclusion criteria used

Inclusion Criteria for Apps	Exclusion Criteria for Apps
Focuses on teaching Arabic sign language	Focuses on teaching languages other than Arabic
Uses gaming elements	Does not use gaming elements
Available in Arabic language	Not available in Arabic language
Targets children	Does not target children
	Duplicates found in Android and Apple Stores
Application categorised as an educational application	Other category

2.2 Related work

Many web-based and mobile applications have been reviewed and analysed to finalise the desired features of our proposed mobile application. The applications presented here mainly focus on teaching sign language to the deaf. A few applications have been developed for teaching ArSL, such as [12], [19], [39], while others teach different sign languages [13] – [16]. Various applications were explored by searching the Google and Apple stores using keywords such as 'sign language' 'Arabic sign language' ' تعلم لغة الاشارة بالعرب' as shown in Table 2. As indicated in Table 2, not all applications teach the alphabet and numbers; some teach 50 words while others teach 10,000 words. Also, some applications support additional features intended to make the learning process more enjoyable such as 3D animation, search engine, games, and pictures.

An android well-designed application to teach the alphabet, numbers and words using American Sign Language was developed [13]. It adopts a fun and easy interface where the learner can choose to learn from four different instructors through real-life conversations and examples. The application allows the user to memorise the words and the signs learned on a daily basis, using a reminder to practice the words. While the application design is fun and attractive, it does not focus on children's learning and is not available for free. A web-based British Sign Language application and tool called Sign to Me, was developed by Simon Harvey [14]. This application is used for educational purposes, but it can also be used at home. It contains over 1,700 searchable sign clips linked to a picture dictionary of English words and their definition as well as fun

games and printable flashcards [14]. The application only supports the English language.

The sign language application: ASL Kids [15] is designed for children aged 1–12 years to learn American Sign Language. The application uses the peer role model, where children teach other children the sign language. The application has approximately 20 signs for free. The application is teacher-approved and needs to be purchased to have access to all the available features. The application design is easy to use and intuitive for the target audience and available for android and IOS users. Another application available in the Google store to teach the American Sign Language is the 'ASL American Sign Language' app. The application provides a dictionary of American Sign Language and targets all ages. It has a baby sign language dictionary that targets children, and covers the alphabet, numbers (0–100) and the signs of common words used in sentences. New features such as games will be added to this application [16].

A mobile application to teach ArSL, called 'Sign Language: لغة الإشارة', was proposed [12]. The application was developed by the Dubai Police to give the UAE Community the opportunity to learn Emirati Sign Language. The application contains video tutorials recorded by Emirati (male/female) to learn letters, numbers, and other categories. A small quiz is available after each module. The application targets anyone in the UAE community who is interested in learning the Emirati sign language. However, the used characters and the application design and layout may be difficult for children to use. The application is free and available in the Google and Apple stores. The fingerspelling editor, Esharti [39], is a Saudi application available on both android and IOS platforms. The application provides information about the Saudi sign language and offers some online courses related to different life sectors that allows the learner to initiate conversations related to topics such as banking, health, and other aspects of life. However, the application targets adults and its design and topics covered are not suitable for children.

Table 2. Comparison between similar systems

	ASL Kids	**Lingvano: Sign Language - ASL**	**Sign to Me**	**Sign Language – لغة الإشارة،**	**Esharti**
Sign Language	American Sign Language	ASL	BSL	ARSL	ARSL
OS	iOS/Android	Android	Web-based tool	Android/iOS	Android
Alphabet	Yes	Yes	No	Yes	Yes
Numbers	Yes	Yes	No	Yes	Yes
Words	Yes	Yes	Yes	Yes	Yes
Number of Words	21	-	1700+	-	-
3D Animation	Yes	Yes	No	No	No
Video	Yes	Yes	Yes	Yes	Yes
Search Engine	Yes	Yes	Yes	Yes	No
Exercises/Games	Yes	No	Yes	Yes	No
Pictures	Yes	Yes	Yes	No	Yes
Child-oriented	Yes	No	Yes	No	No

We noticed that few applications have been developed to teach sign language which consider gaming elements in their design and targeting children below 12 years in general and in the Arab community. Therefore, the next section presents the methodology followed and the proposed prototype of a mobile application for children under 12 years old to learn the ArSL at an early stage using an easy and fun approach.

3 Research methodology

The aim of this research is to develop a mobile application that allows children to learn the ArSL using a fun and enjoyable approach and to test the impact of using the mobile application on children's performance. To achieve this goal an experimental research methodology has been adopted [40], [41]. This research has been undertaken in two stages:

- First stage: develop the mobile application for ArSL.
- Second stage: an experiment has been conducted on deaf children to verify the impact of using the mobile application.

3.1 First stage: Mobile application development

The team followed Agile methodology which is iterative in design to develop the application. The application went through analysis, design, and then followed by implementation. To follow is a description of each phase and the main output.

Analysis phase. This application was developed based of the requirements of a local school that teaches sign language. In the analysis phase, requirements for the application were collected from two instructors with impairment hearing. A web-based survey was then forwarded to 38 parents to determine the requirements of the application based on their observations of their deaf children's needs. The main output are features of the application.

Design and implementation phase. Based on the collected requirements, the application was designed and developed using the following:

- Java and XML languages
- Eclipse IDE
- Android System Development Kits (SDKs)
- Android Virtual Device

The developed mobile application, called MySign, was developed to teach the deaf and people with special-needs, the ArSL. The developed application can be used at letter and/or word level, and to teach numbers and common sentences. The application supports the learning process of a deaf child by adopting an interactive and fun approach. Figure 1 shows the main menu of the application.

Fig. 1. The main menu of the MySign application

MySign application features. My Sign is an application designed to be installed on android-based tablets to help users learn ArSL. The application has a child user-friendly interface and a parent/teacher user interface. The application teaches a child the ArSL through different categories: letters, numbers, and vocabulary. The vocabulary category is grouped into six sub-groups that include animals (الحيوانات), food (الغذاء), home (البيت), colours (الألوان), family (العائلة) and social relationships (العلاقات الاجتماعية). In the number and letter groups, an image is used to teach the sign language for the corresponding letter or number, while for the vocabulary, a video clip is used to show the corresponding word. The suggested application allows parents and teachers to record a video and upload it to expand the word list. As an example from MySign, Figure 2 shows the subcategories of the vocabulary and the words under the food group.

After finishing a certain category, the child can play a quiz-based game to test their acquired knowledge. The tests include two different categories: memory-based games and multiple-choice question-based games. Figure 3 shows the two types of games that can be used by the teacher to assess the student's required knowledge.

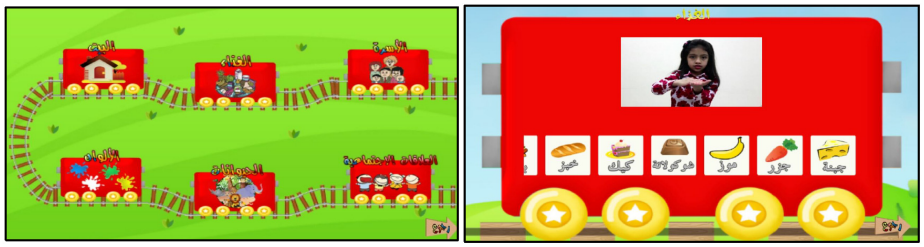

Fig. 2. (A) Vocabulary categories menu (B) Food categories

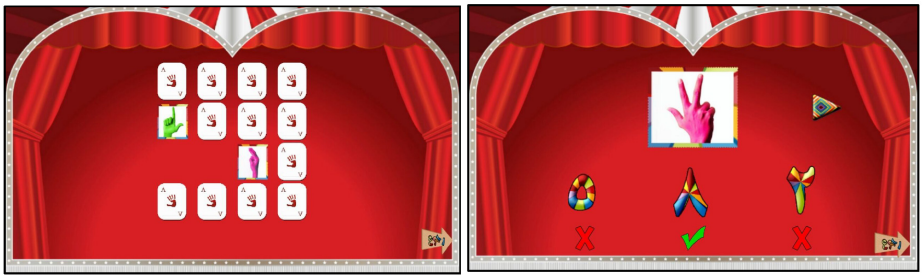

Fig. 3. (A) Memory-based game (B) Multiple-choice question-based game

3.2 Second stage: Experiment

The aim of this phase was to evaluate the impact of using the application on students' scores. To achieve the goal of this stage, the team did the following:

1. Ten deaf children aged six years old were chosen from a local school. The selected sample of children with impairment hearing had the same level of moderate impairment hearing disability.
2. A pre-quiz and post-quiz was conducted on all children. The aim of this was to test the impact of the application adoption on the children's performance (test-scores).
3. The children were divided into two groups: group A - the experimental group, were children who had been exposed to the mobile application to learn new signs and to try all the application features. The second group B, learned the same new signs using a face-to-face approach and the traditional approach. A pre-test quiz and post-test was conducted on both groups.

For group A: an introductory session was conducted for the experimental group after obtaining consent forms from the parents. All subjects were introduced to the application and how it works in one 60-minute session during which an explanation of the tasks that the children should perform was given by the teacher. The application was installed and downloaded on their personal tablets, and they were asked to use it for one week under their instructor's supervision. The children were asked by their instructor first to try all categories of the MySign application: numbers, letters, and words. Table 3 summarizes the tasks given to the students.

Table 3. Students tasks summary

Task	Description
1	Learn letters
2	Learn numbers
3	Learn vocabulary
4	Play multiple-choice question-based game
5	Play memory-based game

4 Experimental results and discussion

The pre-quiz and post-quiz results are presented in Tables 4 and 5.

Both Group A and Group B had close scores in the pre-quiz—this assures that both groups had no prior knowledge about the given content. Tables 4 and 5 show that children who use the mobile application in their learning process score higher than their peers in Group B. Furthermore, the results in Table 6, confirm such result with the significance of the t-test where 0.01<0.05. This proves that introducing the mobile application in learning new sign language has a positive impact on children's learning. Table 7 presents the calculated Eta as recommended in [42] where it is noticed that children scores increase by almost 60% for group A. This result can be explained due to the fact the children of Group A were more excited about learning the signs because of the games which had been followed by each module in accordance with [32], [38]. This was excepted because children are more involved and engaged with game-based learning compared to the traditional approach.

Table 4. Mean difference in experimental and control groups pre-quiz

Group Statistics				
	Group	***N***	***Mean***	***Std. Deviation***
scores	Group B: Control Group	5	4.7	0.5701
	Group A: Experimental Group	5	4.7	0.7583

Table 5. Mean difference in experimental and control groups post-quiz

	Group	**N**	**Mean**	**Std. Deviation**
scores	Group B: Control Group	5	6.900	.6519
	Group A: Experimental Group	5	8.200	.5701

Table 6. Independent t-Test of post-quiz

	Independent Samples Test					
		t	***df***	***Significance Two-sided p***	***Mean Difference***	***Std. Error Diff***
scores	Equal variances assumed	-3.357	8	.010	-1.3000	.3873
	Equal variances not assumed	-3.357	7.860	.010	-1.3000	.3873

Table 7. Eta measurement of post-quiz

Measures of Association		
	Eta	***Eta Squared***
scores * group	.765	.585

5 Conclusions and future work

This paper has proposed a mobile-based application to teach the ArSL to deaf children using a game-based approach. The application is convenient, cheap, and easy to learn and use and an attempt to fill the need for an impairment hearing educational application for ArSL (as per the academic survey conducted by the researchers and lack of such an application in the Google and Apple stores). The reported results in the above sections have confirmed the positive impact of using mobile applications based on gaming-elements on children's performance in learning new signs. It is essential to consider different elements that attract learners in terms of the design, layout, variety of activities, and rich content to enhance their learning experience [32]. In addition, as per the instructor's observation, it is important to choose an appropriate system of reward within such applications to keep students engaged and attracted [22]. Students' performance in the post quiz prove the importance of adopting the gaming approach for learning the sign language using the emerging educational technologies such as mobile devices, augmented reality, and others for children with disabilities [22], [38], [32]. Most of the research and commercial products based on sign language systems focus on adults. To integrate hearing impaired people with the community we need to focus on the early ages of their life to make their blending with the community much easier. Focusing on the knowledge, memory, and communication skills of deaf children [38], [22] through embedding different technologies in their daily life will facilitate their learning. The application's features will be enhanced in future work, such as adding a real-based translation from speech to sign language and vice versa, and to translate from sign language to text and vice versa. The improved application should be tested for an extended period and on a more significant number of users.

The research has some limitations due to the small sample size in educational research settings. For more quantitative statistical analysis, it is recommended to have a larger sample size to be able to generalise the study findings. Therefore, the authors will repeat the study with a lager sample size to conduct more statistical analysis for generalisation. The given sample size helped us to shed light on other elements through teacher observations of the small number of students [43]. The feedback from instructors is under further investigation such as the impact of the reward system for students during the games and how this truly impacts and influences the children's learning performance. Additionally, what level of difficulty should be considered to trigger the children's learning? Such observations can be further investigated with a larger sample for generalisation purposes [4], [29], [30], [32], [43-44].

6 References

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