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Development of Teleaudiology Service in Special Education Service Centre in Malaysia: Lessons Learned

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ABSTRACT

Teleaudiology has been implemented in several settings, including hospitals, nursing homes, community-based programmes, and educational institutions. Despite its numerous advantages, teleaudiology is still relatively new in Malaysia and is gaining popularity among audiologists. Additionally, the majority of studies have been conducted on normal-hearing individuals. Thus, as a pioneer in Malaysia, this study established teleaudiology services for students who are deaf or hard of hearing (DHH) at the Special Education Service Centre. The researchers examined two critical factors that contribute to the service's proper operation: internet speed and the audio-visual quality of the ICT applications employed. This study documented the details of the service's implementation, which included 25 sessions of synchronous teleaudiology with DHH school children. Additionally, this study revealed that upload and download speeds exceed prior research-recommended minimums. Meanwhile, most teleaudiology service sessions are done in high-quality audio and video, except for the Skype programme, which has a moderate visual quality. To summarise, teleaudiology services have been effectively deployed amongst institutions and have the potential to be expanded to another location in Malaysia.

1. Introduction

Teleaudiology refers to the technology of providing audiological services and information to clients using ICT applications, including phone, email, and videoconferencing [1]. Teleaudiology has been utilised in many settings, including hospitals, nursing homes, community-based programs and schools. Owing to the multiple benefits of teleaudiology, the American Speech-Language-Hearing Association (ASHA) recommends telepractice be incorporated into the school system [2]. It can help schools overcome personnel shortages and implement more intensive listening programmes [2,3]. According to ASHA, in 2016, 16.6% of audiologists in the United States reported using teleaudiology in schools, compared to only 7.4% in 2014 [4,5].

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Many researchers and organisations have developed guidelines for implementing telepractice. As an example, ASHA emphasised the following critical aspects of implementing teleaudiology:

i. the role and responsibilities of audiologists
ii. the ethical principles to be followed
iii. licensure and individual qualifications
iv. the method of payment for services
v. client selection [2].

The stability of the internet connection is the primary predictor of this service's success. The previous researcher had proposed 3 Mbps or higher internet connections [2,6,7]. Apart from that, audio-visual quality is also considered important and should be evaluated in telepractice [8]. In addition, previous studies have examined the reliability of tests conducted using teleaudiology. Despite this, Krumm explained that most of the studies carried out in the past focused mainly on subjects with normal hearing [9]. The reliability of hearing assessment on children with hearing loss via teleaudiology is not been sufficiently investigated yet.

In Malaysia, teleaudiology is rarely practised even though approximately half of the audiologists reported that teleaudiology could improve the quality of care, accessibility, and professional practice [10]. To optimise learning in the school, the Ministry of Education Malaysia introduced the Special Education Service Center (SESC) as a one-stop centre for children with disabilities. It supports parents and teachers in professional care that includes audiology, speech-language, occupational therapy, psychology and peripatetic. The SESC's primary goal is to minimise or diminish learning handicaps and to develop independence among children with disabilities. For audiology, the services include hearing tests, rehabilitation, and counselling. Only five qualified educational audiologists in Malaysia serve under the SESC [11]. This study aims to demonstrate how researchers used teleaudiology technologies and services in SESC for deaf and hard-of-hearing students. Teleaudiology is the first service to be introduced in SESC, specifically in SESC Selangor. As a result, two main critical variables have been considered by researchers to ensure the service functions properly, including the internet speed and the audio-visual quality of the ICT application employed.

2. Development of the Teleaudiology Services

The teleaudiology system's functionality is critical to assuring the quality of the teleaudiology services implemented. As a result, teleaudiology services between Universiti Kebangsaan Malaysia (UKM) and SESC Selangor have been developed following the guidelines of ASHA and previous researchers [2,12-14]. The implementation details of this service will be discussed in detail below.

2.1 Selection of Location and Room

The control and testing centres were located in separate locations in this investigation. The researcher is in the control room, while the special needs students (MBK) and educational audiologists are in the testing room. The postgraduate audiology programme at UKM was chosen as the control centre because the space featured a stable internet connection through cable, a suitable lighting system for video calls, and a calm environment that guaranteed the participants' privacy and confidentiality. Meanwhile, three justifications were advanced for choosing SESC Selangor as the testing centre. To begin, SESC Selangor was conveniently located near UKM and was staffed by an educational audiologist, making it easier for the researcher to set up the room. Second, SESC Selangor is housed within a special education institution, facilitating MBK recruitment.

Additionally, the SESC Selangor testing room complies with teleaudiology service regulations. The test room in SESC offers adequate lighting for the live video feed during the hearing test, and MBK is not distracted visually. A silent room is devoid of noise sources that could impair two-way communication or the hearing test in this study. To ensure the hearing test's quality, environmental noise levels were assessed before and following the hearing test. Google Maps calculated the distance between these two points to be 35.8 kilometres.

2.2 Selection of Audiology Equipment

Audiology equipment specifications are critical for the effective operation of teleaudiology services. Researchers initially selected and evaluated numerous pieces of equipment. However, the devices needed to be changed as they could not promise good image quality for video otoscopic examination, and for the audiometer and acoustic immittance, the licences were restricted to internal use. They could not be operated via a computer. As a result, the researchers upgraded the equipment to ensure that teleaudiology services could continue as planned. The study subjects' hearing levels were determined using audiometers, and the state of the middle ear and the auditory pathway were determined using acoustic immittance.

Along with the audiological assessment instrument, a sound level meter (SLM) is utilised to determine the noise level in the test room before and after the audiological examination. Because this study employs a direct or synchronous teleaudiology approach, it necessitates employing equipment with computer-operated software. All of this essential audiology equipment has been installed at SESC Selangor (testing centre) and is still within the specified calibration time.

2.3 Selection of Information Communication Technology (ICT)

This teleaudiology service relied on two computers, a desktop and a laptop. UKM's control centre is a Dell Inspiron Small Desktop (3470) with Windows 10 Pro 64bit. It is connected to a high-definition Dell 27-inch display. Meanwhile, Dell laptops running Windows 10 Pro 64bit were stationed at SESC Selangor as a testing centre and connected through a universal serial bus (USB) or Bluetooth to audiology equipment. Each of these tools, such as DinoCapture 2.0 (video otoscopy), Titan Suite (acoustic imitations) and Equinox Suite (audiometer). Additionally, the Logitech C922 Pro HD Stream Webcam has been attached to the laptop as a backup device in case of communication or internet outages. During audiological testing, webcams are utilised to monitor the MBK's condition or responsiveness.

Following that, researchers identified many applications that would connect the two computers above, allowing laptops (SESC) to be remotely controlled by desktop PCs (UKM). For example, some previous researchers have remotely operated PCs using the TeamViewer application [3,15,16]. The researchers compared three apps deemed adequate: TeamViewer, AnyDesk, and Chrome Remote Desktop (CRD). After a comparison, the researchers discovered that the CRD application had the best visual display quality and speed compared to the other two programs. Additionally, this CRD app is free, has never been utilised by a previous researcher, particularly in the field of teleaudiology, and provides an opportunity for researchers to evaluate this novel research approach. As a result, both computers are equipped with the CRD application, which enables researchers at UKM to remotely control laptops (at SESC) via an internet connection.

The SESC is equipped with Streamyx internet service, and a speed test conducted using a YES smartphone revealed 45.4 Mbps (download) and 46.8 Mbps (upload) (upload). The researchers then connected the cable to a D-Link Wireless AC1750 Dual Band Cloud Router to establish a wireless zone at SESC. Meanwhile, the UKM control centre was connected by cable to the Maxis network. Additionally, the researchers linked the connection to the D-Link WL AC1750 Dir-868L Router to create a wireless zone in the room. Both places include a stable wireless network that enables internet connectivity (local internet sharing) for each piece of hardware.

Internet speed tests are run at both sites using the website https://www.speedtest.net periodically before and following the hearing test. Since 2006, the Ookla corporation has maintained the website, which has over 25 billion tests utilising Speedtest and broadband connection measurement parameters [17,18]. Three critical parameters are monitored via the website: upload, download, and ping. As a guideline to assure the smooth operation of this teleaudiology service, several researchers have established a minimum upload and download internet connection speed of between 0.1 Mbps and 0.38 Mbps [3,6-7,15]. Researchers also measured ping values for internet speed. Still, no precise values had previously been established, and only Penteado *et al.,* [19] estimated the rate of the ping value to be between 58.5 ms and 7.3 ms in their analysis.

2.4 Closed-Circuit Television (CCTV) and Skype Application

The SESC Selangor testing facility has a D-Link HD Wi-Fi Camera DCS-936L closed circuit television. The purpose of installing this CCTV is to allow researchers to monitor the test room's state, the position of the MBK, and the facilitator during the conventional hearing and teleaudiology tests. Observation sessions will be conducted live via video and audio recording on a tablet or smartphone equipped with the myDlink programme.

Additionally, researchers compared MBK's visual quality and response time with CCTV and Skype applications. Although the visual quality of the CCTV is excellent, there is a 5 to 10-second latency in the MBK response, and the link is unstable and requires reconnection. As a result, researchers used the Skype application to communicate with an educational audiologist and view MBK response during audiological assessments, as other researchers have done [20-22].

After selecting the Skype application, the researchers installed it on the laptop. Following testing, the Skype communication via the Sony WH-CH400 Wireless headphones was stopped due to the Bluetooth connection between the laptop and the headphones occasionally being lost. As a result, the Skype programme has been loaded on YES smartphones and tablets to address this issue. The details of this connection will be discussed in further detail below. Additionally, this programme is installed on the tablet, which will be discussed later.

2.5 Smartphone and Tablet

The researchers (control centre) and educational audiologist (testing centre) communicated two-way, utilising tablets and cell phones equipped with the Skype application. In the UKM control centre, a Samsung Galaxy Tab A tablet (2017, 8.0 "LTE) was placed to allow researchers to monitor the room and MBK in the testing centre. Researchers communicated with an educational audiologist at the testing centre via Skype with speakers. Meanwhile, an educational audiologist at the test facility (SESC) used a YES Altitude smartphone equipped with Sony WH-CH400 Wireless headphones for Skype video calls. Figure 1 to 3 illustrate hearing assessments conducted using teleaudiology and conventional services.

Fig. 1. Hearing assessments were conducted using teleaudiology approach at postgraduate audiology programme, UKM (control centre)

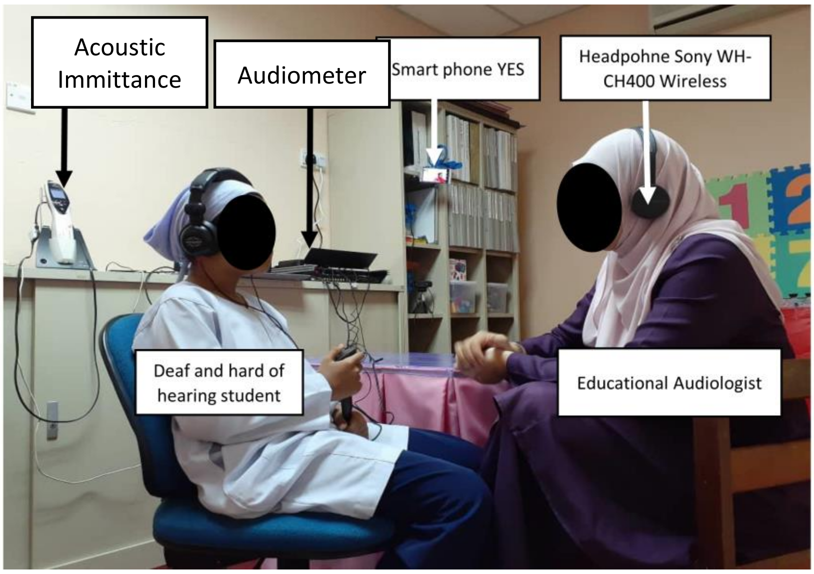

Fig. 2. Hearing assessments were conducted using teleaudiology approach at SESC Selangor, (testing centre)

Fig. 3. Conventional hearing assessments were conducted at SESC Selangor, which the researcher observed through CCTV

2.6 Synchronous Teleaudiology Testing Procedures

Before conducting the actual study, the researchers met with an educational audiologist to explain the study protocol and proper use of audiology equipment. Additionally, brief discussions were made multiple times to ensure the data collection process ran properly. The educational audiologist determined the date and time of MBK's participation in this study based on the MBK class schedule to avoid interfering with MBK's learning and teaching processes.

The study is separated into three stages: a pre-teleaudiology assessment, a teleaudiology assessment, and a conventional assessment. Numerous evaluations are required before teleaudiology assessment to guarantee the study method runs smoothly. Researchers at the UKM control centre used a tablet to make a video conversation through Skype with the educational audiologist at the SESC test centre. Researchers gathered personal information about MBK and compiled a brief history of the school's students. For this study, the MBK's background, such as age, gender and academic performance, was not analysed.

Additionally, researchers used the website https://www.speedtest.net to measure internet speeds in UKM (tablets) and SESC (smartphones). The educational audiologist then assessed and recorded the noise level in the test room setting using SLM. Educational audiologists and researchers log onto their computers using CRD software. Educational audiologists offer researchers access to code that enables them to operate computers at SESC from UKM remotely. The researchers kept track of the time it took to link these two computers. Following that, the researchers measured the internet speed on both machines.

Following the pre-test stage of establishing the Skype video call and CRD application, audiological testing was undertaken using a synchronous teleaudiology approach. Additionally, the researchers noted the test's commencement time. Researchers use the remote control to operate basic audiology equipment at SESC Selangor. The researcher was aided in conducting the MBK by an educational audiologist who served as a facilitator. This study performed three major audiological tests on MBK: video otoscopic examination, acoustic imitations, and pure tone audiometry (PTA). Additionally, play audiometry will be administered to children who are incapable of undergoing pure-tone audiometry (PTA). This method serves as a diagnostic tool for determining the hearing condition in children. Generally, the play-based approach is a natural method for detecting issues in children [29]. The researcher documented the expiration time of each audiology test once it was completed. The educational audiologist also recorded the noise level in the testing room setting. The researchers also examined the internet connection speeds for CRD, Skype, and audio-visual quality. The audio quality rating applies only to Skype applications, whereas the visual quality rating applies to CRD, Skype, and CCTV programmes. Audio-visual quality is classified into 'Low', 'Medium', and 'Good'. The 'Low' classification is used for applications that require reconnection after being disconnected, the 'Medium' classification is used for applications that experience delay or ambiguity but do not require reconnection, and the 'Good' classification is used for applications that do not experience any interruption.

An educational audiologist from SESC administered all three major audiology tests to MBK in person (conventional). Before conducting the test, the educational audiologist took measurements of the noise level in the test room and entered them into the study data collection form. The researcher at the UKM control centre was not required to perform any tasks during the hearing assessments and instead conducted observations through Skype and/or CCTV. Additionally, the educational audiologist documented the test's start and finish times. After the test was completed, the educational audiologist took a second measurement of the room's noise level.

3. Results and Discussion

The internet connection was measured using the website https://www.speedtest.net, and the average internet speed in UKM exceeded SESC except for the ping value for CRD applications (Figure 4). Pearson product-moment correlation and paired t-tests on Skype ping values found no statistically significant difference in mean between UKM and SESC. Additionally, the average ping levels for CRD applications demonstrate similar results.

The paired t-test found that there were significant differences in the mean download values for Skype applications and CRD between UKM and SESC [$t_{23} = 3.76$, $p<0.05$] and CRD [$t_{20} = 10.39$]. Meanwhile, the Pearson correlation coefficient demonstrated no statistically significant relationship between the mean download value of the Skype application and the mean download value of the CRD application at both sites [$r = -0.55$, $p>0.05$]. The negative correlation suggests that when UKM download speeds increase, SESC download speeds for CRD applications decrease. In UKM, the average download speed for Skype is 23.50 Mbps [95% CI (10.58, 36.43] while for CRD, it is 38.31 Mbps [95% CI (30.61,46)]. Additionally, a statistical study of the average value of uploads for UKM and SESC applications indicated comparable findings.

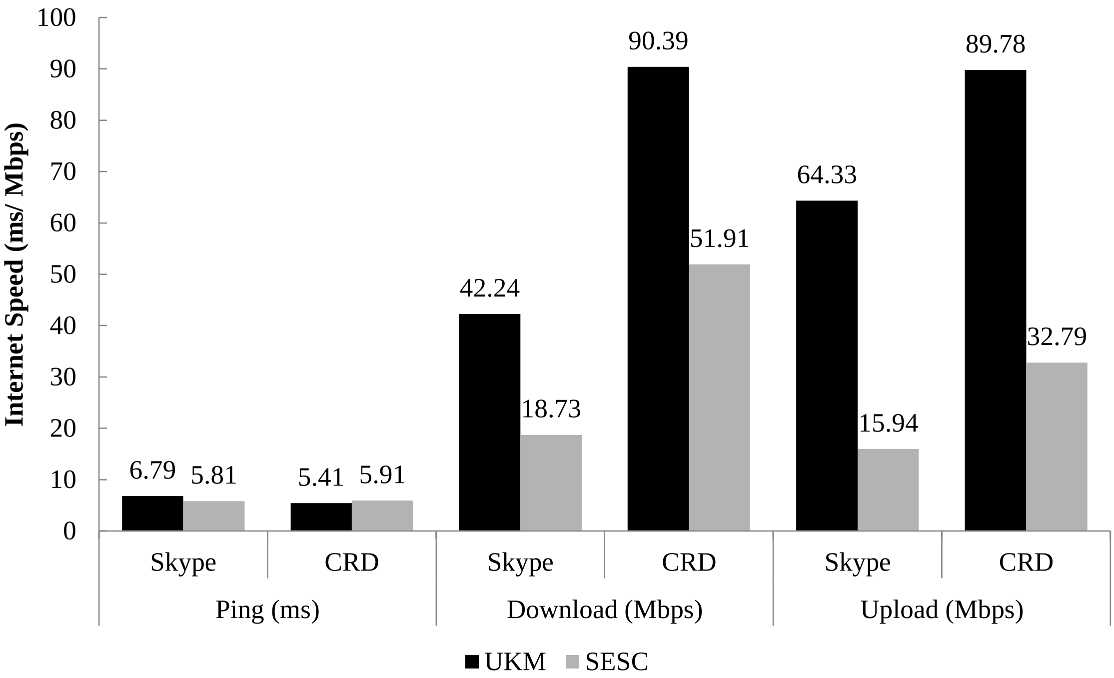

Fig. 4. Internet speed for Skype and Chrome Remote Desktop (CRD) applications based on their respective locations

Although there are significant differences between applications and locations, the average internet speed is acceptable at 5.98 ms (ping), 50.82 Mbps(download), and 50.71 Mbps (upload). Most previous research did not include ping values, except Penteado *et al.,* [19], who reported a ping value of between 58.5 ms and 7.3 ms in their study. Thus, this study's ping values are faster than that, as a lower ping value indicates a faster server response [17]. While both upload and download speeds are above the minimum recommended by particular research [3,6-7,15] the recommended internet rates for high-definition and high-quality Skype video calls range between 0.45 Mbps and 1.5 Mbps for download and upload [23-25]. According to Figure 4, the lowest Skype download and upload speeds are in SESC Selangor, but they are faster than the suggestion above, which is 18.73 Mbps (download) and 15.94 Mbps (upload). In contrast, Google's website and other sources do not provide detailed information about the minimum internet speed required for CRD applications.

According to the results of the 25 hearing test sessions, the majority of audio quality levels for Skype applications (n = 18, 72%) and visuals for CRD applications (n = 25, 100%) and CCTV applications (n = 22, 88%) are good, indicating that the application did not encounter any interference during the teleaudiology service (Figure 5). Additionally, for Skype, CRD, and CCTV applications, a relationship between internet speed and audio-visual quality was examined. Pearson coefficient correlation study found a positive relationship between upload speed and Skype audio quality [$r = 0.53$, $p<0.05$], as well as a positive relationship between upload speed and CCTV visual quality [$r = 0.41$, $p<0.05$]. Additionally, there was a substantial inverse relationship between the quality of Skype audio and the ping speed data [$r = 0.65$, $p<0.05$]. Meanwhile, Skype's visual quality is unrelated to the internet connection speed.

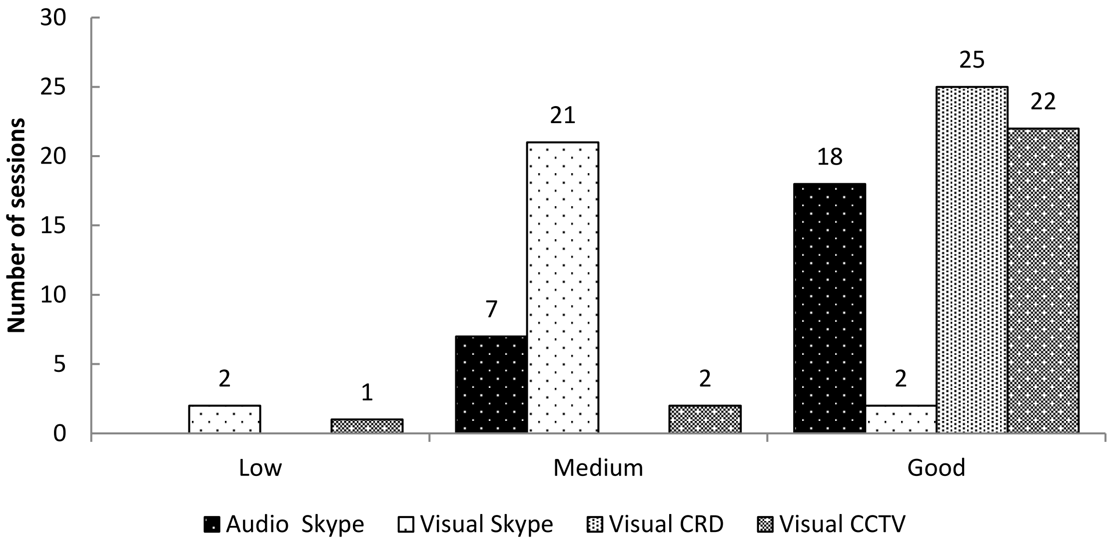

Fig. 5. Audio-visual quality for Skype, Chrome Remote Desktop (CRD) and CCTV

Most teleaudiology sessions undertaken have excellent audio-visual quality, except the Skype application, which has a moderate level of visual quality. The camera resolution value, the high-definition video support system, and the internet connection are all elements that affect the quality of Skype video chats over the phone [26]. The Samsung Galaxy Tab A tablet and the YES Altitude smartphone both meet the Skype system requirements. As a result, one aspect that may have a mild effect on the quality of video calls is the internet connection. Although the researchers' internet speed measurements satisfied the criteria stated by Microsoft and Courtney [24,26], there may be other variables affecting internet speed. For example, Kurosaki *et al.,* [27] and Zhang *et al.,* [28] discovered that the 'packet loss rate' and 'round trip duration' of the internet network affected the quality of Skype. Additionally, De Cicco, Mascolo, and Palmisano said that most Skype video calls do not offer the highest video quality possible within the limitations of the internet network [23]. Nonetheless, a full analysis of this topic was not undertaken in this study; however, it may be conducted by researchers in the field of ICT.

4. Conclusions and Suggestions

Teleaudiology services have been built efficiently by the partnership between UKM and the Malaysia Ministry of Education, specifically SESC. This achievement is due to two key factors. To begin, UKM audiology equipment placed at SESC Selangor can be operated remotely over an internet connection. The second factor is that the ICT infrastructures at UKM and SESC Selangor meet the fundamental standards stated by past studies. This is because the quality of the audio-visual signal, the principal mode of communication, is affected by the reliability of the internet connection.

Due to the global epidemic of COVID-19, ICT advancements and the teleaudiology method have recently gained popularity not only in healthcare sectors but for the teaching and learning process [30]. For instance, numerous accessible applications incorporate two-way communication and applications that enable remote computer control. As a result, the tester (audiologist) may communicate and conduct hearing evaluations using a single application. In conclusion, the teleaudiology approach may succeed with great teamwork and collaboration between two institutions. This approach may be applied to connect other SESCs in Malaysia that lack educational audiologists.

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