ORIGINAL ARTICLE

A novel computer-based simulated learning environment in audiology with learning assistance: Preliminary findings

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ABSTRACT

Introduction: This paper describes the development and the evaluation of a new Two-dimensional (2D) computer-based (CB) Simulated Learning Environment (SLE) software for routine audiology tests that comes with learning assistance for audiology students. The aim of the study was to serve as preliminary evaluation on the effectiveness of the new 2D CB SLE audiology software among audiology students.

Materials and Methods: The development process of the new 2D CB SLE includes, (i) the identification of common errors made by students in the audiology clinic, (ii) the development of five case simulations that include four routine audiology tests incorporating learning assistance derived from the errors commonly made by audiology students and, (iii) the development of 2D CB SLE from a technical perspective. A preliminary evaluation of the use of the 2D CB SLE software was conducted among twenty-six second-year undergraduate audiology students.

Results: The pre-analysis evaluation of the new 2D CB SLE showed that the majority of the students perceived the new 2D CB SLE software as realistic and helpful for them in achieving the course learning outcomes and in improving their clinical skills. The mean overall scores among the twenty-six students using the self-reported questionnaire were significantly higher when using the 2D CB SLE software than with the existing software typically used in their SLE training.

Conclusions: This new 2D CB SLE software has the potential for use by audiology students for enhancing their learning.

KEY WORDS:
simulation, audiology, simulation training, medical education

INTRODUCTION

The Simulated Learning Environment (SLE) has been recognised as one of the training tools in audiology by many institutions worldwide offering audiology programs.[1,2] There is some evidence supporting the use of SLE in audiology with several types of SLE training tools being described in the literature.[1-6] Despite the potential use of these SLE training tools, there are some limitations highlighted by Dzulkarnain et al.[7] that need to be further addressed. One of the significant features necessary in SLE audiology training is the inclusion of an on-going feedback or "learning assistance" to rectify clinical errors made by the student whilst handling an audiology clinical case. On the other hand, there are few studies in medicine and nursing that reported the use of various SLE training tools with on-going feedback; this technique was reported to be able to enhance student clinical skills more than the SLE training without a proper feedback.[8,9]

Some of the SLE training modules reported in the audiology literature do include a feedback component; however, the feedback component is limited to only a "decision-making skill" (cognitive domain), but not the student clinical skill (psychomotor learning task).[3,7,10] In addition, the nature of the feedback given previously is summative in nature, being given at the end of the session instead of immediately when the errors are first been found.[6,10] While both types of feedback are essential, continuous feedback will help the students to note their mistakes immediately and thus motivate them to move further on with their learning. Both summative and continuous feedback can be delivered during the SLE training by the instructor. However, feedback given by an instructor may not be quite so effective for intensive SLE training that requires deliberate practice and for the SLE training that requires the student to perform the training themselves (self-learning) whilst not being in a classroom setting.

In this paper, we describe the development and the preliminary evaluation of a new self-training two-dimensional (2D) computer-based (CB) SLE for routine audiology tests (otoscopy examination, pure tone audiometry, tympanometry and acoustic reflex) that includes an on-going feedback or prompting specifically for second-year undergraduate audiology students who are yet to enter their clinical placements. Given the limited knowledge on the use of SLE in audiology in general and the limited knowledge and tools for SLE training with a learning assistance to the audiology student, the development of such a software module is warranted.

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MATERIALS AND METHODS

The development of the 2D CB SLE for audiology

Figure 1 summarises the development of the 2D CB SLE for audiology students. Prior to the development of the new 2D CB SLE, one systematic and narrative reviews were carried out to identify the common features of the existing SLE software in the literature (Phase one).[1,7] The development of the new 2D CB SLE involves the identification of errors made by the audiology students (Phase two), the development of five case simulations by the researchers that include step-by step instructions by the audiology researchers to conduct all the routine audiology tests (Phase three) and, the technical production of the 2D CB SLE software by an expert on the software development (based on the step-by step instructions) (Phase four). In the last phase (Phase five), the 2D CB SLE was evaluated by measuring its effectiveness among audiology students.

Phase two: Identifications of prompting from errors made by the students

To develop a feedback module in a CB SLE, a study to understand the typical errors made by clinical audiology students has been carried out.[11] In this study, we reviewed the International Islamic University Malaysia (IIUM) audiology clinic protocol and audiology clinical rubric to identify statements that highlighted any potential clinical errors made by the students. The information from the review was used as the framework to develop a questionnaire to identify common errors made by audiology students in their clinical placements. The newly-developed questionnaire achieved the acceptable limit for the content validation index (CVI) with excellent internal consistency, suggesting the information presented on the audiology students' common errors in the questionnaire were valid and reliable. Using the identified common errors from the input of this questionnaire, the researchers developed a 2D CB SLE module with different levels of prompting/feedbacks. Specifically, when using this software, the software would, (i) identify the errors made by the students and, (ii) provide prompts for the students to correct their mistakes. If the students continued to make such errors after a few promptings have been given, the software would automatically inform the student of the correct procedure.

Phase three: Development of five case simulations

The researcher selected five real cases that had complete routine audiological test batteries. These included a complete background case history, otoscopy examination, pure tone audiometry with a complete audiogram, acoustic reflex and tympanometry test results. Details on each of the procedures (for example, seeking for hearing thresholds) were developed to serve as a guideline for the 2D CB SLE software development by the programmer. All five cases were real-adult cases based on different patient concerns, such as complaints on ear discharges, difficulty in hearing background noise or severe tinnitus. The audiograms were varied across five simulation cases ranging from the cases with bilateral or unilateral loss, different degrees of hearing loss and different types of hearing loss. The cases were selected and vetted by three audiology instructors, including the first, second and sixth authors. These five simulation cases selected by the instructors met the learning outcomes for second-year audiology students, in which the cases cover only basic hearing and balance disorders. Complex cases, for example, auditory neuropathy and complex audiological assessments procedures; for instance, cases, with complex audiometry masking that might consist of a "masking dilemma", were excluded.

Phase four: Development of the new 2D CB SLE software

The technical development of the audiology CB SLE involved two stages. In the first stage, the programmer gathered the data from the cases developed by the audiology researchers. The programmer then identified the appropriate model to design the 2D audiology simulation. In this stage, the programmer explicitly analysed the existing SLE (commercial) software for the development of the new model of the 2D CB SLE that consisted of learning assistance. The programmer studied the existing SLE interfaces and process flows to adapt them into the new model of the 2D CB SLE software.

Based on the first stage, the training flows and task interactivity were then finalised. The second stage involved the programmer designing the user interface and interaction with the system. Any sketch storyboard pertaining to the simulation was converted to an image in the 'png' format. The materials and images stream of the digital transformation was then processed using Adobe Photoshop CS. The 2D images were mapped to the tasks, and the participants in the simulation were immersed in an as-real-a-life-training-experience as possible. The interfaces were sketched and designed in 2D contents through C# programming; this included user interactions, event handler flows and the user interface elements (message box, instruction tab, buttons). The interface would allow the student to later perform learning tasks and activities. The 2D CB SLE simulation flow allows the user to manage the instructable tasks using the drag-and-drop method to perform interactions with the contents. The programmer then formulates the interaction techniques and reconstructs any issues with the usability. In general, the 2D CB SLE allows and generates sets of random clinical cases (5 cases). The system then converts the process and algorithm into a simulation using C# programming.

New 2D CB SLE for audiology training features

In general, the new 2D CB SLE has similar features to the basic audiometry SLE software available commercially (and reported in the literature), for example, the *Parrot Audiology software*.[10] The SLE for basic audiometry typically includes an otoscopic examination, tympanometry, acoustic reflex and pure tone audiometry tests. Unlike, the commercialised software, the new 2D CB SLE comes with a few additional features that include, the continuous feedback from the system throughout the training, and some opportunity for the simulation of the physical clinical skills training for all of the above tests that include otoscope handling, probe placement for acoustic reflex and headphone placement for pure tone audiometry. Figure 2 shows the interface for our new 2D CB SLE. The example of the continuous feedback provided by the system for each routine test is summarised in the next sections.

Otoscopic examination
One of the examples of the feedback provided in the otoscopic examination test is the selection of the otoscope speculum. There are four speculum choices given, as shown in Figure 3 (upper left (A)). If the student selects the wrong speculum, the system will provide a prompt by stating "select the correct speculum size". The student will then be given the opportunity to try other speculums, until the system mentions the "appropriate size".

Tympanometry
One of the examples of the feedback provided in the tympanometry test is the selection of the probe tip. There are eight probe tips choices given, as shown in Figure 3 (upper right (B)). If the student wrongly selects the proper rubber tip, the system will promptly "leak". The student will then be given the opportunity to try other speculums until the system mentions "appropriate size".

Acoustic Reflex
One of the examples of the feedback given in the acoustic reflex test is the intensity selection during the test. If, for example, the student forgets to check the growth of the compliance in the acoustic reflex testing (by increasing the intensity by 5 dB from the last level at which the previous reflex has been observed), the system will prompt by stating "check your intensity level". This is illustrated in Figure 3 (lower left (C)).

Pure Tone Audiometry
One of the examples of the feedback given by the new 2D CB SLE for pure tone audiometry is in prompting the students if they are not be able to present the correct masker and tone levels whilst carrying out the audiometry masking procedure. If the student is unable to select the correct intensity for both the masker and tone, the system will prompt "check the intensity and masker level". If student is unable to select the level appropriately after two trials, the system will show the correct answer, as summarized in Figure 3 (lower right (D)).

Phase five: Preliminary evaluation on the effectiveness of the new 2D CB SLE software
Once the 2D CB SLE software was developed and fully reviewed by the researcher, the software was piloted among twenty-six undergraduate audiology second-year students who had yet to enter a clinical placement. The students had learned the fundamental courses of hearing science, the basic courses about routine audiology testing (that include basic audiometry) and were in the process of learning the advanced course for audiology testing, called the Advanced Techniques in Audiology. The students were all asked to perform the five simulation cases with the new 2D CB SLE software. As a requirement for the advance techniques in the audiology course, the students were also requested to perform five simulation cases from a commercialised software (the Parrot Software, audiology clinic with generator, version 2.1). The cases had been pre-determined by the researcher to be equivalent in their levels of difficulty with those cases from the new 2D CB SLE software. Parrot Software was chosen as the standard commercialised software for further comparisons with the new 2D CB SLE, because it is the only simulation software that is available commercially and that has received positive feedback among audiology students in the literature[10] (this, to the authors' knowledge). Students were not informed of the details of each software (the new 2D CB SLE or the commercialized software) and the software were labelled as software one and two.

Prior to the training, all students were given a demonstration and tutorial on how to operate both the new 2D CB SLE and the existing commercialized software. Students had not been exposed to either software prior to the study by any of the researchers or instructors in any of their audiology courses. The software is a self-learning package, in which the student can complete the cases in the software without the presence of an instructor. The students were asked to install the software into their personal laptops. Students were given two weeks to complete all ten cases (five cases for each software). The students worked individually in completing the cases. At the end of the training, they were asked in a questionnaire to demonstrate their understanding and their perception when using both the new and the existing SLE software. The questionnaire consisted of 31 questions in a series of statements using a four-points Likert-type rating scale (0=totally disagree to 3=totally agree) to rate their perception of the usage of both types of software in the several aspects relating to their clinical training. The questionnaire consisted of five domains that included (i) interface and design, (ii) usage and technicality, (iii) how the software helps them to improve their clinical skills, (iv) how the SLE software helps them to achieve the course learning outcome and, (v) how the use of the software increased their motivation to learn. This questionnaire had undergone content validation among five experienced audiology clinical preceptors prior to this study. Each item in the questionnaire CVI, the overall scale of the CVI and the universal agreement among the experts had more than the acceptable 0.8 cut-off limit. This questionnaire has an excellent overall internal consistency (overall Cronbach Alpha= 0.98) and an acceptable convergent and divergent validity.[12]

The mean overall score differences between the student's perception of learning usage between the new 2D CB SLE and the commercialized Parrot Software was compared statistically, using a paired-t test at the 95% confidence level.

RESULTS
This section reveals the result from phase five mentioned in the methodology section. The mean score differences in the student's perceptions when using the new SLE software and the commercialized SLE software were compared using a paired-t test at the 95% confidence level. The analysis showed a significantly higher ($p<0.001$) mean score in student perceptions when using the new 2D CB SLE software (Mean=2.25, standard deviations=0.48) than the existing commercialized SLE software (Mean=1.41, standard deviations=0.50).

Figure 4 summarised the student perceptions of the questionnaire from the five domains (percentage average of agreement across the items in each domain). Overall, more than 90% of the students agreed that (i) the new 2D CB SLE software interface was easily navigated and student-friendly,

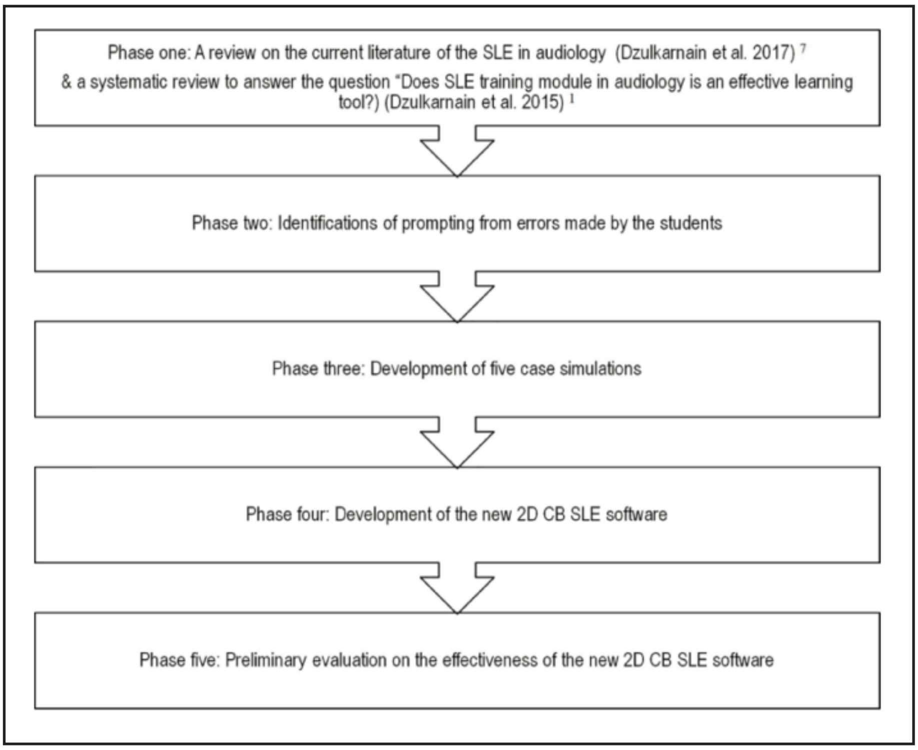

Fig. 1: Summary on the development of the new 2D CB SLE.

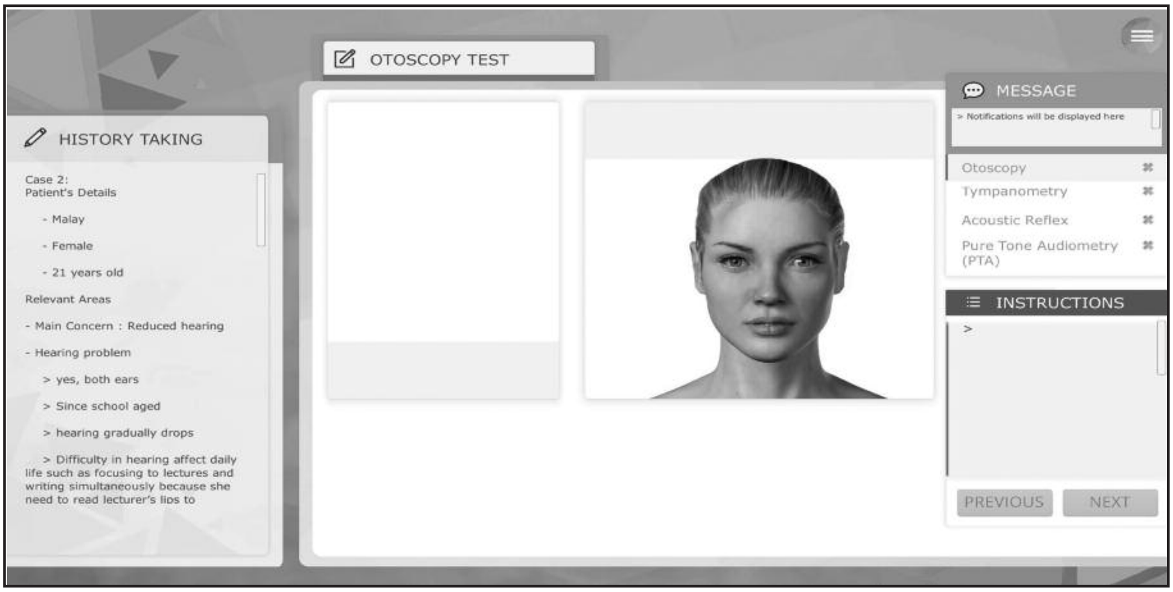

Fig. 2: User interface of new 2D CB SLE. Message box will display the prompts given to the student.

(ii) the 2D CB SLE software is realistic and provides sufficient guidelines for the student to explore and, (iii) the 2D CB SLE was able to assist them in achieving the learning outcome for the *advanced techniques in the audiology* course. Of the students, 87.32% agreed that the 2D CB SLE software could assist them in improving their clinical skills and 75.64% of the students agreed that the software provided encouragement to the students and motivated them to continue using the software. On the other hand, the perception of the students using the existing commercialized SLE software was relatively low in all of the five domains assessed. Only 48.08 to 67.31% of the students agreed with the positive statements in all of the items of the questionnaire for all of the five domains.

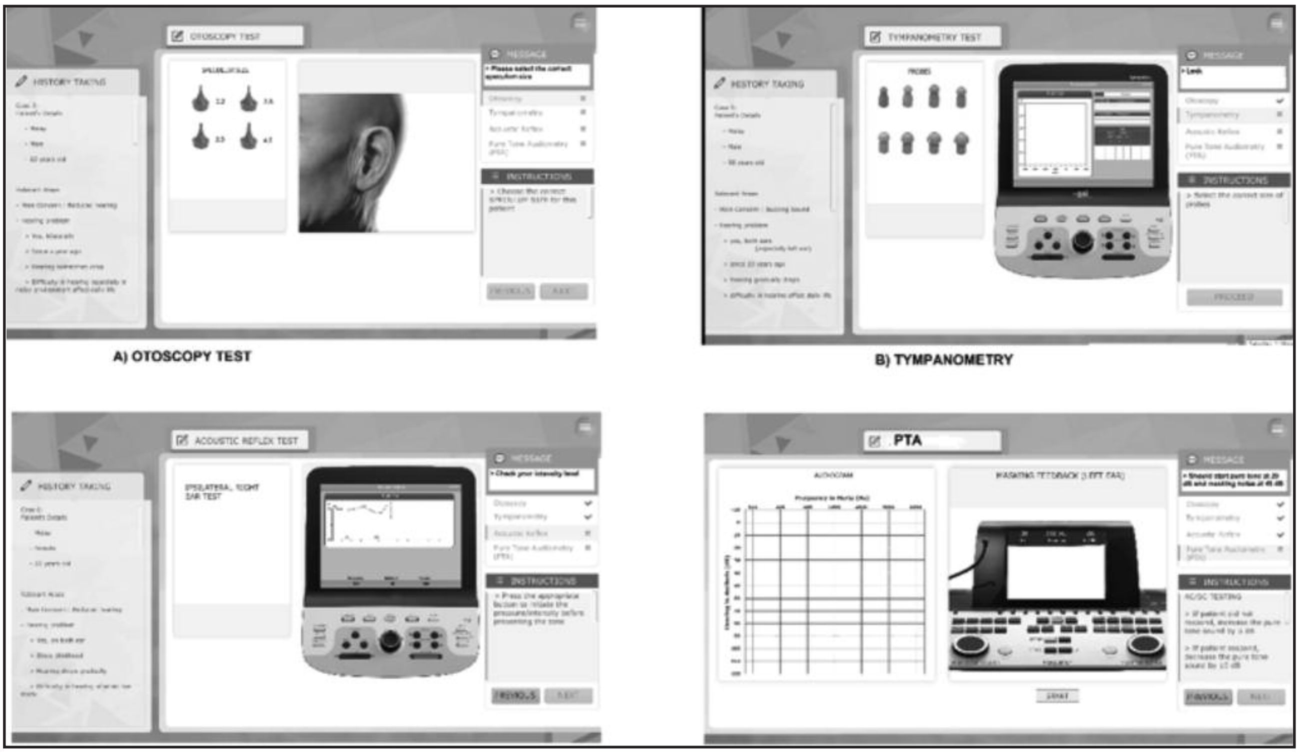

Fig. 3: Upper left (A): Student need to choose the correct speculum based on the ear canal size for otoscopic examination
Upper right (B): Student need to choose a correct probe size; a small probe size may cause the system to prompt 'leak'
Lower left (C): The 2D CB SLE will monitor the correct intensity level sequence for acoustic reflex testing as shown in the figure.
Lower right (D): Inappropriate initial intensity or masker level will trigger the system to provide prompt

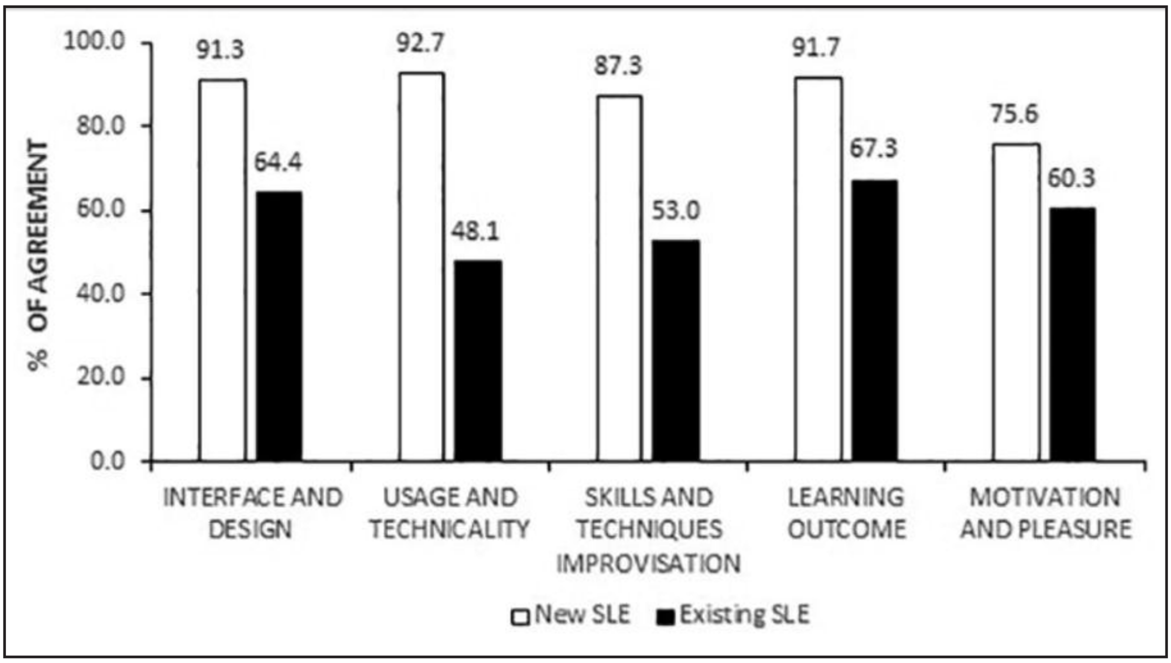

Fig. 4: Percentage of agreement (%) from the questionnaire for both types of SLEs.

DISCUSSION

The present study discusses the development of a new 2D CB SLE software for audiology that includes a learning assistance module to resolve the limitations in the majority of the existing SLE software that has been reported in the literature.[1,7] To ensure that the new 2D CB SLE software does help the student in conducting their clinical assessments, the present study evaluated the efficacy of using this new 2D CB SLE in a group of audiology students (N=26) in addition to their standard training in using a commercialised SLE software. As highlighted, the general student perception was positive when using the newly SLE software as compared to their standard training using the existing commercialized SLE software. This finding suggests great potential in the use of the new 2D CB SLE software with learning assistance to enhance student learning, particularly for the student who is yet to enter clinical placement. This positive finding was consistent with other types of SLE training that incorporated a feedback module in the fields of medicine and nursing.[8,9] Further investigations in a larger group of students are needed to validate this notion. In addition, further investigation is also needed to understand the perceptions of the audiology instructors (experts) when using this software to train audiology students prior to their clinical placement.

The questionnaire items covered the evaluations for any models of the CB SLE audiology software used for routine audiology assessments. The findings from the present study indirectly highlight the weakness of the existing CB SLE software that had been used. Wilson, et al.[10] investigated the use of a commercially available SLE software together with a training case history via a simulated patient. In contrast to the present study, Wilson, et al.[10] audiology students reported a positive feedback when dealing with the CB SLE training. The poor student perception when using the existing software could not be generalised with other types of CB SLE software or other versions of the existing commercially available software, because this present study did not explore the use of various types of SLE software.

The findings from the present study are limited to only the new 2D CB SLE and/or Parrot Software (commercially available software) and do not reflect on the whole SLE training in audiology or other commercially available or research SLE softwares. The evaluation of the SLE in the present study is also limited to the IIUM second-year audiology student (pre-clinical student) and therefore, caution must be taken before applying the study conclusion to other populations. It is also acknowledged that the training of the new 2D CB and commercially available SLEs software was conducted over a two-week period without fixed training durations of a fully-controlled experiment. There is the possibility that some students might use the software more frequently than the others, therefore creating a potential bias towards this study's conclusion.

CONCLUSION

This paper has described a new 2D CB SLE software (with learning assistance) that is intended to assist students in learning routine audiology testing prior to their actual clinical training. The present study has shown the potential of this 2D SLE software as a learning tool to assist the audiology student, when compared to the existing commercially available software used as part of the SLE training.

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