Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students

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A Dissertation Submitted in Part of Fulfilment of the

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University of Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING, MANASAGANGOTHRI,

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CERTIFICATE

This is to certify that this dissertation entitled **"Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science **(Audiology)** of the student with Registration Number **P01II24S023035**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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8th June, 2026

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CERTIFICATE

This is to certify that this dissertation entitled " **Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students** " has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled " **Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students** " is the result of my own study under the guidance of Ms. Nirupama S, Assistant Professor of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysuru
June, 2026

Registration no. P01II24S023035

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If life were predictable it would cease to be life and be without flavour."

— Eleanor Roosevelt

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ABSTRACT

Introduction:

Auditory Brainstem Response (ABR) is an essential objective electrophysiological test used in audiology to evaluate the integrity of the auditory pathway and to estimate hearing sensitivity. The complex and technical nature of ABR procedures often poses difficulties for undergraduate audiology students in understanding waveform interpretation, recording procedures, and clinical applications, despite its clinical importance. Higher-order analytical and clinical reasoning skills may not be adequately supported by traditional teaching methods. Interactive e-learning approaches based on principles of multimedia learning may enhance understanding, engagement, and retention of knowledge.

Aim: The study aim was to create a valid e-learning module on advanced ABR topics and to determine whether this module will improve the knowledge and clinical reasoning skills of undergraduate audiology students

Objective: The objective of the present study was to develop and validate an interactive e-learning module on advanced ABR concepts and to assess the effectiveness of the module in improving knowledge and clinical reasoning abilities of the undergraduate audiology students.

Method: The study used a quasi-experimental pre-test-post-test design. A total of 30 undergraduate audiology students participated in the study and five expert audiologists assessed the content validity of the module and assessment tool. The e-learning module consisted of four units: neuroanatomy and physiology of ABR generators, recording protocols, factors affecting ABR waveform, and clinical applications. Knowledge assessment tool (50 items) was given pre and post intervention. Usability of the module was evaluated

using the System Usability Scale (SUS). Statistical analysis was done using the Wilcoxon Signed-Rank Test.

Results : The module had a satisfactory content validity with Scale Level Content Validity Index values ranging from 0.9 to 1.0. The post-test scores were significantly higher than the pre-test scores ($p < 0.05$), indicating improvement in knowledge and clinical reasoning skills. The mean SUS score of 76.41 indicated good usability and positive learner experience.

Conclusion: The developed e-learning module is valid, effective, and user-friendly to improve ABR-related knowledge and clinical reasoning of undergraduate audiology students.

CHAPTER I

INTRODUCTION

The Auditory Brainstem Response (ABR) is an objective electrophysiological assessment that quantifies electrical activity along the auditory pathway, from the auditory nerve to the brainstem, in reaction to auditory stimuli. It was first used in clinical audiology by Jewett et al. (1970) and subsequently adopted clinically in the 1970s and has since become a key part of hearing tests, especially for individuals who are unable to undergo conventional behavioural audiometric assessments (Hall, 2007)

Auditory brainstem response (ABR) is an electrophysiological measure used for the assessment of hearing sensitivity as well as for the differential diagnosis of auditory disorders. It has gained considerable popularity in screening programs and in the estimation of hearing thresholds, particularly in difficult-to-test populations such as young children, as it does not require voluntary cooperation and is not significantly affected by the subject's state. ABR is also widely used for newborn hearing screening and forms an essential component of universal hearing screening programs implemented in many countries(Galambos & Hecox, 1978); Galambos et al., 1982, 1984; Alberti et al., 1983; Alberti et al., 1985; Hyde et al., 1991; Sininger & Abdala, 1996; Mason & Hermann, 1998; Mehl & Thomson, 1998; Hyde et al., 1998; Norton et al., 2000). However, despite its widespread acceptance as an objective measure of hearing sensitivity, conventional ABR is often limited by the relatively long time required for testing (Northern & Downs, 1991).

Electrodes are placed on the scalp, typically at the vertex or forehead, and near the ears at the mastoids or earlobes. Then, earphones deliver brief clicks, and surface electrodes on the scalp record the neural potentials that follow. These signals are extremely small, typically in the microvolt ranges, so to get a clear reading, the system averages hundreds or thousands of presentations of each stimulus. (Norrix & Velenovsky, 2014)

The ABR waveform typically consists of five to seven positive peaks occurring within the first 10 ms following stimulus onset that have a range of 1ms between each and are termed as Wave I to VII. Each peak corresponds to activity within the auditory pathway e.g. Wave I refers to activity of the distal auditory nerve, Wave III is associated with activity of the superior olivary complex, and Wave V is thought to originate from activity of the lateral lemniscus or inferior colliculus. The timing of the waveform, the interval between peaks, and amplitude of the peaks is observed and used for interpretation of results. (Jacobson et al. 2007).

A delay in latencies and the absence of one or more waves indicate a pathological process; for instance, diseases that involve the integrity of neural conduction such as vestibular schwannomas will prolong the inter-peak interval. Neural desynchronization of the later peaks due to pathology such as auditory neuropathy can result in the absence of or delay of the later peaks. (Eggermont, 2019)

The learning of auditory brainstem response (ABR) is fundamental to audiology students, providing them with a technique for objective measurement of auditory pathway integrity, especially among those who are unable to tolerate conventional audiometry. ABR is paramount in diagnosis of hearing loss, acoustic and cerebellopontine angle tumours. Furthermore, as screening guidelines for newborn hearing assessment become evermore important, understanding ABR will enable audiologists to identify hearing sensitivity thresholds efficiently and intervene at an early stage. (Young et al. 2021)

Understanding auditory brainstem response (ABR) is critical for audiology students. It provides them with a tool to objectively measure the functional integrity of the auditory pathway, particularly for patients unable to cooperate with standard audiometry. ABR testing is vital in the diagnosis of hearing loss, acoustic tumors, and cerebellopontine angle tumors. As the prevalence of newborn hearing screening programs continues to rise, familiarity with ABR will allow audiologists to determine hearing sensitivity thresholds efficiently and to initiate appropriate intervention for congenital hearing impairment at an early age. (Young et al. 2021)

The understanding of Auditory Brainstem Response (ABR) is important for audiology students, as it gives them the ability to assess the functional integrity of the auditory system, especially the central nervous system. Moreover, it helps in diagnosing the hearing loss, acoustic tumours and Cerebellopontine Angle Tumours. With the growing significance of Newborn hearing screening program, knowing about ABR assists audiologists to screen infants at early stage for hearing loss sensitivity, thus facilitating timely rehabilitation and intervention for this patient population. (Polonenko & Brown, 2019).

It is important for audiology students to understand the Auditory Brainstem Response (ABR) because this test provides important objective information on the functional capacity of the auditory pathway, from the auditory nerve up to the brainstem . As an electrophysiological test, it is not subjective and provides meaningful diagnostic information when evaluating patients unable or unwilling to participate in behavioural audiometric testing. Furthermore, understanding of ABR aids in the differential diagnosis of sensorineural hearing loss, retro cochlear pathology such as vestibular schwannomas and acoustic neuromas, as well as central auditory processing disorders (Guo et al. 2015).

High-quality instructional materials in Auditory Brainstem Response (ABR) are crucial because they facilitate learning, improve the interpretation of electrophysiological data, assist in clinical diagnostics and eventually better patient outcomes for hearing loss. (Erra et al. 2025).

E-learning represents a paradigm shift; it provides the solution to various complexities through interactivity, simulation, and accessible standard content. According to the constructivist learning theory, learners construct their knowledge from experiences and an e-module offers simulated experiences, which will provide a learning by doing experience. The objective of this dissertation is to present a detailed study on systematic design and rigorous testing of a holistic e-module that targets complex learning components of ABR. It aims not just at an online learning module but rather an evidence-based E-learning technology aimed at increasing cognitive integration, clinical reasoning and, consequently, the clinical proficiency of the future audiologists to have diagnostic decision-making in a risk-free simulated environment. It bridges the gap between theory and practice.

The Auditory Brainstem Response (ABR) is a significant electrophysiological test in audiology that has the potential to reveal a wealth of information about the auditory pathway ranging from the auditory nerve up to the brainstem. Proficiency in performing and interpreting the ABR is therefore a vital component of a clinical audiologist's role and requires comprehensive knowledge of its neurophysiological generators, technical mastery of recording techniques and procedures, understanding of the parameters affecting the waveform and their implications, and knowledge of its clinical application in various populations.

Despite its undeniable importance ABR is generally considered one of the more challenging concepts to be learned by undergraduate audiology students. Traditional pedagogical approaches such as didactic lectures and static textbooks can be inadequate in transmitting the dynamic and multidimensional nature of ABR and students often experience difficulties in:

Visualising the anatomical generators in three dimensional space

Predicting parameters and assessing their effects on ABR waveform

Making clinical judgments based on data.

E-learning offers a unique learning paradigm through interactivity, simulation and standardisation. The constructivist learning theory postulates that the acquisition of knowledge is built on experience and thus an e-module that simulates clinical practice where the student actively constructs knowledge by interacting in tasks (like selecting protocols and viewing results) is highly beneficial. This dissertation proposes to present systematic development and testing of a comprehensive e-module tailored to this purpose and aimed not only at producing an online resource but more importantly at using an evidence based E-learning strategy to enhance the integration of knowledge, clinical reasoning, and ultimately the clinical competence of future audiologists; facilitating accurate diagnostics and bridging the theory–practice gap.

Need for the Study

The availability of high-fidelity, interactive, pedagogically robust e-learning resources in audiology with the aim to educate students on complex cognitive and clinical issues in ABR interpretation remains minimal. The existing resources include recorded lectures, videos and PDFs and are essentially passive learning tools which do not sufficiently enable active learning, critical thinking, and clinical decision making. Further, they often present knowledge in a disconnected and discrete manner, and this further makes it challenging for students to integrate their theoretical knowledge with clinical practice.

This study proposes to address these limitations by developing a structured and integrated e-learning module that aims to enhance learning about ABR at both the theoretical and clinical levels.

1. Integrate theory with practice:

This study suggests and implemented the integration of underlying theory with the simulation of actual clinical ABR testing. This enables learners to effectively implement their knowledge and build a deep understanding of interpreting ABR waveform in a clinical context.

2. Standardise the learning experience:

Differences in training and learning environments can lead to variation in the students' level of experience, in addition to limitations in patients and supervisor availability. This research will contribute a standard learning tool that will provide consistent training experiences, ensuring development of uniform proficiency.

3. A framework for future e-module development:

Beyond ABR, other audiological procedures like the VEMP and ECoG also require expert interpretative skills. The research will aim to provide a pedagogical framework for the development and implementation of learning modules for various audiological procedures using a systematic design and evidence-based approach.

The research intends to improve the existing training by providing interactive learning for the students at the theoretical and practical level which would improve their learning outcomes in audiology.

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Aim of the Study

The study aims to create a valid e-learning module on advanced ABR topics and to determine whether this module will improve the knowledge and clinical reasoning skills of undergraduate audiology students.

Objectives of the study:

1. Development of an Interactive E-Module:

Develop a fully interactive e-learning module divided into four in-depth e-learning units/modules covering:

a) Neuroanatomy & physiology of the ABR generators - establish a good background knowledge;

b) ABR recording procedures & techniques;

c) Factors affecting ABR waveforms and analysis of waveforms; and

d) Clinical application of ABR for diagnosis and intervention-develop an understanding on its usage in the field. The module will be designed to combine theory with interactivity for effective learning.

2. Determination of Content Validity:

Use systematic expert review to ensure both the developed e-module and the knowledge assessment tool are content valid-ensuring that it contains accurate, comprehensive and up to date information for audiology students.

3. Evaluating effectiveness of E-module:

Assess how effectively the e-module improve the students' knowledge by using a pre and post intervention testing comparing the performance of the students before and after use of the e-module.

4. Examine the Usability and perceived learning of the E-Module:

Evaluate the usability, accessibility, and the overall learning experience gained from the e-module as experienced by the students by testing factors like navigation of the module, engagement, clarity of information, and perceived usefulness.

CHAPTER II

REVIEW OF LITERATURE

Auditory brainstem response (ABR) was first described in 1970 (Jewett et al., 1970) and later on in 1978 Galambos & Hecox showed its usefulness in detecting hearing thresholds of infants. Since then, ABR has found wide clinical application as an auditory screening test, which is mostly used for newborn hearing screening in hospitals. ABR have a high degree of sensitivity and specificity for detecting hearing loss. This technique is less affected by non-auditory factors such as noise or sedatives, making them a useful tool for objectively assess hearing sensitivity (Mason & Hermann., 1998).

The major clinical applications of Auditory Brainstem Response (ABR) can be categorized into 3 main areas highlighting their diverse applications and utility. Firstly, ABR are considered the "gold standard" in neonatal hearing screening. It is an objective, non-invasive test that can be performed while a neonate is normally asleep hence does not require active cooperation on the part of the neonate which is advantageous as conventional behavioural audiology is not feasible in newborns. According to a large systematic review of Automated ABR (AABR) in neonatal hearing screening, involving more than 460,000 neonates, the sensitivity of screening test was close to 89% and specificity about 94% indicating it as a highly reliable test for the screening of hearing loss in neonates (Mohamed et al., 2020).

Secondly, estimation of auditory threshold in subjects where behavioural responses are unreliable are well established in ABR recording. This could include infants, young children, mentally retarded subjects or patients who fail to show reliable hearing response due to non-organic hearing loss or malingering. ABR is especially beneficial in providing objective evidence of hearing thresholds in such subjects to guide proper intervention and rehabilitation.

Thirdly, it can be used as a neurodiagnostic test. It can determine retro cochlear pathologies such as lesions in the auditory nerve, auditory pathway or brainstem. This can be tumours like acoustic neuroma, or other neurological diseases such as demyelinating disease (multiple sclerosis). The detection of the lesions is usually based on alterations in the latency or interval between waves of ABR (Habib & Habib, 2018).

ABR is often considered as the gold standard for the objective determination of hearing thresholds in infants and young children and is used routinely for neonatal hearing screening, detection of auditory neuropathy spectrum disorder (ANSD), and identification of retro cochlear pathology (Choudhry et al., 2024; Povolotskiy et al., 2021; Damji et al., 2022; Ying et al., 2019; Rai et al., 2023).

Although ABR recording is an objective test of neural pathway function it is still influenced to some extent by subjectivity as there is requirement of user to establish presence, absence and correct identification of peaks depending on waveform morphology and it becomes subjective particularly with subtle or noisy or abnormal peaks. The discrimination of actual neural potentials from noise and correct interpretation of ABR waves (Waves I to V) are a key element and is influenced by the experience and expertise of the audiologist hence can lead to high inter-observer variability. The use of otoacoustic emissions (OAEs) and tympanometry are advisable along with ABR to help rule out any ambiguity in interpreting ABR, particularly in difficult or problematic cases. A limitation of the ABR technique is that the conventional click-evoked ABR are more specific to the basal regions of the cochlea and hence test predominantly high frequency range. Thus, click-evoked ABRs alone may fail to assess completely audiometric profile particularly if high frequencies are not the only area of impairment. Therefore frequency-specific stimuli such as tone-burst ABR should be used when a precise estimate of low-frequency hearing thresholds is necessary (Norrix & Velenovsky, 2014).

One of the most critical and commonly faced challenge in all Auditory Brainstem Response (ABR) studies is correct identification and labelling of wave components i.e. Wave I to V. This is considered "one of the most challenging issues in ABR" according to Dzulkarnain et al (2014). There are numerous factors affecting the morphology of waves and thus contributing to difficulty in identification: high variability between the normal hearing and impaired hearing population, variability among audiologists or listeners on how to properly label the peaks, presence of physiological (i.e., electrical artifact) and non-physiological (i.e., electrical artifact) noise that may obscure wave detection. Errors in correctly labelling the peaks can lead to misinterpretations and thus wrong diagnosis (Dzulkarnain et al., 2014).

To solve this issue Dzulkarnain and colleagues built ABR simulator as a training aid and testing its effectiveness on audiology undergraduate students. In 2011 Dzulkarnain et al compared simulator based training (SBT) with conventional teaching for ABR waveform peak identification and discovered that both the groups demonstrated improved score after training, however no significant differences was found between conventional and simulator based training overall. Nonetheless on waveform identification for complex or harder case the conventionally trained group scored higher than the simulator based training only group indicating a possible advantage over hard case.

The results of a follow-up study in 2011 on 14 third year students gave insight into effectiveness of different methods when students in manual group and manual & simulator group showed significantly increased score post training while the simulator only group showed only insignificant gain suggesting that the simulator alone might not be sufficient. Finally, 2014 study again showed no significant difference on conventional versus simulator based training on general case but confirmed superiority of conventional training for hard case suggesting traditional teaching is still needed to achieve best possible results (Dzulkarnain et al., 2014).

Another problem is that ABR is an objective test which requires subjective interpretation of objective results; According to Norrix et al. 2018 " although the test is objective, interpretation of the results is subjective" so doctors must make correct display scale setting, reference templates for expected response properties and estimation of signal to noise ratio (Norrix et al. 2018)

Surprisingly, an increase in years of ABR testing experience in 61 Australian practicing audiologists was correlated with large variability and inconsistency, not greater consistency or accuracy of ABR waveform interpretation (Zaitoun et al., 2016). This result is contrary to expectations. It can be attributed to multiple confounding factors in addition to years of experience such as clinical background and exposure to numerous clinical cases with various presentations and varying quality of waveform signals. Such variation can be a challenge for students learning how to evaluate and interpret ABR results; this supports the need for a standardized and consistent training approach. The fact that there is no established linear correlation between years of experience and consistency or accuracy of ABR interpretation indicates the difficulties of ABR waveforms analysis; these are further compounded for audiology students learning how to identify various waveforms and how to accurately conduct tests for the optimal waveform interpretation (Zaitoun et al., 2016)

In the study conducted by Reed et al. (2021) to evaluate the proficiency of graduate audiology students in various tasks involving ABR testing; certain procedures and technical skill areas such as correct skin preparation, anatomical landmark identification for appropriate electrode placement and electrodes mounting in various montage configurations needed practice to achieve the same proficiency level, indicating the fact that these skills need time to learn and gain accuracy and consistence from both theory and practice point of view. Moreover, simulation-based training improved both the accuracy and the time required to complete the tasks but this effect varies among individual students and specific tasks; Some students improve significantly while others still needed more support from instructors; it indicated the necessity of individual teaching with continuous feedback. (Reed et al., 2021)

Similarly, in a survey by Mondul et al. (2025) to a total of 537 audiology students, clinicians and educators; it revealed that both the survey participants and trainers agree that solid neuroscience and Auditory Evoked Potentials background is essential to becoming a knowledgeable audiologist. However, a lot of audiology training programs do not provide neuroscience course and many undergraduate students are not even required to have such background before they enter audiology programs. Consequently, students may begin learning Auditory Brainstem Response (ABR) testing without fully understanding the underlying neural generators, auditory pathways, and physiological mechanisms that produce these waveforms, making it more challenging to learn about the underlying principles and to interpret waveforms appropriately. (Mondul et al., 2025).

This problem was predicted by James Jerger when he said "anyone who is working with auditory brainstem response must be at the same time both an audiologist and a neurophysiologist" (Jerger., 1980).

The Dzulkarnain et al. group also found that simulator-based training alone was not enough for "difficult and tricky" ABR waveforms. Complex cases are easier to learn via face to face, instructor guided training than simulators which means that tricky, difficult to interpret ABR must need guided, individual teaching. (Dzulkarnain et al., 2021).

Jacobson et al (1980) also states that, the latency-intensity function of the Wave V depends on intrinsic factors (age, sex, hearing loss) and extrinsic factors (stimulus parameters, recording condition), all of which must be controlled or accounted for in learning students. Results from general e-learning research indicate a pattern that interactive and technology enhanced learning modules improve knowledge gain considerably in various health professions when examined through pre-post intervention design studies. Such modules may consist of various elements, such as simulation, quizzes, instantaneous feedback, and various types of multimedia to actively engage learners to deeper understandings unlike passive modes of learning.

Showing such examples, a randomized controlled trial performed by Alfieri et al (2012) among Radiation Oncology student shows participants performing significantly better than the control group who were trained using conventional method of learning, with average increase in knowledge score of 17% for those who used the module versus 5% in the conventional group. The difference is obvious and thus the advantage of interactive e-learning can be extended in complex, conceptually dense topics such as audiology and ABR teaching. (Alfieri et al., 2012).

In teaching pathophysiology, an e-learning module yielded comparable results as face to face training between the control and the experimental group in randomized controlled trial with 271 students which shows that e-learning can yield learning outcomes similar to classroom training, specifically in the acquisition of knowledge. Donkin et al (2011) showed that well designed modules with clearly defined objectives, learning structure, and interactivity will contribute towards meaningful learning and knowledge retention. While these results are valuable and supportive of e-learning, the findings from this nursing education context may not be directly applicable to audiology and specialized training such as ABR since ABR requires skills that extend beyond knowledge and into complex interpretation. (Donkin et al., 2011).

Dzulkarnain, Faizah Sapian, W. Wilson, A. Bradley, & S. Jamaluddin. (2012). Development and evaluation of an auditory brainstem response (ABR) simulator for audiology training. International Journal of Audiology, 52(9), 601-608. The module included approximately 250 ABRs from normal and hearing impaired patients and provided immediate feedback on the correct/incorrect identification of ABR peaks.

A. Dzulkarnain, Wan Mahirah Wan Mhd Pandi, W. Wilson, A. Bradley, & Faizah Sapian. (2011). Effectiveness of simulator-based versus combined training in auditory brainstem response interpretation. International Journal of Audiology, 53(12), 885-892. The team performed both simulation based training and instructor guided training in 3rd and 4th year audiology students and their findings indicated that neither approach was better than the other for learning scores overall, however instructor guided teaching was superior for complex/ambiguous waveform interpretation.

A. Dzulkarnain, Wan Mahirah Wan Mhd Pandi, W. Wilson, A. Bradley, & Faizah Sapian. (2014). Effectiveness of simulator-based versus combined training in auditory brainstem response interpretation. International Journal of Audiology, 53(12), 885-892. 14 students showed that manual/combined training groups were better than the simulation-based training group suggesting the value of the instructor was still significant.

A. Dzulkarnain, S. Rahmat, A. Ismail, R. Musa, & M. Badzis. (2015). Development of a 2D computer-based simulated learning environment for audiology education. International Journal of Audiology, 54(7), 475-482. Developed a 2D computer based simulation including all basic audiology tests along with an integrated learning guide, it was tested among 26 audiology students and was deemed favorable among users for clinical skills training.

Dani Tomlin, Patrick Bowers, & Kelley Graydon. (2023). Evaluation of an e-simulation module for paediatric diagnostic audiology training. American Journal of Audiology, 32(2), 456-468. This module focused on paediatric infant diagnostic testing which would have included ABR and results were very similar for learning outcomes between traditional problem-based learning and e-simulation in 108 students. This may be the nearest modern e-learning platform published.

A systematic review published by Alanazi and Nicholson (2023) in the American Journal of Audiology on the usage of simulation in audiology over two decades from 2000 to

2023 reported on a mere 19 studies which were included, revealing that despite a global emphasis on simulation based learning in healthcare, simulation in audiology education appears to be lagging behind that in many other health professions, with very few published studies utilizing it. Their review indicated that simulation in audiology needs to become more robust by implementing successful strategies from more advanced healthcare disciplines with simulation such as medicine, nursing and allied health. They stressed that there should be more collaboration between audiology programs and other health professions to enable the successful implementation of stronger, evidence based simulation in audiology training (Alanazi & Nicholson, 2023)

There was only one scoping review of simulation training on teaching audiology communication and counselling skills and identified just 17 studies that have used these methods in audiology education, published predominantly in the paediatric field and overwhelmingly with the use of standardized patients to simulate real-world scenarios, thus demonstrating a limited focus and scope in content and instructional strategies (Kanji & Watermeyer, 2024).

However, the studies suggested that, through these simulation methods, students are able to get structured, valuable practice in communicating difficult information, counselling patients/families and managing clinical situations; they may not alone be enough to guarantee complete mastery and competence in communication and counselling. The researchers noted that simulation should be used in conjunction with real-life experience, clinical practice and reflective learning to optimise skill development. They suggested the need for a range of training techniques and a more diverse range of simulations be developed and employed in audiology education in the future. In summary, a major challenge in teaching the practical components of audiology education such as communication, counselling and, more specifically in the next topic, auditory electrophysiology may be the limitation of currently available simulation methods. Nevertheless, the few studies using some simulations show good and promising learning results.

As noted in a comment about the work of Kanji and Watermeyer, a range of e-learning modules have also been tested, with some encouraging results. For example, the first study compared a pilot e-simulation module designed for paediatric infant diagnostics with traditional problem based learning, and learning was comparable in both modalities, with students rating the e-learning favourably. (Kanji & Watermeyer, 2024).

The few audiology specific e-learning modules available to date show promise. Tomlin et al (2023) designed and tested an e-simulation for pediatric infant diagnostic testing and compared outcomes between 108 students using the e-simulation with 67 students using problem-based learning. No differences in learning outcomes were found and the students in the e-simulation rated the module positively. (Tomlin et al., 2023)

An earlier study of a web-based audiometry simulator by Lieberth & Martin (2005) in JAAA showed it was successful in teaching basic audiometric testing skills in SLP students and transferable to a real portable audiometer. (Lieberth & Martin, 2005)

Hohenberg et al. (2016) designed an interactive computer module for teaching auditory physiology and tested it on 44 audiology undergrads. The students in the module stated it was very useful for the physics components of audiology. (Hohenberg et al., 2016)

Kruglik et al. (2025 International Journal of Audiology) designed smartphone-accessible audiology modules for primary healthcare workers in Tanzania and found that all trainees had increased skills in ear and hearing care following the module, however students still required physical practice to interpret audiograms and tympanograms. (Kruglik et al., 2025)

Similar results were seen with an intervention by Yarza et al. (2023) who developed a computer-based course on newborn hearing screening for use in rural Philippines and found a 24% improvement in post test scores and high usability ratings despite low resources. (Yarza et al., 2023)

When student feedback on online learning experiences during the COVID-19 pandemic in an audiology program was analysed, it was found that the quality varied between different student levels. Higher degree students, whose academic work is primarily research-oriented and less reliant on practical skills development, were more satisfied with the online format than those at earlier stages in their training (undergraduate and master's degree students), whose programs require substantial hands-on practice and clinical interaction. This is consistent with the premise that e-learning can be effective for teaching theoretical aspects of audiology, such as principles of auditory physiology and diagnostic interpretation, but less so for clinical skills. Consequently, learners at the practical stages of audiology training may face significant learning challenges and inequities in entirely online learning environments. This suggests that while online delivery offers advantages in terms of accessibility, flexibility, and continuity of learning, it may not be sufficient on its own to fully support the acquisition of essential clinical skills in audiology. Thus, blended learning models, combining the benefits of digital and in-person instruction, would be most effective in this context to ensure optimal learning outcomes across all educational levels. (Roghani et al., 2021)

With regard to a lack of training for ABR testing, at an institutional level, South African research has shown poor ABR training for a group of ENT specialists and registrars, who indicated a strong need for further education (Sahli et al., 1999).

Professionally, ABR training was recently described as a literature gap at the text book level, even though a book had been released ten years prior with that intention.

“Atcherson and Stoody's Auditory Electrophysiology: A Clinical Guide (2012) was considered to fill 'a gap in the literature for an up-to-date text and reference on all aspects of auditory evoked potentials.' The book's positioning as a 'gap filler' may be telling, especially considering that more than a decade has passed since its publication.” (Atcherson & Stoody, 2012)

On a population level, ABR testing quality is demonstrably poor. As revealed by one retrospective study in 2024, fully 85% of outside ABR tests did not adequately incorporate tone burst bone conduction and polarity elements, and one third of re-test results led to changes in diagnosis, implying incomplete or faulty original ABR testing. These figures reflect a gap in effective practice of guideline compliant ABR procedures by practicing professionals. (Choudhry et al., 2024)

The lack of standardized assessment mechanisms within audiology programs is another concern regarding the adequacy of the training that students are receiving in specific skills like ABR. The proposal to use standardized patient assessment for audiology programs highlighted that “there are no generally accepted mechanisms for the assessment and the measurement of these proficiencies” among the current curricula. If the programs themselves are unable to assess for mastery, there are potential problems even in recognizing when more ABR training might be needed. (Dinsmore et al., 2013)

Bakhos et al. (2020) compared VR vs. Conventional audiology training with 29 first-year audiology students and found that the students in the VR group scored about 21% higher than those in the traditional group (compared to only a 7% difference in the traditional group). Students in the VR group were more satisfied with their learning, more engaged in the coursework, and more confident in their abilities. This finding of increased confidence, engagement, and performance persisted even when the traditional training group was later taught using VR training, which also brought their scores up to the original VR group's level.

This evidence suggests simulation-based VR may best be used as a complement to conventional teaching rather than a replacement.

The study also indicated the benefits of the VR system in increasing student engagement, better teaching of procedure-based learning, and providing a safer learning environment since students could gain extensive practice without the fear of hurting a patient or causing permanent harm. ABR testing requires exposure to hundreds of waveform patterns, learning how to place the electrodes properly and testing effectively to gain both technical proficiency and knowledge of how to interpret the ABR. It's evident that this mastery will be significantly enhanced through the VR simulations. One also needs to note the shortcomings of conventional teaching, including restricted access to varied cases, limited opportunities to practice skills over and over again (particularly complex interpretation skills like those used in interpreting ABR waveforms) due to limitations in time, equipment, and laboratory space. As a result many audiology students graduate from their programs not well prepared for clinical practice. This also suggests a need for incorporation of additional e-learning and simulation technology into the audiology curriculum (Bakhos et al., 2020).

A recent pilot randomized controlled trial done by Alothman et al. (2026) assessed standardized patients for simulation training versus a traditional case scenario discussion with a sample size of 16 audiology students and discovered that students trained using simulation showed significant improvement in professional competencies, including but not limited to patient-centered communication, empathy, and interpersonal communication. This study is important as it assesses students' ability to use their training in more realistic interactions with standardized patients. Not only does simulation training allow students to gain proficiency in both what to say, but also how to say it. While the vast majority of current research on simulation-based learning and audiology focuses on enhancing technical skills like those taught in ABR testing or ABR waveform interpretation, it is worth noting that this pilot study examined training of interpersonal and communication skills. This research highlights a critical need for further research into the simulation-based training of non-technical clinical skills. One does not gain technical knowledge by practicing their interpretation skills on another student, but rather through continued interaction and discussion with experts. Based on the research found it appears simulation is effective and best used as an enhancement to the traditional curriculum for Auditory Brainstem Response (ABR) testing where there is an extensive amount of procedural knowledge required from learning to place the electrodes correctly to operating equipment and obtaining good readings. Simulation training increases confidence in performing these skills and reduces performance anxiety.

However, in a study by Alothman et al. (2026) students who underwent simulation-based training demonstrated significant improvement in interpersonal and communication skills. This means that as students are still practicing interpreting ABR waveforms the instructors are likely the ones to continue facilitating learning for the non-technical side of the curriculum by presenting a variety of cases and engaging students in discussions. For a blend that consists of simulation-based and traditional instructor-led training for Audiology students it would appear that simulation is best for improving technical and procedural skills while instructor-led training is necessary for the acquisition of critical thinking and cognitive skills like interpretation of ABR waveforms (Alothman et al., 2026).

The literature suggests that the utilization of simulations is highly effective and most well-suited to the technical and procedural aspects of Auditory Brainstem Response (ABR) testing. This method has proven useful for increasing student confidence in tasks like placing electrodes, utilizing test equipment correctly and follow protocols for collecting ABR readings. Despite the benefits of simulations, a barrier for the widespread use of these advanced training modalities remains.

Andre et al. (2021) found that only about 50% of the programs that offer Audiology education utilize some form of simulation training, meaning many programs may be in early stages of its integration. These barriers can include cost and the lack of technology or equipment needed to implement simulation-based learning in programs. (Andre et al., 2021).

In comparison to traditional face-to-face instruction, well-designed on-line learning is generally equivalent to traditional learning and is sometimes slightly more effective. This was seen with students who were taught using interactive rather than passively presented on-line modules. As per a systematic review in health professions George et al. (2014) reported eLearning was equivalent and sometimes better than face-to-face instruction and in another review e-learning participants were scoring on average 5 pts higher than traditional students. However, results were inconsistent in these studies because learning differed between each of the programs in terms of design and learner population, outcome measure and method of evaluation. The evidence presented supports the theory that e-learning is often equal to and sometimes superior to traditional learning in terms of results. must be interpreted cautiously due to the many variations between the studies. (George et al., 2014).

A comprehensive look at these studies reveals that on-line learning is equal to traditional learning based on each learning program, a systematic review done by Voutilainen et al. (2017) who looked at 91 studies showed that the result was approximately even, with 41% reporting that on-line learning was more effective, 41% having no significant difference, and only 18% favouring face-to-face instruction.

The implications that can be drawn from these results indicate that there is not one superior mode of delivery over the other, as the effectiveness of any educational intervention depends on the nature of the topic (whether theoretical or hands on), the quality of instructional design, level of student participation, technological infrastructure and if there is a choice of whether the students preferred face to face, online or blended learning. For example, a stimulating practical component or the real-time application of clinical reasoning skills may require face to face or blended teaching over pure online practices, while knowledge projects could be incorporated online effectively, or even more so. This type of distribution of result emphasizes that format itself is not a primary factors influencing effectiveness, but rather the design, implementation and alignment of learning objectives and educational delivery. (Voutilainen et al., 2017)

What seems to show e-content its most promising attributes are primarily its market flexibility and use as a component of blended learning rather than its use as a pure substitute for traditional instruction. The blended approach-using online resources in conjunction with direct teacher led learning-uses the best of both approaches, the access and efficiency of digital content coupled with the supportive structure of face to face instruction. Supporting this is a study of higher education in the United Kingdom (Al-Qahtani & Higgins, 2013)

Interestingly, this study also showed a result that e-learning by itself did not show significantly different result from face-to-face teaching, thus implying that digitized content on itself doesn't really add value to learning experience. The only added value is in how the new tools are used- for example, to enhance the content taught in class by providing online tutoring, giving more practice opportunities or prepping the student in advanced before the classroom sessions ("flipped classroom" concept), allowing the classroom work to be more focused on higher-level application tasks such as reflection, discussions, formulation of hypotheses etc. Overall, these results demonstrate that e-content is most effective within a blended model with a number of other interventions rather than as a standalone product.

Another meta-analysis of blended learning concluded overall differences compared to traditional face-to-face/school instruction were small and “at best could be slightly positive and slightly negative, respectively." Therefore, similar results were obtained using less classroom time. In some skill-intensive domains, satisfaction with the face-to-face approach still remains superior even when equivalent academic outcomes are attained. (Mller and Mildenberger, 2021)

E-content modules support learning through accessibility, flexibility and interactivity. Although these advantages are often linked to classroom-based teaching, accessibility and flexibility can stand out because of the ability for e-content to give learners immediate access to information at any place at anytime. This overcomes the constraint of locational or time bound disability in set delivery of content. Flexibility is also one of the greatest benefits as customizable pace of learning helps to adapt to the preferred learning scheme of a student and encourage improved performance.

An essential benefit of e-content module is also due to its multimodal and accessibity features. E-modules utilize modalities such as videos, animations, simulations, online quizzes, visual and audio explanations that help learners with diverse cognitive preferences in getting the essence of the knowledge taught by the course. Such multimodal presentation of courses warrants learner activities instead of passive reception of text. Manggala et al. (2021) outlines the several attractives and usefulness of e-modules such as the flexibility of time and accessibility as well as the multisensory interactivity of online sources. (Manggala et al., 2021)

Research has established that the use of e-modules can impact upon key elements of student learning-motivation, depth of learning and critical thinking skills. Due to the interactive/visual nature of e-modules learners are more likely to become actively engaged with course materials and thus more motivated than they might be when confronted with traditional text-based learning materials . Use of clickable quizzes, problem solving exercises and immediate feedback are also associated with increased level of deep learning through improving content processing and facilitating the acquisition of concepts.

Furthermore, e-modules may solicit the learner to comprehend data and make clinical decisions and make use of data in simulated or scenario based. This encourages higher-order thinking, such as applying knowledge. Learners are not merely content with absorbing information but actually constructing it, which is more effective.

Complementing these advantages is the quasi-experimental report by Dewi et al. (2020) who found that the use of e-modules result in significant increase in students' self-efficacy, learning motivation and academic performance. An even more notable finding is that collaborative formats of e-modules-where students work together on shared tasks, and participate in interactive activities through discussion or group problem-solving-are associated with the most dramatic increase in performance, implying that computer-based instruction can work better with appending collaborative learning components, such as idea-bouncing with partner, peer explanation and inductive thinking, which would amplify learning engagement and consolidate knowledge through multiple dialectics. (Dewi et al., 2020)

Meta-analysis within the health professions education literature has provided evidence that digital ways of learning are at least as successful as traditional face to face methods in knowledge acquisition, and for many practical and clinical skills may even be better than face-to-face education. This is an important consideration for workshops and education within training for the great majority of health professions disciplines, such as audiology, medicine and allied health, where skills and clinical reasoning are a critical element of training.

Another reason may be that well-developed digital modules, which include tools such as simulations, case-based learning, and instant feedback, provide learners with a safe space to repeatedly practice skills, improve their decision-making, and gain confidence in their new skills before attempting to practice in real-life clinical environments. Digital modules may also provide the benefit of a standardized learning experience.

This body of research itself demonstrates that well-intergrated e-modules can be as effective and even more so then 'traditional' methods when viewed for select outcomes.

Blended learning allows us to integrate the strengths of traditional and digital learning methods in quite diverse ways, rather then simply replacing one with another. (Dunleavy et al., 2019)

A content module is helpful for three distinct reasons. First, it allows standardisation of student experience with respect to waveform morphology, peak labelling and interpretation, as opposed to purely rely on variable face-to-face presentations. Second, students are given repeated and self-paced learning with respect to ABR interpretation which remains tricky as one misplaced peak leads to misinterpretation. It requires a very high level of clinical experience and knowledge, according to the paper published by the simulator company. Third, it complements and not supplants live instruction (Dzulkarnain et al., 2012). Conventional instruction still had a statistically greater impact on tricky questions which means that an e-module must be developed as a learning companion, not an alternative (Reed et al., 2021).

A necessity to develop an E-content module on ABR stems from its function to simplify this complex diagnostic procedure for audiology students by making it accessible, structured and user-friendly. E-content module benefits are amplified when applied to audiology education by providing a way to learn complex ABR concepts at a self-pace and in a flexible manner, improving understanding and knowledge on interpretation of waveforms and clinical application. It would enhance clinical knowledge through demonstrations and repeated practice beyond that of the live teaching environment, thus bridging any existing knowledge or experience gaps and increasing students' competence and confidence in their ABR assessments.

CHAPTER III

METHOD

3.1 Study Design

The present study was carried out using a quasi-experimental, prospective research plan, it also used a single-group pre-test and post-test approach along with a descriptive component for usability evaluation, and validation. The whole layout seemed suitable because it let the researcher check in a steady way how well the developed e-learning module worked, by looking at changes in participants' knowledge plus clinical reasoning abilities after they were exposed to the intervention. The quasi-experimental approach was chosen over a randomized controlled trial because of logistical , and ethical issues in an academic context. Random assignment of students into intervention and control groups was not really possible, since all students were anticipated to benefit from contact with the educational resource. Also, not allowing access to a potentially helpful learning tool would have created ethical concerns. So, a within-subject comparison strategy was used, meaning each participant functioned as their own comparison point. With the pre-test post-test structure, there was a more direct comparison of starting knowledge levels versus what they showed after the intervention, which helped in spotting knowledge gains that could be linked to the module. In addition, adding a descriptive evaluation element supported a broader check of user experience, perceived usefulness, and day to day practical applicability of the module.

3.2 Study Setting

The study was conducted within a structured academic environment, involving undergraduate audiology students enrolled in an accredited training program. This institutional context ensured that participants had a consistent educational background, and prior exposure to baseline audiology concepts, which in turn strengthened the internal validity of study. In this study, all assessment tools, including pre-test, post-test, and usability evaluations, were performed either in proctored classrooms or via controlled and secure online testing platforms. Standardized conditions, including but not limited to time limitations, instruction procedures, and monitoring techniques, were implemented to reduce any possible bias.

The research was methodically undertaken in three phases as follows:

1. **Phase I:** Development of the e-learning module

2. **Phase II:** Validation

3. **Phase III:** Implementation and Evaluation

3.3 Participants

Participants for this study comprised two distinct groups: An expert panel (Group 1) and undergraduate audiology students (Group 2). These two groups were included to undertake different roles within different phases of the study.

Expert Panel (Group 1)

Five subject matter experts with knowledge of Auditory Brainstem Response (ABR) were recruited to validate the content of the developed e-learning module and the ABR knowledge assessment tool. The subject matter experts were all faculties of AIISH with several years of experience in ABR testing and analysis. Inclusion Criteria for **Experts**

- Minimum of three (3) years of professional experience in Audiology
- Demonstrated expertise in ABR testing and waveform interpretation
- Evidence of involvement in teaching, research or clinical practice
- Willingness and availability to participate and provide informed consent
- Other specialists working with ABR testing and application

- Individuals with a deep understanding of the Auditory Pathway and Brainstem structures involved in ABR generation and ABR test and results interpretation.

Exclusion Criteria for Experts

- Less than three (3) years of professional experience

- Unwillingness or unavailability for the full duration of the validation process

The panel expertise assisted in verifying the scientific accuracy, clinical relevance, and pedagogical suitability of the module's content and assessment item.

Student Participants (Group 2)

Thirty (30) undergraduate audiology students were involved in the implementation and evaluation of the module.

Inclusion Criteria for Student Participants

- Currently enrolled in an undergraduate audiology program

- Having already completed theoretical coursework relating to ABR

- Having a basic understanding of audiological diagnostic procedures

- Willingness to participate voluntarily and provide informed consent

Exclusion Criteria for Student Participants

- Students not having completed ABR-related theoretical coursework

- Students having previously accessed or participated in this e-learning module.

- Individuals unable to commit and unable to provide informed consent

3.4 Sampling Technique

The study used a combination of sampling methods:

Purposive Sampling was used in recruiting the subject matter experts, to ensure that the selected experts possessed the necessary domain specific knowledge and expertise.

Convenience Sampling was employed in recruiting the student sample due to practical limitations regarding access to participants. Convenience sampling can limit generalizability to a wider population, but it is commonly considered acceptable for early educational intervention research, especially when feasibility is a concern.

3.5 Study Design and Procedures

The research was conducted in three sequential phases:

Phase I:

Development of the E-Learning Module Instructional Design Framework A comprehensive approach that integrates relevant educational and instructional design theories guided the development of the e-learning module. The underlying frameworks used included:

Multimedia Learning Principles The instructional designer followed the tenets of Mayer's (2009) Cognitive Theory of Multimedia Learning when designing the module. The module sought to engage learners by presenting both visual and auditory information in an interactive manner, aiming to enhance comprehension and retention and support the development of higher-order cognitive skills such as critical thinking and clinical reasoning.

Description of E-Module Units

Unit 1: Neuroanatomy and Physiology of ABR Generators

The initial unit was developed in response to the perceived challenge learners had in relating a comprehensive understanding of the anatomical and physiological origins of the various ABR waves. Content included visual presentations of the brainstem structures and normative values of the waveforms (Waves I-V) and explicit descriptions of the related neuronal pathways. Interactivity within this module allowed learners to interactively explore anatomical diagrams and gain better spatial comprehension and conceptualization.

Unit 2: **Protocols and Procedures**

Protocols and Procedures for ABR Recording This unit covered the practical aspects of ABR testing and involved:

- Step-by-step guidelines for ABR recording.
- Standardized clinical protocols.
- Modulation of recording parameters such as stimulus intensity, rate and electrode positioning.
- This enabled practical application of theoretical knowledge.

Unit 3: **Factors Affecting ABR Waveform**

This unit gave an intuitive understanding of variables that influence ABR recording:

- Physiological and non-physiological factors that impact waveform morphology
- Interactive sliders were incorporated to allow parameter manipulation
- A library of common artifact responses that plague recording attempts.
- This allowed a more in-depth analytical understanding of changes to the waveform.

Unit 4: Clinical Applications

This unit focused on case-based learning with the intent to encourage real-world clinical reasoning.

Students were expected to:

- Interpret findings of an ABR test
- Evaluate associated clinical findings
- Formulate differential diagnoses.

This integrated theoretical understanding with the acquisition of clinical reasoning skills.

Development Tools :

The e-learning module was developed utilizing:

1. Microsoft Power Point for a structured presentation of information
2. Ani maker to produce animated visual aids and clips
3. Java Script for the inclusion of interactive elements and simulators.

These tools proved beneficial in developing a comprehensive, multimedia e-learning experience.

Development of ABR Knowledge Test

A 50 multiple-choice question ABR knowledge test assessing theoretical knowledge, procedural aspects, and application to clinical practice was designed.

PHASE II:

Validation Content Validation The e-learning module and the knowledge test were validated using a standard validation proforma. Evaluation Criteria Relevance, Accuracy, and Clarity. Scoring Scale A four-point Likert scale was utilized to quantify expert assessment. Expert assessment was used to compute: the Item Level Content Validity Index (I-CVI) for each item; the scale level content validity index (S-CVI) for each tool. An acceptable CVI of 0.78 was achieved.

Phase III:

Implementation and Evaluation Pre Test Assessment Participants completed a 50 item ABR knowledge test to assess baseline knowledge, both theoretical and practical. Intervention Participants explored the e-learning module for two weeks.

Post Test Assessment The participants were retested using the same 50 item ABR knowledge test.

The comparison of pre and post test results revealed the amount of learning acquired during the intervention.

The developed e-learning module is provided in Appendix I for reference and accessibility.

Usability Assessment The participants completed:

The System Usability Scale (SUS) The SUS, a standard, quantified scale that measures the ease of use, learnability, efficiency, and overall satisfaction experienced by the participants.

A feedback questionnaire which provided qualitative feedback regarding perceived clarity, engagement, navigation, and efficacy of the e-learning module. Combined, these tools provided a broad perspective on user experience and perceived efficacy of the module.

Data Collection

The data were collected using the following tools:

ABR knowledge test

System Usability Scale (SUS)

Feedback questionnaire

All tools utilized were developed, checked for validity, and reliability was ensured.

3.6 Ethical considerations:

The study was approved by the Institutional Ethical Committee of the All India Institute of Speech and Hearing (AIISH), Mysuru, and followed the bio-behavioural ethical guidelines outlined by Venkatesan and Basavaraj (2009). All participants were recruited on a voluntary basis. Before data collection, written informed consent was obtained after a detailed explanation of the study's purpose, procedures, and any potential risks.

3.7 Data Analysis

Statistical analysis was completed using IBM SPSS Statistics. Descriptive statistics (mean, standard deviation, frequencies and percentage) were utilized to interpret data such as demographics, pre- and post-test scores, SUS score and CVI values. A Shapiro-Wilk test was employed to determine the normality of the data distribution. As the data were not normally distributed, a Wilcoxon Signed-Rank test was used to determine significant differences in pre- and post-test scores. Correlational analysis was conducted to determine whether usability scores were associated with post-test performance using Spearman correlation Test.

CHAPTER IV

RESULTS

A sample of 30 undergraduate audiology students who had previously studied ABR courses was enrolled in this research in order to determine whether it would be possible to create and validate an e-learning module of advanced ABR concepts and to evaluate any enhancement in the students' knowledge and clinical reasoning ability post module completion, in addition to its usability and clinical relevance.

Descriptive data on participant demographics, module and ABR knowledge assessment tool validation, analysis of the pre-and post- test score comparison, module usability analysis and possible correlation between usability and post-test performance are presented below.

In Section 4.1 presents participants' demographic data with regard to gender, age, year of study and is aimed at presenting the general composition of the student population that took part in this study.

In section 4.2 content validation of the e-learning module and ABR knowledge assessment tool in terms of relevance, accuracy and clarity is established using both expert opinion and evaluation based on expert rating criteria.

In section 4.3 results associated with students' pre-and post- test scores comparison and the role of the e-learning module in improving students' clinical reasoning and theoretical ability regarding advanced ABR principles are analysed and presented.

In Section 4.4 includes the analysis of results relating to how easy the e-learning module was to use via the system usability scale (SUS)

In section 4.5 the study focuses on exploring whether the system usability scale (SUS) had any association with post-test performance among the participants of the study.

In section 4.6 it focuses on descriptive analysis feedback questionnaire.

4.1 Demographic Characteristics of Participants

Thirty undergraduate audiology students who had previously attended a course on ABR were included in this study as participants. The demographic data was determined as follows:

Table 4.1

Distribution of Participants Based on Gender

Gender	Frequency (*n*)	Percentage (%)
Male	6	20
Female	24	80
Total	30	100

The majority of the participants were females.

4.2 Content Validity of the e-learning Module and the Knowledge assessment Tool

The content validity of e-learning module and ABR knowledge test was assessed by the opinions of 5 experienced audiologists(Faculties at AIISH), each with more than 3 years of clinical experience. The material was judged for relevance, accuracy and clarity on a 4 point scale.

Table 4.2

Item-Level Content Validity Index (I-CVI) for the E-Learning Module

Domain	**Relevance I-CVI**	**Accuracy I-CVI**	**Clarity I-CVI**
Neuroanatomy and Physiology of ABR Generators	1.0	1.0	1.0
Protocols and Procedures for ABR Recording	1.0	0.8	0.8

Factors Affecting ABR Waveform	1.0	0.8	0.8
Clinical Applications of ABR	1.0	1.0	1.0

The Item-Level Content Validity Index (I-CVI) values for all domains were above the acceptable criterion of 0.78, indicating satisfactory content validity.

Table 4.3

Scale-Level Content Validity Index (S-CVI)

Instrument	**Relevance S-CVI**	**Accuracy S-CVI**	**Clarity S-CVI**
E-learning Module	1.0	0.9	0.9

The Scale-Level Content Validity Index (S-CVI) values demonstrated excellent agreement among experts regarding the relevance and appropriateness of the module content.

Table 4.4:

Content Validity of ABR Knowledge Assessment Tool- ABR Knowledge Test tool contains total 50-items.

Domain	**Range of I-CVI**
Relevance	0.4-1.0
Accuracy	0.4-1.0
Clarity	0.4-1.0

Initial I-CVI values ranged from 0.40 to 1.00. Items with I-CVI values below the acceptable criterion of 0.78 were revised based on expert suggestions prior to finalization of the assessment tool.

4.3. Comparison of Pre-Test and Post-Test Knowledge Scores

The effectiveness of the e-learning module was evaluated by comparing pre-test and post-test scores obtained by the participants**.**

Table 4.5

Descriptive Statistics for Pre-Test and Post-Test Scores

		Mean	**Median**	**Std. Deviation**	**Minimum**	**Maximum**	**Interquartile Range**
Statistic	ABR-PRE	30.33	31.00	8.707	15	45	14
	ABR-POST	37.93	40.00	8.686	17	49	11
	SUS	76.417	80.000	14.7052	47.5	100.0	20.6

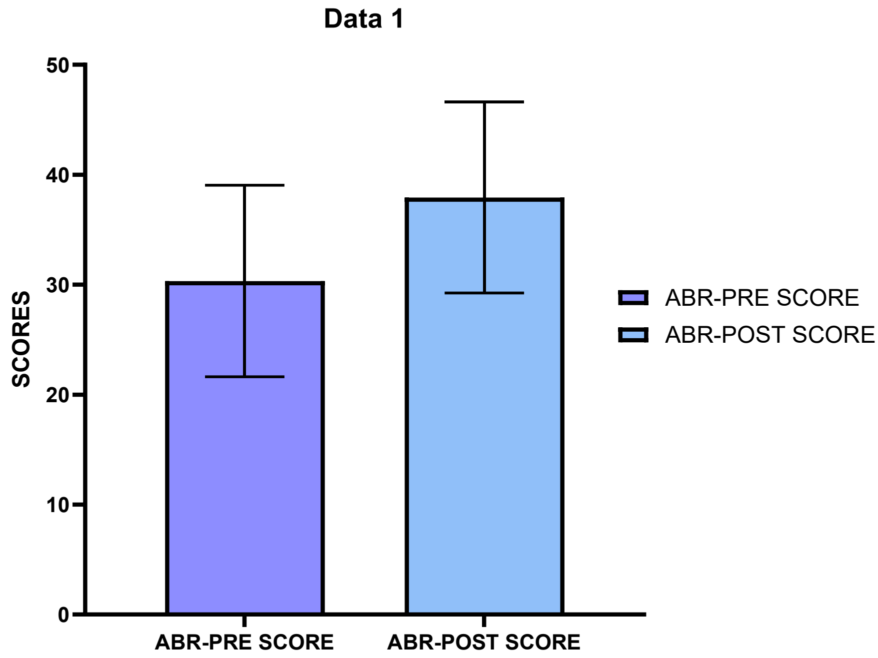

Figure 4.1

Comparison of pre and post ABR scores

The mean post-test score was higher than the mean pre-test score, suggesting improvement in students' knowledge and clinical reasoning abilities following exposure to the e-learning module.

Test of Normality

Normality of the data was assessed using the Shapiro–Wilk test.

Table 4.6

Shapiro–Wilk Test for Pre-Test and Post-Test Scores

	Statistic	df	Sig.
ABR-PRE	.969	30	.524
ABR-POST	.909	30	.014
SUS	.949	30	.164

The Shapiro–Wilk test indicated that ABR-POST scores were non-normally distributed (p = .014), while ABR-PRE scores were normally distributed (p = .524). Given the non-normal distribution of post-test scores, the non-parametric Wilcoxon Signed-Rank Test was employed.

Inferential Analysis

Wilcoxon Signed Rank test was used to compare pre-test and post-test scores.

Table 4.7

Comparison of Pre-Test and Post-Test Scores

Test Statistics	
	ABRPOST - ABRPRE
Z	-3.571b
Asymp. Sig. (2-tailed)	.000

Note. Based on negative ranks.b

The analysis revealed a statistically significant difference between pre-test and post-test scores ($p < 0.05$), indicating that the e-learning module was effective in improving students' understanding of ABR concepts.

Interpretation

The findings suggest that exposure to the e-learning module significantly enhanced participants' theoretical knowledge, analytical abilities, and clinical reasoning skills related to Auditory Brainstem Response testing and interpretation.

4.4 Usability Evaluation of the E-Learning Module

The usability of the developed e-learning module was assessed using the System Usability Scale (SUS) and a structured feedback questionnaire.

Table 4.8

Descriptive Statistics for System Usability Scale (SUS) Scores

	Mean	Median	Std. Deviation	Minimum	Maximum	Interquartile Range
SUS	76.417	80.000	14.7052	47.5	100.0	20.6

The mean SUS score indicated that the module demonstrated **Good** usability with a mean of 76.41**.**

Interpretation of SUS Scores

SUS Score Range	**Interpretation**
> 80	Excellent usability
68–80	Good usability
< 68	Needs improvement

The obtained SUS score suggested that the participants found the module easy to use, accessible, and engaging.

Correlation Between Usability and Post-Test Performance

4.5 Correlation analysis

Correlation analysis was conducted to determine whether usability scores were associated with post-test performance using Spearman correlation Test.

Table 9

Correlation Between SUS Scores and Post-Test Scores

			ABRPOST	SUS
Spearman's rho	ABR-POST	Correlation Coefficient	1.000	.559
		Sig. (2-tailed)	.	.001
		N	30	30

SUS	Correlation Coefficient	.559	1.000
	Sig. (2-tailed)	.001	.

*Note. ** Correlation is significant at the 0.01 level (2-tailed)*

This represents a moderate positive correlation (r = .559, p < .001), suggesting that perceived usability accounted for approximately 31% of the variance in post-test scores**.**

Interpretation

This finding suggests that students who perceived the module as more usable and engaging also tended to demonstrate better learning outcomes**.**

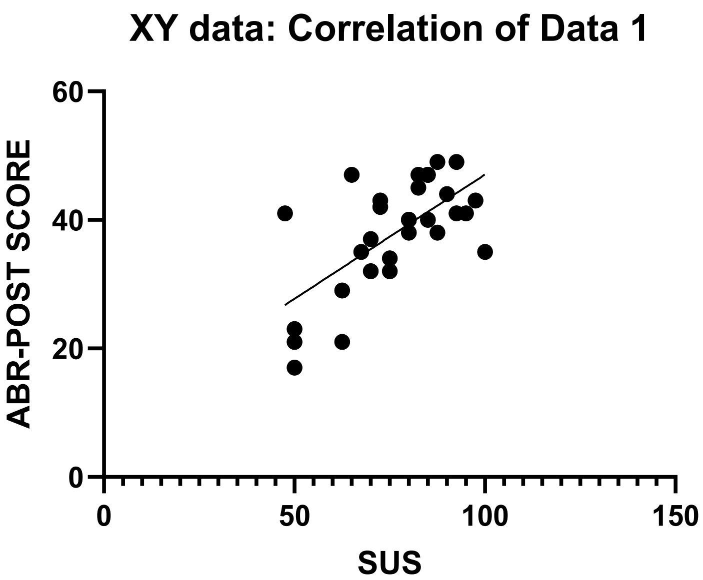

Figure 4.2

Correlation of ABR post score and SUS

4.6 Analysis of Structured Feedback Questionnaire

Descriptive analysis of the structured feedback questionnaire was carried out to understand participants' perceptions regarding the strengths and limitations of the module.

Q1. Most Useful or Engaging Component

Q1 Most useful or engaging			
		Frequency	Percent
Valid	Everything	5	16.7
	Interactive	11	36.7
	Knowledge about ABR	14	46.7
	Total	30	100.0

Most participants identified the interactive tools, animated descriptions and case discussions in clinical scenarios as the most useful aspect of the module. Students welcomed the cases in the module for providing practical examples of how to apply theoretical concepts to clinical interpretation.

Q2. Least Useful or Engaging Component

Q2 Least useful or engaging			
		Frequency	Percent
Valid	Better voice explanation	2	6.7
	No	25	83.3
	Time taking	1	3.3
	Video	2	6.7
	Total	30	100.0

Some participants felt that some areas contained lots of theoretical concepts and could have been shortened in smaller segments for easier learning and had better audio/visual quality and voice**.**

Q3. Helpfulness of Interactive Elements

Q3 Did interactive elements help			
		Frequency	Percent
Valid	Helpful	4	13.3
	Yes	26	86.7
	Total	30	100.0

Most participants stated that interactive features, such as adjustable sliders and visual displays helped a lot in their understanding of ABR and its waveform interpretations..

Q4. Clinical Application Section

Q4 How was case studies in clinical applications			
		Frequency	Percent
Valid	Good	10	33.3
	Helpful	12	40.0
	Practical cases	5	16.7
	Variety cases	3	10.0
	Total	30	100.0

Most of the students in the clinical application and case-study section rated this as improving their confidence in analysing ABR findings and in making clinical decisions..

Q5. Suggestions Provided by Participants

Q5 Any Specific Suggestions			
		Frequency	Percent
Valid	Add protocols and parameters	1	3.3
	More engaging	4	13.3
	More Quiz	2	6.7
	No	21	70.0
	Summary	2	6.7
	Total	30	100.0

The following were general recommendations:

- Inclusion of more case studies (clinical examples)
- Inclusion of end-of-unit quizzes for self-assessment
- Option for downloading summary notes
- Inclusion of additional real ABR waveform examples

Q6. Recommendation of the Module

Q6 Would you recommend this module

		Frequency	Percent
Valid	Yes	30	100.0
	Total	30	100.0

The majority of respondents felt they would recommend the module to future audiology students as it was clear, engaging, and easy to use in helping students understand difficult ABR concepts.

Summary of Findings:

Results from the current study indicate that:

1. The e-learning module effectively enhanced students' knowledge and clinical reasoning abilities regarding advanced ABR concepts.
2. The module was found to be usable and highly satisfactory by the participating students.
3. Interactive and case-based learning materials were viewed as especially helpful in understanding challenging material.
4. The e-learning module was successful in integrating basic knowledge and clinical application.

In general, the data indicates that this e-learning module can be a useful adjunct in audiology programs to teach difficult electrophysiological topics.

CHAPTER V

DISCUSSION

This study aimed to design and validate an e-learning module about advanced ABR topics, as well as assess its effects on the knowledge and clinical reasoning skills of undergraduate audiology students. It was found that the designed module had good content validity, had a positive effect on post-test performance and had high ratings from students regarding usability and engagement. The results corroborate recent studies indicating that an interactive e-learning environment can be a beneficial additional teaching method in audiology education, particularly when teaching advanced electrophysiological procedures, such as ABR.

This study had several key findings; most notably that the developed e-learning module achieved a good content validity. All of the domains contained high I-CVI values above the threshold of 0.78 and the S-CVI also indicates high consensus among the experts about the content of the e-learning module and the assessment tool being relevant, appropriate, and clear. These findings suggest that the content of the learning module and the assessment tool was scientifically sound, clinically relevant, and pedagogically sound for undergraduate audiology students. The content validity of the learning module and assessment tool was strengthened by utilizing the expertise of audiology professionals with ample clinical and academic experience that ensured the developed materials were in agreement with current ABR practice and education.

The high content validity found in this study aligns with research in educational literature; it recommends that expert involvement should be utilized to develop digital learning resources in health professions education. The validity testing that took place systematically ensured that the content covered the important domains of ABR education, namely, neurophysiology of the ABR, recording methods, waveform analysis, and clinical applications. This is important since previous literature has found a lack of organized and structured ABR learning resources available on complex higher-order cognitive skills such as interpretation and analysis (Dzulkarnain et al., 2014; Reed et al., 2021).

An important finding of the current study was the statistically significant difference between the mean pre-test and post-test scores of participants in response to an e-learning module on ABR. Mean post-test score was greater than the mean pre-test score ($z=-3.571$, $p < 0.05$) on the Wilcoxon Signed Rank Test. These data suggest that the e-learning module successfully improved students' theoretical and clinical reasoning knowledge base regarding ABR.

Several features of the developed module likely contributed to the improvement of learning outcomes. Inclusion of a visual demonstration of ABR, interactive simulation of parameters that influence the ABR waveform, case based learning and manipulation tools within the module may have engaged students more actively in the learning process and enhanced deeper conceptual learning. According to constructivist theory (Jonassen, 1999), learners become more engaged when they are actively involved in their own learning process. The current module actively engaged students in manipulating components that are important in understanding the ABR and actively applying this knowledge. The use of interactive simulations, case based learning and the manipulation tool within the module may have facilitated deeper and more integrated learning of ABR.

The case-based clinical application section of the module was a significant contributing factor to the development of clinical reasoning abilities in the study population. Students felt that the case based discussions were helpful in the interpretation of ABR waveform information in clinical practice. This finding agrees with past research that supports the effective role of case based simulations in higher level decision making skills development . Since interpretation of an ABR waveform depends not only on memorizing components of an ABR but also interpreting the data critically and synthesizing clinical information, these interactive clinical scenarios may have helped participants in developing a more advanced level of understanding.

One significant result of the present study was the significantly positive correlation between the usability score and the post-test learning gain. Students that felt the module was more usable and engaging had higher post-test learning gains. This is an important finding and strongly supports the premise that usability and a positive user experience are essential components in designing effective e-learning materials for learning complex material. Modules that are easier to use may enable the learner to focus on content learning as opposed to trying to figure out how to use the module. Such modules will likely lead to greater time spent with the content and improved learning outcomes.

The results of the structured feedback questionnaire revealed more about what learners felt was most valuable and engaging in the module. Most students indicated that they found the interactive elements of the module, animations and case based application most valuable. This agrees with previous findings that Multimedia learning and simulations in particular have demonstrated success in enhancing the learning and understanding of complex clinical processes . There were a few comments indicating that future modules might be more useful if they were slightly more succinct, had more quizzes and sample waveforms, or provided summarized information that could be downloaded. Such comments are valuable for continued development of the module. The students' indication that they would like additional quizzes is consistent with literature that highlights the value of frequent practice and immediate feedback in formative assessment of learning .

The data from this study corroborate other research that advocates for the use of blended learning in health sciences education. While e-learning can be successful in improving learning, it has been noted in the literature that simulations and learning modules work best when integrated with instructor-led training rather than completely replacing it (Dzulkarnain et al., 2014). The module was developed to complement, not replace, instructional activities that students encounter in their training, including lectures, text-based reading assignments, and lab experiences. This is particularly relevant for audiology programs as many procedural skills involved in ABR testing are still best learned in a supervised laboratory and/or clinical setting.

The current findings also hold significance for the field of audiology education. They demonstrate that interactive e-learning modules are a viable option for complementing conventional instruction in electrophysiology courses, and that integrating interactive and case based components can effectively improve students' learning and clinical reasoning skills in ABR. This modular learning tool will likely provide students with a standardized experience irrespective of variations in laboratory instructors or opportunities to work with specific waveform types.

The findings in this study also support the limited body of research on simulations and e-learning in audiology education. As noted by Alanazi and Nicholson (2023), simulation-based education in audiology lags behind other health professions, thus providing an urgent need to incorporate it in the curriculum. The current study offers proof of concept and effectiveness of utilizing structured learning modules in audiology training.

Limitations of the study:

The sample size is relatively small and all participants are from the same institution which may affect the generalizability of the findings to the larger audiology student population. The single-group pre-test post-test design without a control group makes it difficult to rule out practice effects and independent study on test performance. Furthermore, this study measured learning in the short-term as long-term retention of learned knowledge was not assessed.

Another limitation of this study was the assessment of learning of theory and clinical reasoning rather than procedural and technical skills. While the module provided an opportunity for simulation-based practice, hands-on, real world interpretation of ABR data is not the same as this training. Future research needs to explore the utility of this learning module in teaching actual procedural skills, and how well the learning gained from this module is maintained in practice over time.

Future research would ideally be a randomized control trial of a similar module. Larger and more heterogeneous student populations would increase the power of the study and generalizability of findings. Comparative studies evaluating this learning module, a simulation only module and traditional lecture based learning modules would provide important information regarding effective pedagogical approaches for teaching complex topics such as ABR. Additional research is also warranted in the application of virtual reality, artificial intelligence, and advanced waveform simulation techniques to learning the interpretation of electrophysiological data in audiology training.

Identical pre and post test measures were used; thus there may have been a practice effect from taking both tests. The findings support the integration of structured e-learning approaches into audiology education as supplementary tools to enhance learning outcomes and bridge the gap between theoretical instruction and clinical applications.

In summary, the developed e-learning module on advanced ABR concepts was found to be valid, reliable, usable, and successful in improving undergraduate audiology students' knowledge base and clinical reasoning ability with high learner satisfaction. The interactive components and case based activities within the module appeared to facilitate deep learning of ABR knowledge and clinical reasoning abilities. This study supports the effective use of an interactive learning module as a supplementary learning resource for enhancing knowledge and clinical reasoning skills among audiology students learning complex electrophysiological topics.

In conclusion, it was found that the e-learning module effectively increased the students' ABR knowledge and clinical reasoning. While there is scope for further research and development

First, the module needs to be tested on larger, multi-institutional, diverse student populations using the Randomized Controlled Trial method. The pre-test, post-test, single-group design used in this study only demonstrates the module's effectiveness; comparisons of the module against traditional teaching methods, blended learning methods and e-learning intervention are required to definitively conclude its effect.

Secondly, follow-up tests can be employed months after the module to assess knowledge retention.

In future iterations, the module could incorporate more real clinical ABR waveform examples, additional complicated cases, and automated feedback to enhance clinical reasoning and interpretation abilities.

Ultimately, the instructional framework employed in creating this module could be modified and applied to other electrophysiological procedures used in audiology (VEMP, ECoG, cortical auditory evoked potentials). This would help build robust digital learning tools throughout audiology and facilitate the competency based education of future audiologists.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The current study was designed to develop, validate, and evaluate an interactive e-learning module on complex topics in Auditory Brainstem Response (ABR) for undergraduate audiology students. The interpretation and assessment of electrophysiological responses generated during an ABR are complicated, requiring theoretical knowledge, practical interpretation of waveform, and clinical rationale to analyse waveforms. Traditional classroom learning may not allow enough time for repetitive practice and standardized case presentation for the students to reach proficiency levels. Thus, the e-learning module was designed using Rich E. Mayer's Cognitive Theory of Multimedia Learning.

The study utilized a quasi-experimental pre-test-post-test design with a descriptive component to evaluate usability. ABR e-learning module was evaluated by 5 audiologists in the validity and evaluation stages, whereas 30 audiology students participated in the implementation and evaluation stages of the module. The module had 4 major topics: neuroanatomy and physiology of the generators of ABR; recording protocols and procedures for ABR; factors affecting ABR; and the clinical application of ABR. The module was enriched with a number of interactive elements such as animations, simulators, examples of waveforms, artifact library, and case-based discussions that enhanced student engagement.

The content validity of the ABR knowledge assessment tool (50-item) and e-learning module was established by calculating the Content Validity Index (CVI). The Scale-Level CVI of the ABR knowledge assessment tool was 0.9, whereas it was 1.0 for the e-learning module. An expert panel of 5 audiologists(faculties of AIISH) evaluated all the topics in both the e-learning module and ABR knowledge assessment tool and confirmed that they were all relevant, clear and accurate to represent advanced ABR topics for undergraduate students. Students were assessed with pre- and post-tests, and their score was analysed using a Wilcoxon

Signed-Rank test. Students' post-test scores on the knowledge assessment tool were statistically higher than pre-test scores ($p < 0.05$).

The usability of the e-learning module was evaluated by calculating the System Usability Scale (SUS) of all the participants, which yielded an average score of 76.41. The students reported that animated procedures and clinical case studies were most beneficial for understanding complex topics. A moderate positive correlation between SUS scores and students' post-test scores indicated that higher perceived usability and better student engagement with the module lead to increased learning outcomes.

These findings are consistent with the application of multimedia-based e-learning in audiology education and provide evidence that it is a beneficial tool to use as a complement to conventional teaching. Such approaches may also be applicable for learning other complex electrophysiological techniques.

Conclusions:

1. The developed e-learning module on advanced ABR concepts provided a satisfactorily content valid measure as validated by audiologists.

2. The ABR e-learning module was effective in enhancing audiology students' ABR-related knowledge, analytical skills, and clinical reasoning as evidence from pre- and post-test results.

3. The e-learning module was found to have a good usability with average score of 76.41 from the SUS tool, and most participants found it to be easy to use and navigate.

4. The module's interactive and animated content along with case-based learning activities positively influenced student engagement and facilitated a deeper understanding of the ABR concepts.

5. A significant moderate positive correlation was observed between the perceived usability of the module and the post-test scores, supporting the premise that user-friendly design can lead to better learning.

6. The current findings advocate for the integration of multimedia-based e-learning and blended learning methods into audiology curriculum to augment traditional classroom instruction.

7. The developed module has the potential to be an effective teaching tool for improving ABR-related competencies among undergraduate audiology students.

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APPENDIX I

Access Link for the Interactive E-Learning Module

Title of Module: Interactive E-Learning Module on Auditory Brainstem Response (ABR)

Access Link:

https://samarth06trivedi.github.io/ABR-E-Module/

Description

This E-module was developed for fulfilment of dissertation for the year 2024-2026 by Ms. Swasti Trivedi under the guidance of Ms. Nirupama S. This e-module is thoughtfully structured into four comprehensive modules, each designed to enhance understanding through multiple learning approaches. Each module features engaging video lessons that support visual learning and help explain key concepts in a clear and accessible manner. To further deepen understanding, the module includes interactive sliders that allow learners to adjust different parameters and observe how various factors influence the Auditory Brainstem Response (ABR). This hands-on interaction encourages active exploration and strengthens conceptual clarity. Finally, every module concludes with a quiz, enabling students to assess their understanding and reinforce the concepts they have learned. Overall, this e-module combines visual instruction, interactive learning, and self-assessment to create a dynamic and effective educational experience.

APPENDIX II

Expert Content Validation Form

Project Title: Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students

Dear Expert,

Thank you for agreeing to serve as a content validator for this research project. Your expertise is crucial in ensuring the accuracy, relevance, and clarity of the educational material and assessment tools. Please evaluate the provided e-module content outline and the knowledge test items based on the following scales.

Part 1: Evaluator Information

Name: __________________________

Designation: __________________________

Area of Specialization: __________________________

Years of Experience: __________________________

Affiliation: __________________________

Part 2: Rating Scales

Please use the following scales to rate each component:

A. Relevance: 4 = Highly Relevant, 3 = Quite Relevant, 2 = Somewhat Relevant, 1 = Not Relevant

B. Accuracy: 4 = Highly Accurate, 3 = Accurate, 2 = Somewhat Accurate, 1 = Inaccurate

C. Clarity: 4 = Very Clear, 3 = Clear, 2 = Somewhat Clear, 1 = Unclear

Part 3: E-Module Content Validation

Please rate each of the four units of the proposed e-module.

Module Unit	Relevance (1-4)	Accuracy (1-4)	Clarity (1-4)	Comments / Suggestions for Improvement
Unit 1: ABR Generators				
Unit 2: Protocol & Procedure				
Unit 3: Factors Affecting ABR				
Unit 4: Clinical Applications				
Overall module				

APPENDIX III

ABR PRE and Post 50- item knowledge Test

1. **Which of the following is considered the primary generator site for Wave III of the click-evoked ABR?**
   a) Auditory Nerve (Distal)
   b) Cochlear Nucleus
   c) Superior Olivary Complex
   d) Inferior Colliculus
2. **For Site of lesion ABR, what is the primary purpose of using a high stimulus repetition rate (e.g., 90.1/sec vs. 11.1/sec)?**
   a) To improve the wave morphology
   b) To stress the auditory system and amplify latency abnormalities
   c) To reduce the test time
   d) To estimate the hearing threshold more accurately
3. **A patient has a Bilateral moderate to severe high frequency sensorineural hearing loss. How is the click-ABR waveform most likely to be affected?**
   a) Wave I amplitude will be enhanced.
   b) Absolute latencies of all waves will be significantly prolonged.
   c) The waveform will be poorly defined with reduced amplitude.
   d) There will be no effect on the click-ABR.

4. Which of the following structures is considered the primary generator of Wave V in the click-evoked ABR?
a) Cochlear Nucleus
b) Superior Olivary Complex
c) Lateral Lemniscus/Inferior Colliculus
d) Auditory Nerve (Distal)

5. In a patient with vestibular schwannoma, which ABR finding is most commonly observed?
a) Reduced Wave I amplitude with normal interpeak latencies
b) Prolonged I–III or I–V interpeak latency
c) Enhanced Wave V amplitude
d) Shortened absolute latencies of all waves

6. A patient shows normal absolute latency of Wave I but prolonged Wave V latency, with an increased I–V interpeak latency. The most likely site of lesion is:

a) Cochlea
b) Distal auditory nerve
c) Lateral lemniscus
d) Middle ear

7. When stimulus rate is increased from 11.1/sec to 90.1/sec, which ABR component is most vulnerable to degradation?

a) Wave I latency
b) Wave III amplitude
c) Wave V latency
d) Interaural latency difference

8. A significant interaural Wave V latency difference (0.8 ms) with asymmetric hearing thresholds suggests:

a) Cochlear pathology
b) Retro-cochlear pathology
c) Conductive hearing loss
d) Normal variation

9. Which ABR finding best differentiates cochlear from retro-cochlear pathology?

a) Delay of absolute latency
b) Reduced amplitude
c) Interpeak latency prolongation
d) Absence of Wave I

10. In high-frequency moderately severe sloping SNHL, why is Wave V often still recordable at high intensities?

a) Contribution from low-frequency regions
b) Neural synchrony improves
c) Basal cochlear regions still contribute
d) Artifact contamination

11. ABR testing reveals absent auditory brainstem response waveforms, while otoacoustic emissions (OAEs) are robustly present bilaterally. What is the most likely diagnosis?

a) Cochlear hearing loss
b) Auditory Neuropathy Spectrum Disorder (ANSD)
c) Conductive hearing loss
d) Middle ear pathology

12. Waves I and III are clearly identifiable with normal latencies, but Wave V is consistently absent despite repeated recordings at high stimulus intensity. This finding most likely suggests dysfunction involving the:

a) Distal part of Auditory nerve
b) Lower brainstem

c) Auditory maturation process/upper brainstem auditory pathway
d) Cochlea

13. Which parameter is most sensitive for detecting small vestibular schwannomas?

a) Wave I amplitude
b) Absolute Wave V latency
c) I–V interpeak latency
d) Wave III amplitude

14. What is the physiological basis for latency prolongation at higher stimulus rates in retro-cochlear pathology?

a) Hair cell fatigue
b) Neural adaptation and reduced synchrony
c) Middle ear stiffness
d) Cochlear dead regions

15. Which ABR abnormality is most characteristic of auditory neuropathy spectrum disorder (ANSD)?

a) Prolonged Wave V latency
b) Absent ABR waves with preserved OAE
c) Reduced Wave I amplitude
d) Increased interpeak latency

16. In a patient with conductive hearing loss, increasing stimulus intensity will:

a) Reduce prolonged absolute latencies
b) Eliminate latency shifts
c) Further delay waves
d) Reduce amplitudes only

17. Which wave is most likely to disappear first as stimulus intensity decreases?

a) Wave V
b) Wave III
c) Wave II
d) Wave I

18. Which ABR finding is most consistent with a lesion involving the lateral lemniscus?

a) Prolonged I–III interpeak latency with normal III–V latency
b) Delayed Wave I with normal interpeak latencies
c) Prolonged III–V interpeak latency with normal I–III latency
d) Absent Wave I with normal Wave V

19. During Auditory Brainstem Response (ABR) testing, contralateral masking noise is presented to the non-test ear primarily to:

a) Improve waveform amplitude in the test ear
b) Prevent the non-test ear from detecting the stimulus through crossover hearing
c) Reduce electrical artifacts from the recording electrodes
d) Increase neural synchrony of the auditory nerve

20. Which ABR pattern suggests demyelinating pathology (e.g., multiple sclerosis)?

a) Reduced amplitudes only
b) Markedly prolonged interpeak latencies with relatively preserved amplitudes
c) Absent Wave I only
d) Normal latencies

21. A patient shows delayed Wave I, III, and V with normal interpeak latencies. The most likely diagnosis is:

a) Retro-cochlear lesion
b) Conductive hearing loss
c) Brainstem lesion
d) Auditory neuropathy

22. Which factor most improves amplitude of Wave I in ABR?

a) High repetition rate
b) Rarefaction polarity
c) Horizontal montage
d) Wide filter settings

23. A patient presents with asymmetric sensorineural hearing loss. Which ABR parameter is considered the most sensitive and clinically valuable for detecting retro-cochlear pathology?

a) Absolute Wave V latency in the poorer ear
b) Interaural difference in Wave V latency
c) Wave V amplitude in the poorer ear
d) Presence or absence of Wave II

24. Which finding is most suspicious for a small acoustic tumour when hearing is near normal?

a) Absent waves
b) Prolonged Wave I latency
c) Increased I–V interpeak latency and interaural asymmetry
d) Reduced Wave V amplitude

25. Why is Wave V more resistant to changes in stimulus parameters compared to earlier waves?

a) It originates from cochlea
b) It reflects summed activity from multiple brainstem generators
c) It has highest amplitude
d) It is least affected by neural synchrony

Section B: Clinical Scenario-Based Questions

A 45-year-old female presents with a 6-month history of unilateral tinnitus and asymmetric hearing loss in her right ear. Her MRI is pending.

26. What is the most appropriate initial ABR protocol for this patient?
a) Threshold Estimation using tone bursts
b) Site of lesion ABR using clicks
c) Intraoperative Monitoring protocol
d) Speech-ABR

27. The ABR results show a normal Wave I latency but a significantly prolonged I-III interpeak latency on the right side. What does this finding most likely suggest?
a) A cochlear pathology
b) A retro-cochlear pathology between CN VIII and the Cochlear Nucleus
c) A generalized neurological disorder
d) A middle ear dysfunction

A 32-year-old male reports sudden hearing loss and persistent tinnitus in the left ear for the past 3 months. Pure tone audiometry shows asymmetric sensorineural hearing loss, worse in the left ear. The clinician decides to perform an ABR test to evaluate possible retro-cochlear involvement.

28. Which ABR finding would most strongly suggest a retro-cochlear lesion in this patient?
a) Normal absolute latencies but reduced Wave V amplitude
b) Prolonged interaural Wave V latency difference (>0.4 ms)
c) Increased Wave I amplitude
d) Shortened I–V interpeak latency

29. In an adult with normal hearing sensitivity and a clearly identifiable Wave V, Wave I is not visible despite adequate stimulus intensity. What is the most likely explanation?

a) Poor electrode placement
b) Severe cochlear hearing loss
c) Brainstem neural synchrony disorder
d) Middle ear pathology

30. **During ABR testing, the clinician reduces the stimulus intensity from 90 dB nHL to 60 dB nHL. What change is most likely to occur in the waveform?**
    a) Absolute latencies of waves will increase
    b) Absolute latencies will decrease
    c) Wave amplitudes will decrease significantly
    d) Interpeak latencies will become shorter

A 40-year-old female presents with unilateral tinnitus and progressive hearing loss in the right ear. MRI is pending. ABR testing is performed.
Questions:
31. Which ABR finding is most suggestive of retro-cochlear pathology?
a) Symmetrical Wave V latencies
b) Prolonged I–III interpeak latency
c) Increased Wave I amplitude
d) Reduced Wave II amplitude

32. Which interaural Wave V latency difference is most widely accepted as suggestive of retro-cochlear pathology in adults with asymmetrical hearing thresholds?
a) >0.2 ms
b) >0.3 ms
c) >0.4 ms
d) >0.6 ms

33. ABR is performed to evaluate for possible retro-cochlear pathology. Which ABR wave is most commonly compared between ears to assess interaural latency differences?
a) Wave I
b) Wave II
c) Wave III
d) Wave V
34. ABR testing shows a normal Wave I latency in both ears, but the right ear demonstrates a prolonged Wave V latency and an increased I–V interpeak latency. Which site of lesion is most likely?
a) Cochlea
b) brainstem pathway
c) External auditory canal
d) Middle ear
35. A patient with normal middle ear function undergoes ABR testing. Wave I is present at the expected latency, but Waves III and V are significantly delayed. What does this pattern most likely indicate?
a) Cochlear hearing loss
b) Conductive hearing loss

c) Retro-cochlear pathology
d) Normal hearing sensetivity

A 3-month-old infant fails newborn hearing screening. ABR is performed to estimate hearing thresholds.
Questions:
36. As the stimulus intensity is gradually decreased, which ABR wave is typically tracked to determine the electrophysiological threshold because it remains identifiable at the lowest intensity levels?
a) Wave I
b) Wave II
c) Wave III
d) Wave V

37. If Wave V disappears at 50 dB nHL, threshold is approximately:
a) 20 dB nHL
b) 30 dB nHL
c) 50 dB nHL
d) 70 dB nHL

38. Tone burst ABR is preferred because:
a) It gives frequency-specific information
b) It is faster
c) It produces larger amplitudes
d) It avoids artifacts

39. what findings are typically expected in infants:
a) Shorter latencies
b) Prolonged latencies
c) No Wave V
d) Larger amplitudes

40 . Which factor improves waveform clarity?
a) Increasing impedance
b) Increasing stimulus rate
c) Increasing number of averages
d) Reducing repetitions

A 2.5-year-old child was referred to AIISH with parental complaints of reduced hearing and persistent ear discharge. Otoscopic examination revealed a tympanic membrane perforation in the affected ear. Due to poor cooperation during behavioural audiological assessment, ABR testing was recommended to estimate hearing thresholds objectively.

Questions:

41. Compared to a child with normal hearing, what ABR finding is most likely in this child?

a) Prolonged absolute latencies of all waves
b) Prolonged interpeak latencies only
c) Absent Wave V only
d) Reduced Wave I latency

42. Why are the ABR wave latencies delayed in conductive hearing loss?

a) Impaired neural conduction in the brainstem
b) Reduced neural synchrony of the auditory nerve
c) Attenuation of the stimulus reaching the cochlea
d) Damage to outer hair cells

43. During threshold estimation, the audiologist decreases the stimulus intensity from 80 dBnHL to 60 dBnHL. What change is expected in Wave V?

a) Latency decreases and amplitude increases
b) Latency increases and amplitude decreases
c) Latency remains unchanged
d) Amplitude increases only

44. To improve confidence in hearing threshold estimates obtained from ABR, which additional assessments are most commonly used for confirmation?

a) MLR
b) OAE and behavioural audiometry
c) LLR
d) P300

45. As stimulus intensity approaches the ABR threshold, which wave is typically the most reliable and persists the longest?

a) Wave I
b) Wave V
c) Wave III
d) Wave IV

A 5.5-year-old child is brought to AIISH because of delayed speech and language development. The parents report that the child often fails to respond when called from another room and frequently increases the volume of the television. Otoscopic examination is unremarkable, and tympanometry reveals normal middle ear function. Behavioural audiometry could not be completed reliably due to poor cooperation. Therefore, ABR testing is performed to estimate hearing thresholds

Questions:

46. ABR testing reveals a replicable Wave V at 70 dBnHL but not at 60 dBnHL. What is the estimated hearing threshold based on ABR?

a) 50 dBnHL
b) 60 dBnHL
c) 70 dBnHL
d) 80 dBnHL

47. Which ABR pattern is typically associated with sensorineural hearing loss?

a) Prolonged absolute latencies caused by conductive pathology
b) Elevated ABR threshold with preserved interpeak latency values
c) Absence of Wave I while Wave V remains normal
d) Normal hearing threshold with isolated prolongation of Wave V

48. What is the primary clinical advantage of using ABR in infants and young children?

a) It directly measures speech understanding
b) It provides an objective estimate of hearing sensitivity
c) It evaluates middle ear status
d) It assesses receptive and expressive language skills

49. A patient shows no identifiable ABR responses to click stimuli at the maximum output level of 90 dBnHL. Which procedure should be performed next to assess hearing thresholds across specific frequencies?

a) Conclude that the patient has profound hearing loss
b) Repeat click ABR using the same parameters
c) Conduct tone-burst ABR beginning at 80 dBnHL
d) Present clicks at intensities greater than 90 dBnHL

50. In ABR threshold estimation, the electrophysiological threshold is defined as:

a) The intensity producing the largest Wave V amplitude
b) The lowest intensity at which a replicable Wave V can be identified
c) The intensity at which Wave I first appears
d) The intensity at which all ABR waves are present

Answers:

1. b) Cochlear nucleus
2. b) To stress the auditory system and amplify latency abnormalities
3. c) The waveform will be poorly defined with reduced amplitude

4. c) Lateral Lemniscus/Inferior Colliculus
5. b) Prolonged I–III or I–V interpeak latency
6. c) Lateral lemniscus
7. c) Wave V latency
8. b) Retro-cochlear pathology
9. c) Interpeak latency prolongation
10. c) Basal cochlear regions still contribute
11. b) Auditory Neuropathy Spectrum Disorder (ANSD)
12. c) Auditory maturation process/upper brainstem auditory pathway
13. c) I–V interpeak latency
14. b) Neural adaptation and reduced synchrony
15. b) Absent ABR waves with preserved OAE
16. a) Reduce prolonged absolute latencies
17. d) Wave I
18. c) Prolonged III–V interpeak latency with normal I–III latency
19. b) Prevent the non-test ear from detecting the stimulus through crossover hearing
20. b) Markedly prolonged interpeak latencies with relatively preserved amplitudes
21. b) Conductive hearing loss
22. c) Horizontal montage
23. b) Interaural difference in Wave V latency
24. c) Increased I–V interpeak latency and interaural asymmetry
25. b) It reflects summed activity from multiple brainstem generators
26. b) Site of lesion ABR using clicks
27. b) A retro-cochlear pathology between CN VIII and the Cochlear Nucleus
28. b) Prolonged interaural Wave V latency difference (>0.4 ms)
29. a) Poor electrode placement
30. a) Absolute latencies of waves will increase
31. b) Prolonged I–III interpeak latency
32. c) >0.4 ms
33. d) Wave V
34. b) Auditory nerve or brainstem pathway
35. c) Retro-cochlear pathology
36. d) Wave V
37. b) 30 dB nHL
38. a) It gives frequency-specific information
39. b) Prolonged latencies
40. c) Increasing number of averages
41. a) Prolonged absolute latencies of all waves
42. c) Attenuation of the stimulus reaching the cochlea
43. b) Latency increases and amplitude decreases
44. b) OAE and behavioural audiometry
45. b) Wave V
46. a) 50 dBnHL
47. b) Elevated ABR threshold with preserved interpeak latency values
48. b) It provides an objective estimate of hearing sensitivity
49. c) Conduct tone-burst ABR beginning at 80 dBnHL
50. b) The lowest intensity at which a replicable Wave V can be identified.

APPENDIX IV

System Usability Scale (SUS) Instructions: Please indicate your level of agreement with the following statements about the ABR e-learning module you just used. Please check the box that best matches your experience

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1. I think that I would like to use this module frequently.	◻	◻	◻	◻	◻
2. I found the module unnecessarily complex.	◻	◻	◻	◻	◻
3. I thought the module was easy to use.	◻	◻	◻	◻	◻
4. I think that I would need technical support to be able to use this module.	◻	◻	◻	◻	◻
5. I found the various functions in this module were well integrated.	◻	◻	◻	◻	◻
6. I thought there was too much inconsistency in this module.	◻	◻	◻	◻	◻

Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
7. I would imagine that most people would learn to use this module very quickly.	□	□	□	□	□
8. I found the module very cumbersome to use.	□	□	□	□	□
9. I felt very confident using the module.	□	□	□	□	□
10. I needed to learn a lot of things before I could get going with this module.	□	□	□	□	□

APPENDIX V

Semi-Structured Feedback Form

Instructions: Please share your honest feedback about your experience with the ABR e-learning module. Your responses are anonymous and will be used to improve the module.

1. **What did you find MOST useful or engaging about the module?**

2. **What did you find LEAST useful or engaging? Was any part confusing or frustrating?**

3. **Did the interactive elements (simulators, sliders, clickable models) help you understand the concepts better than a textbook or lecture would? Please provide an example.**

4. **How did the case studies in the "Clinical Applications" unit impact your understanding of how to use ABR in real-world practice?**

5. **Do you have any specific suggestions for improving the module? (e.g., more examples, different types of activities, additional topics)**

6. **Would you recommend this module to other students learning about ABR? Why or why not?**

Thank you for your valuable time and feedback!

APPENDIX VI

INFORMED CONSENT FORM

Title of the Study:

Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate Audiology Students

Principal Investigator:

Swasti Trivedi

2nd Msc.(Audiology)

All India Institute of Speech and Hearing (AIISH), Mysuru

Purpose of the Study:

You are invited to participate in a research study that aims to evaluate the effectiveness of an interactive e-learning module developed for teaching Auditory Brainstem Response (ABR) concepts to undergraduate audiology students. The findings of this study may contribute to the improvement of teaching-learning methods in audiology education.

Procedure:

If you agree to participate, you will be asked to:

1. Complete a pre-test assessing your knowledge of ABR.
2. Access and complete the interactive e-learning module.
3. Complete a post-test after reviewing the module.
4. Provide feedback regarding the learning experience, if required.

The total duration of participation is approximately [duration] minutes.

Risks and Discomforts:

There are no foreseeable physical, psychological, or social risks associated with participation in this study. Participation involves only educational activities and assessments.

Benefits:

You may benefit from improved understanding of ABR concepts through the interactive e-learning module. The information obtained from this study may help improve educational practices for future students.

Confidentiality:

All information collected during the study will be kept strictly confidential. Participants will be assigned identification codes, and no personally identifiable information will be disclosed in any report, publication, or presentation arising from this study.

Voluntary Participation:

Your participation in this study is entirely voluntary. You may refuse to participate or withdraw from the study at any time without any penalty or effect on your academic standing.

Compensation:

No monetary compensation will be provided for participation in this study.

Contact Information:

If you have any questions regarding the study, you may contact: Ms. Swasti Trivedi

Principal Investigator:

Ms. Swasti Trivedi

2nd Msc(Audiology)

All India Institute of Speech and Hearing (AIISH), Mysuru

Guide: Ms. Nirupama S

Assistant Professor in Audiology

Department of Audiology

All India Institute of Speech and Hearing (AIISH), Mysuru

Consent Statement:

I have read and understood the information provided above. I have had the opportunity to ask questions and have received satisfactory answers. I voluntarily agree to participate in this study**.**

Participant Name: ______________________________

Participant Signature: ____________________________

Date: __________________

Investigator Signature: ___________________________

Date: __________________

All India Institute of Speech and Hearing
(An autonomous Institute under the
Ministry of Health and Family Welfare, Govt. of India)
Center of Excellence - Assessed & accredited by NAAC with 'A' Grade
ISO 9001: 2015 Implemented Institute
Manasagangothri, Mysuru - 570 006

ಅಖಿಲ ಭಾರತ ವಾಕ್ ಶ್ರವಣ ಸಂಸ್ಥೆ
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मानसगंगोत्री, मैसूरु – 570 006

INSTITUTE REVIEW BOARD (IRB) APPROVAL FOR BIO-BEHAVIOURAL RESEARCH PROPOSAL INVOLVING HUMAN SUBJECTS AT AIISH

AIISH Institute Review Board (IRB)

Ref: SH/IRB/M.4/AUD.13/2025-26 **Date: 06.01.2026**

Title of the Dissertation	: Development and Validation of an Interactive E-Content Module on Auditory Brainstem Response (ABR) for Undergraduate udiology Students
Name of the Investigator	: Ms. Swasti Trivedi
Guide	: Ms. Nirupama S
Co-Guide (if any)	: -
Proposed Duration of the Project	: 08 months
Source of funding	: Non-funded Master's dissertation
Estimated budget	: Nil
Reference Number of the Project	: Nil
Date on which the IRB meeting was held	: 02.01.2026

A clear statement of the decision reached IRB meeting
(In the vent of the proposal is not approved, a statement
of reasons for the same must be indicated) **: APPROVED**

Advice & suggestions (if any) : NIL

Signature & Name of the Member Secretary-IRB
Dr. Animesh Barman
Professor of Audiology
All India Institute of Speech and Hearing, Mysore-570006

सदस्य सचिव / Member Secretary
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