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Developing and Validating a Contextualized Science Literacy Assessment for Adults: The Case of Parents of Hard of Hearing Children

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Abstract: The diversity of definitions of science literacy has resulted in a diversity of measurement tools. However, adult science literacy is mainly assessed on short standardized and non-contextualized questions, thus making the study of adult science literacy more qualitative than quantitative. Here we describe the rationale, development, and validation of a questionnaire that associates the use of science in the specific science-related setting of parents of hard of hearing children with general and topic-specific science knowledge. The questionnaire went through four developmental steps: (1) gathering input from hearing rehabilitation experts and parents, (2) testing the close-ended questionnaire (n=10), (3) open-ended questionnaire (n=24), (4) online close-ended questionnaire (n=91). These all assessed general science knowledge, contextual science knowledge in the field of hearing and parents' advocacy knowledge and attitudes. These steps and the resulting assessment tool can thus inform the further development of measures of adult science literacy in context. The findings suggest that although general science knowledge enables the application of science to everyday science-related problems it only explained a small proportion of the variance in contextual science knowledge. Thus, the results strongly point to the importance of measuring adults' science literacy in a context that is relevant to the responders. The findings also underscored the disappointing outcomes of secondary science education, in that formal scientific background predicted general science knowledge but did not account for contextual science knowledge at all. This should elicit concern as to the ability of students to use science knowledge in future personally important science related contexts.

Keywords: *Lifelong learning, measurement in the context, public engagement with science, science literacy.*

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Introduction

Today's world is characterized by the need to implement science and technology in our daily life, alongside the much greater access to information on these topics. One of the aims of science education is to educate independent learners, who can identify situations in which scientific knowledge is relevant, find it and use it wisely (C.E. Snow & Dinber, 2016). The question of whether the acquisition of scientific contextual knowledge is contributed by the existence of general scientific knowledge is still open. There is insufficient empirical evidence regarding the acquisition of new scientific knowledge by non-scientists in everyday life (Baram-Tsabari, 2022). Deafness is the most common sensory impairment in humans. Parents of deaf and hard of hearing (D/HH) children face this challenge in particular because a D/HH child's ability to integrate into hearing society depends largely on developing efficient forms of communication. This also hinges on parental dedication to realizing their child’s potential ((Roberts, 2007). However, over 90% of parents of deaf children are not hearing impaired themselves, and have little or no prior knowledge of audiology (Baram-Tsabari, 2022; Ravi et al., 2016) ,). Thus, for most families the moment of diagnosis is their first exposure to the world of hearing problems and their possible solutions (Molchanova & Chekanova, 2018; Vaccari & Marschark, 1997). Parents need to find, assess and understand vast amounts of varied information in a very short time. Relevant information to caring for a deaf and hard of hearing child can take many forms, such as scientific knowledge, audiological knowledge, medical knowledge, and technological knowledge (e.g., ear structure, the mechanism of hearing, language development in children, methods of rehabilitation, critical period, plasticity of the brain, hearing aids and more). Parents of deaf and hard of hearing children need to make many science-based decisions (e.g. type of

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rehabilitation), and use science knowledge to negotiate successful collaborations with the different professionals (e.g., hearing experts, doctors and educational staff). For example, a parent with a better understanding of an audiogram is able to better present the hearing difficulties of his/her child to the educational staff in school(Shauli & Baram-Tsabari, 2019) Ferguson et al. (2019) showed the usefulness of science knowledge for hard of hearing adults. They found that an interactive multimedia educational program providing information to hearing aid users increased their use and satisfaction from the hearing aids. Thus, families of people with hearing impairment are a suitable research environment to inquire contextual science literacy during adult's life.

Science educators argue that science literacy is a powerful tool for informed engagement in environmental, health and other socio-political issues (The Organisation for Economic Co-operation and Development [OECD], 2016). Science literacy is now considered to be "the desired outcome of science education" (Deboer, 2000, p.582). Science literate individuals are assumed to have a better starting point when dealing with economic, cultural, and political challenges as well as with personal dilemmas (Glaze, 2018; Snow & Dinber, 2016). Growing exposure to science-related problems in daily life and an abundance of science-related information of uneven quality makes these challenges more pressing, relevant and complex.

The concept of science literacy has frequently been defined and redefined in the literature Fitzpatrick, 1960; (Hurd, 1958; Laugksch, 2000; Singh & Singh, 2016; Valladares, 2021). Roberts (2007) described two main approaches: "Vision I" defines science literacy as 'the products and processes of science itself. At the extreme this approach envisions literacy within science' (p. 2), and "Vision II" defines science literacy as skills and knowledge students and lay people need to deal with science-related problems in their daily lives. Roberts and Bybee (2014) defined a "scientifically literate" person as someone who 'reflects critically on information and appreciates and understands the impact of science on everyday life' (p. 547). The lack of consensus has to do with which types of knowledge and skills are needed to be considered a scientifically literate person. While both visions promote the need for a knowledgeable, skilled citizen who can take an active part in decision-making processes on the individual or social level, Vision I of science literacy is more concerned with science knowledge whereas and Vision II focuses on the ability to use scientific knowledge and a grasp of science for individual and social purposes. This echoes different paradigms of 'public understanding of science' and 'public engagement with science', within the science communication literature

Vision II of science literacy can benefit from studies in the context of ‘Public engagement with science’ describing citizens' ability (or lack of) to actively participate in discourse about science and technology. Ideally, this model of science communication involves engaging the public in agenda-setting, decision-making, and policy-forming activities for policy development (Rowe & Frewer, 2005; Sadabadi & Rad, 2022) encouraging greater democratic participation in decision making in science and technology issues. In this research project, however, the researchers focus on personal relevance and usefulness. Following Feinstein (2011), Bruckermann et al. (2021) and Kurup et al. (2021) we think of engagement with science as ways of connecting science with real-life experience.

Within formal science learning environments, the diversity of definitions of science literacy has led to a diversity of measurement tools (Čavojová et al., 2020; Laugksch & Spargo, 1996; Norris, Phillips & Korpan, 2003; OECD, 2016). However, in adults, science literacy is mainly assessed with short standardized and non-contextualized questions that draw on Vision I public understanding of science type definitions and makes the assessment more qualitative than quantitative.

This study reports on the development and validation of a quantitative assessment tool for contextual science literacy for adults. It focuses on the use of science in the specific science-related life challenge faced by parents of hard of hearing children. Here, Vision I of science literacy is operationalized as general science knowledge, whereas Vision II is operationalized as scientific knowledge in the context of hearing and hearing loss, and public engagement with science ('ways of connecting science with real-life experience'), i.e., knowledge and attitudes towards advocacy for the child. Advocacy is defined as all the actions, including speaking and arguing for the fulfillment of rights and ways to address of the needs of another person or group of people. Naturally, this is an analytical simplification – public engagement includes knowledge, and Vision II aims to inform action and choices. However, this demarcation allows us to address them separately.

The researchers thus present a model to quantitatively assess the role played by science knowledge in the lives of non-scientists faced with science-related decisions while shedding light on the non-trivial relationship between the constructs of science literacy and public engagement with science.

Literature Review

Different stakeholders may have different goals for science literacy and different ideas as to the best ways to measure it. At the turn of the millennium , Laugksch (2000) characterized four 'interest groups’: the science education community, public opinion researchers, sociologists of science and the informal science education community. He viewed the first two groups as concerned with the content, effectiveness and measurement of science teaching and its effect on public support for science activities which primarily used survey questionnaires to evaluate the acquisition of specific science content. He considered the last two groups as dealing with how people understand science in daily life situations, which primarily implemented qualitative tools.

Both theoretical approaches to science literacy can still be found in today's educational environment. Science literacy assessment techniques for K-12 correspond mainly to Vision I since they are usually based on standards of knowledge and practices within science expected at different grade levels. By contrast, the PISA (OECD, 2016) framework for assessing science literacy reflects Vision II. Science literacy is characterized by the acquisition of the ability to explain phenomena scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically. It is also based on three types of knowledge: content knowledge - knowledge of the facts, concepts, ideas and theories about the natural world; procedural knowledge - knowledge of the procedures that scientists use to establish science knowledge; and epistemic knowledge - understanding of the role of specific constructs and defining features essential to the process of knowledge building in science. Roberts and Bybee (2014) and Sjøberg (2018) nevertheless argued that in the last two decades PISA exams and the OECD definition of science literacy has moved closer to the Vision I perspective. They claim that the components of science literacy are defined and measured within science and not in science dilemmas faced by people in their daily lives.

Beyond the differences in theoretical approach, different assessment techniques implement different constructs and outcomes. Fives et al. (2014) developed a science literacy measure for middle school students which includes motivation, beliefs, and personal science epistemology scales. Others, such as Norris and Phillips (2003) and Gormally et al. (2009) and Jennings et al. (2021) have concentrated on deriving pragmatic meaning from popular reports. Čavojová et al. (2020) used Scientific Reasoning Scale (SRS) that measures the ability to read and evaluate scientific evidence. Alongside the SRS, they used measures of thinking dispositions and cognitive ability. They claim that those are the predictors of decision making among the non-scientific population.

The methodological approaches are diverse. Whereas Laugksch and Spargo (1996) and Fang and Wei (2010) and Aderonmu and Adolphus (2021) developed assessment tools based on close-ended questions (110 True/False/don't know, and 25 multiple choice questions and 40 Likert-type questions, respectively), Tomas and Ritchie (2015) constructed an open-ended questionnaire based on short texts that merges scientific and narratives genres about the socio-scientific issue of biosecurity. Flores (2018) created a teaching unit and assessment of science literacy derived from problems-based science. Falk et al. (2016) used an epidemiological approach to develop their questionnaire that examined the effects of science centers on adult science literacy and science understanding. One of the seven criteria they assessed was science literacy and understanding, based on questions they selected from youth international exams (PISA and ROSE). They also included questions on reading science and technology-related books and articles, problem solving, as well as science and technology related hobbies. Sadler and Zeidler (2009) argued that socio-scientific issues (SSI) must be part of every science literacy measurement tool. Romine et al. (2017) developed and validated a Social-Scientific Reasoning (SSR) assessment based on 10 polytomous questions about a fracking scenario. They claimed that SSR was a useful way to assess students' understanding of SSI, which is the foundation for teaching science literacy.

Deboer (2000) and Valladares (2021) cautioned that the range of features tested across these assessment tools is indicative of the absence of a consensual definition of science literacy, and that this makes it difficult to construct a reliable measurement tool. The best-known measure of adult science literacy as content knowledge was developed by Miller (1983) in the US and Durant et al. (1989) in the UK. They suggested three components underlying science literacy: knowledge of science vocabulary, understanding of scientific processes and understanding the impact of science on society. These components constitute the basis for the large-scale surveys administered by the General Social Survey (GSS) biannually on adults in the US, whose results are reported by the US National Science Foundation (NSF). The GSS-NSF measure consists of a short battery of mostly closed-ended questions on factual science knowledge, an understanding of probability and basic constructs about scientific inquiry. A similar battery of questions was adapted for international use (European Commission, 2005; Ministry of Science, 2015).

This survey has been criticized on methodological and ideological grounds. Bauer et al. (2007) and recently Golumbic et al. (2022) noted that a set of short science knowledge questions may not be able to reliably assess science literacy since it is not clear whether these close-ended questions assess comprehension of the entire scientific process. They also argued that the knowledge items in the survey might be culturally biased (e.g., Big Bang) and therefore not reflect certain adults' actual science literacy level. Kahan (2014) went further to state that the NSF survey is invalid since no evidence has been found to prove that the questions selected for the survey reflect the scientific knowledge needed by a layperson to make decisions in daily life. Besley (2018) argues correspondingly that the survey data does not reveal the real groups of knowledge and attitudes among the US citizens consuming information provided by the media. Kahan (2014) noted the low reliability of the questions and made the point that the question about evolution is answered differently by religious and non-religious people as a function of their personal beliefs. His critique included the remarks that the survey has no power to discriminate between higher performance levels. He considered that the ability of a non-scientist to use scientific knowledge in daily science-based problems does not only depend on factual knowledge but rather taps critical reasoning skills, cognitive perceptions, and effortful information processing, none of which are measured. His claims were partly strengthen by Trémolière and Djeriouat (2021).

The literature review only identified a few science literacy assessment tests for the adult general public (rather than for teachers or university students). This argument is echoed by Naganuma (2017). He claims about the importance of use of scientific knowledge and skills, and decision-making in an authentic context for science literacy measurement among adults. Despite the criticism, most science literacy assessment tools are still based on the GSS-NSF battery of questions (Snow & Dinber, 2016; Trémolière & Djeriouat, 2021). Kahan (2017) proposed a tool composed of three questions from the GSS-NSF survey, six numeracy scale questions and three questions from the Cognitive Reflection Test and argued that this combination could better assess science literacy and differentiate levels of science literacy.

Recently Sjöström and Eilks (2018) suggested Vision III or "critical science literacy" which they define as responsibility and critical thinking that is oriented towards science learning for praxis-oriented science engagement and self-determined life.

This study describes the development and validation of an adult science literacy assessment test consistent with Visions II and III of science literacy. It builds on K-12 research. By combining different approaches, it was designed to achieve a better understanding of the role science knowledge plays in adults' lives by relating general and contextualized science knowledge to facets of everyday engagement with science. In the following section, the researchers describe the iterative process of tool development.

Methodology

Research Design

To capture the interactions between demographic characteristics, general and contextualized science knowledge and engagement with science in this study, the researchers focused on four socio-demographic questions (e.g., gender, age, education, scientific background and income), standardized general science knowledge, contextual science knowledge in the field of hearing and advocacy knowledge and attitudes in parents of hard of hearing children. The questionnaire had four stages of development. : a pre-developmental stage (based on input from four hearing rehabilitation experts and three parents), a paper and pencil close-ended questionnaire (n = 10), a paper and open-ended pencil questionnaire (n = 24) and an online close-ended questionnaire (n = 91); see Figure 1.

The general science knowledge questions (as well as the demographic questions) were kept constant between stages. General science knowledge was tested using 12 closed-ended true/false questions from the GSS-NSF's battery of factual knowledge questions (e.g., The center of the Earth is very hot) (National Science Board, 2018). The questions were translated into the local language by the researchers and then back-translated by an English teacher to confirm the quality of the translation. A third translator compared the source text and the back-translated text. Changes were made in the local language version to make it more accurate. The development of the contextual science knowledge and advocacy attitudes and knowledge parts of the questionnaire went through four main developmental stages (Figure 1).

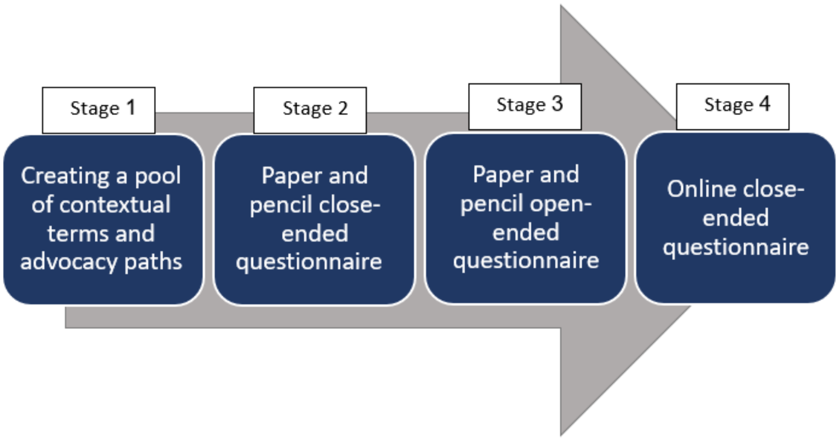

Figure 1. Development of the Contextual Science Knowledge and Advocacy Attitudes and Knowledge Sections of the Questionnaire

Findings

Stage 1: Creating a Pool of Contextual Terms and Advocacy Paths

Four hearing rehabilitation experts (Sara, Robin, Odette, & Ina) and three parents of hard of hearing children (York, Lora&, Loren) were interviewed about the potential needs for science-related knowledge of parents of hard of hearing children and how science could help them to advocate and promote their children's rights. These preliminary open interviews were conducted in the informant's homes or workplace and lasted 30-40 minutes.

The interviews yielded a list of 20 contextual science terms relevant for the advocacy and child's right promotion. For instance, Sara, a speech language pathologist (SLP), with nine years of experience working with hard of hearing two to five-year olds stated that the term "ear fluid accumulation" should be classified as a contextual science knowledge term since it impacts and the challenging decision parents need to make about an educational institute:

> *Parents have to understand that an ear infection (otitis) can influence hearing. It's important for parents to understand that accumulation of fluid in the ears can affect hearing rehabilitation; it might cause a temporary halt in hearing aid use.*

She also stressed one of the first advocacy decisions hearing rehabilitation parents have to make, and the importance of the need to be informed:

> *A lot of parents find it hard to choose an appropriate daycare environment for their hard of hearing child. Many parents have the misconception that sign language is bad. They are afraid it will block their child's oral language development. They tend to choose the type of daycare or argue with the educational staff as a function of this misconception*.

The concepts of "audiogram" (contextual science term) and "acoustic class" (parental advocacy) emerged from the interview with Robin, a parental counselor in an educational rehabilitation center with 30 years of experience.

> *Parents must know how to read and comprehend an audiogram. They have to understand the meaning of their child's hearing decrease. Based on the audiogram, they need to understand which tones their child might not hear*.

She explained the importance of parental insistence for the fulfillment of their child's rights:

Parents have to make sure that their children rights are respected. For example, they must choose an acoustic class if their child has a moderate to severe hearing loss. This might be helpful in noisy classes.

The terms "ABR test" (contextual science) and "financial and academic support" (advocacy path) emerged from the interview with York the father of a 12-year-old boy with a post-lingual hearing loss. He said: 'ABR test… I was trying to understand it. I wanted to understand what the algorithm [flow] of the test is. I mean what procedures will be followed after each kind of test result.' As regards advocacy, he said: 'Parents can request financial support from the Ministry of Health. In school, children have the right to get academic support from special education teachers.'

Next, the list of the 20 science terms related to hearing loss was distributed to another twenty parents and experts, who were asked to rank them in terms of their importance (see table A1). This resulted in a list of the top 10 science terms: hearing aid, cochlear implant, audiogram, hearing test, hearing threshold, speech banana, fluid accumulation (serous otitis media), ABR test, Tympanometry test, sound intensity (decibel) and sound frequency (Hertz). Similarly, a list of parental advocacy terms was generated: disability benefits, academic support, Speech, and Language Pathologist (SLP), educational placement, acoustical adjusted classroom, state financial support for hearing aids, and assistive listening device (ALDs) (such as the FM system).

Stage 2: Paper and Pencil Close-Ended Questionnaire

The ten science terms identified by parents and experts (see table A1) were used to develop questions on scientific knowledge in context. These were ten multiple-choice questions, such as "A decibel is: (a) sound intensity; (b) A unit of measure for sound intensity; (c) A unit of measure for frequency; (d) level of hearing loss." Parents were asked to select the right answer (all questions are listed on Table A3).

Based on findings from Stage 1, parental advocacy attitudes and knowledge were measured on a table listing all nine rights and specific arrangements for children with hearing loss. Parents were asked to mark all the rights their children were currently benefitting from. The ratio of the number of rights to the total number of rights constituted the parental advocacy score. For example, if a parent of a hard of hearing child with severe hearing loss indicated exercising 5 of the 9 rights, the score would be 56% (different levels of hearing loss are eligible for different rights, and this score accounts for this situation).

2.1. Validation.

The validation of the questionnaire in Stage 2 took place in three steps:

(1) Content validity was quantitatively assessed by a panel of five audiology experts. All of the experts had experience of at least three years in rehabilitation of deaf and hard of hearing children. They rated each contextual science knowledge question as essential, useful or irrelevant to measuring the construct. Their responses were analyzed using a content validity ratio (CVR) (Lawshe, 1975). Only questions with a CVR over 0.99) were included in the questionnaire.

(2) Qualitative content validity was assessed by seven science communication experts. Their recommendations concerning grammar, vocabulary, word order and scoring method were used to modify the questionnaire where needed.

(3) The revised versions of contextual science knowledge, general science knowledge and parental advocacy knowledge and attitude questionnaires were validated by two parents (Karabenick et al., 2007). The cognitive pretesting interview protocol consisted of three: reading aloud the question, explaining the meaning of it in their own words, and answering the question. The interview transcripts were analyzed, and unclear items in the questionnaire were modified.

Stage 2: Paper and Pencil Closed-Ended Questionnaire Results

The questionnaires were distributed and filled out by ten parents from 10 different families from January to May 2014 (Table 1). All participants spoke Hebrew fluently, and this was the only language the children were exposed to. Each family had only one hard of hearing child; all other members of the family heard normally. The results are summarized in Table 1.

Table 1. Scores for General Science Knowledge, Contextual Science Knowledge and Parental Awareness and Exercise of the Child's Rights (Advocacy Knowledge and Attitudes) on the Paper and Pencil Close-Ended Questionnaire (n=10)

Age	Gender	Highest level of Education	Formal scientific background	General science knowledge score	Contextual science knowledge score	Awareness and exercise of the child's rights score (advocacy)
36	F	BA degree	Academic	69	87	100
41	M	MA degree	JHS	100	86	100
50	F	BA degree	JHS	85	100	80
45	F	High school diploma	JHS	69	68	100
44	F	BA degree	Academic	54	71	50
38	F	BSc degree	Academic	100	98	80
39	F	MSc degree	Academic	100	100	88
44	M	BA degree	JHS	100	96	90
48	M	BA degree	JHS	69	73	85
45	F	BA degree	JHS	85	86	90

F=female; M=male; academic=university level courses; JHS=junior high school

The small sample precluded statistical inference, but suggested an association between general science knowledge and contextual knowledge, but less of a relationship with advocacy knowledge and attitudes. This stage however pointed to a flaw in the way we measured contextual knowledge and advocacy. This study researchers discovered that one of the reasons so few parents were willing to participate was that parental knowledge and the quality of child's care were combined in the questionnaire. Parents felt that if they failed to do well on the science part it would reflect poorly on their parental skills and dedication.

Furthermore, the list of the rights of hard of hearing children and their implementation did not cover all advocacy situations. For example, one father who filled out the questionnaire told the interviewer that he had had a fight with his child's school because children were playing ball in class with the rubber tips on the chair legs that were part of the acoustic isolation. He had to explain why this was important to the school staff. This type of incident was not represented well on the list. Based on these insights' changes were made to the questionnaire to include more forms of advocacy.

Stage 3: Paper and Pencil Open-Ended Questionnaire

Contextual science knowledge was measured using nine open-ended questions formulated to address the same list of terms as in Stage 1 (Table A1); two terms were measured by one question (Table 2, Figure 2). Answers in this section were coded as either wrong, partial or complete. Inter-rater reliability coding by two experts in the field of hearing was satisfactory (Cohen-Kappa 0.87).

Table 2. Questions and Examples of Complete Answers on the Contextual Science Knowledge on the Paper and Pencil Open-Ended Questionnaire (stage 3)

Contextual science term	**Question**	**Examples of complete answers**
Hearing test, ABR	You were invited to your friends for dinner. During the conversation they mention the behavior of their one-year-old boy which they refer to as "selective hearing." The boy doesn't always answer when they call his name. Your friends think this might be due to hearing loss. The couple asks for your advice. Do you know a medical test that can help resolve their concerns? If so – which one?	A hearing test and an ABR can indicate the type and severity of hearing loss. For babies or children, ABR can be used if there is a suspicion of hearing loss that was not confirmed on the hearing test.
Tympanometry (a medical test)	Your friends are very confused. They are afraid that their son has a hearing loss. They heard that it might be "fluid" in the ears that cause this. They ask you: What medical test would show whether a child has a fluid accumulation in his ears?	A tympanometry test should be used to determine fluid accumulation.
Audiogram, Sound intensity, Sound frequency	The following graph (fig. 2) presents an audiogram of a child. What does the vertical axis represent? What does the horizontal axis represent?	The vertical axis (Y axis) represents the measurement of sound intensity and the horizontal axis (X axis) represents the measurement of frequency.
Audiogram, Hearing threshold	Is the hearing shown in this graph normal?	No. On this graph there is a decline in hearing. Normal hearing is usually between 0 to 15 decibels, and on the graph, hearing is between 30-75 Decibels.
Audiogram, speech banana	Can the child described in the graph hear and comprehend utterances?	No, this child's hearing threshold is below the speech banana for most frequencies.
Hearing rehabilitation aids	The pediatrician directed your friends to go to an educational rehabilitation center for Deaf and Hard of Hearing (DHH) children. In the center, the parents were advised to fit the child with hearing aids. The parents are not sure this will help their son's hearing. They ask you: "How will the hearing aids 'fix' the hearing impairment?"	A hearing aid will increase the sound intensity and enables hearing in the speech banana intensities and frequencies.

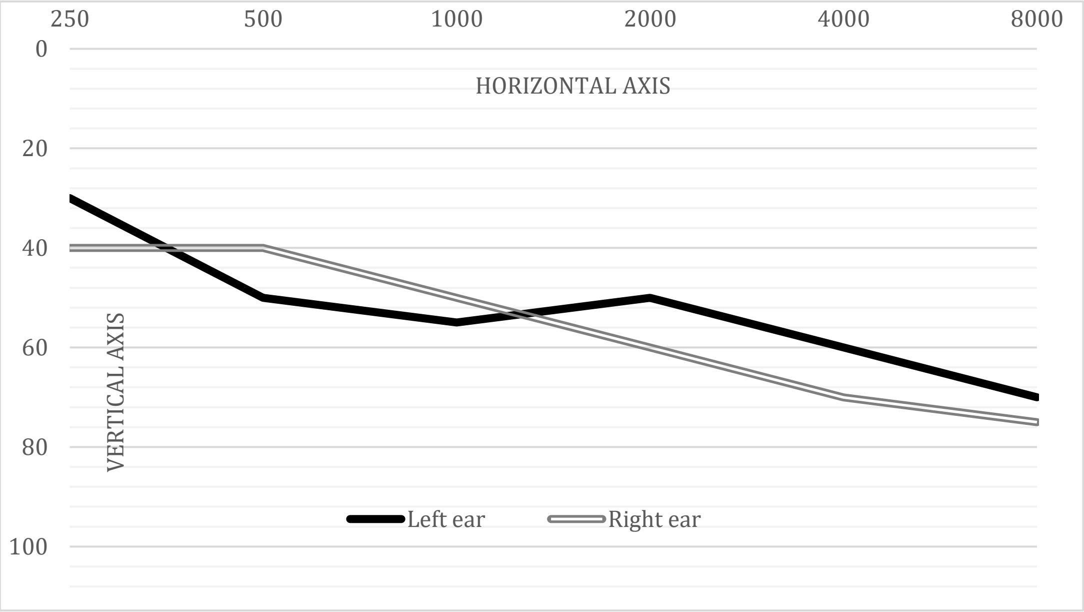

Figure 2. Audiogram of a Child Used in the Stage 4 Questionnaire Based on a Modification of the Audiogram Used in Stage 3

Parental advocacy knowledge and attitudes were measured on three open-ended questions (Table 3) on topics that were highlighted by the hearing rehabilitation experts and parents. Answers were scored as the number of coping solutions suggested by the participants. Answers with three or more coping suggestions were scored as full answers (two points), answers with two or one relevant solutions were scored as partial answers (one point). No answer or irrelevant solutions were scored zero points.

Table 3. Scoring Rubric and Examples of Parental Advocacy Knowledge and Attitude Questions on the Paper and Pencil Open-Ended Questionnaire (Stage 3)

Question	**Complete Answer**	**Partial Answer**	**No Answer/ Irrelevant Answer**
Are there good types of hearing rehabilitation your child has used and can recommend to other parents?	"special daycare for hard of hearing children, special teacher for hard of hearing children, speech-language pathologist treatment and spending time talking and reading with the child"	"hearing aids, implant, speech-language pathology"	"I don't know any"
Your friends decide to try hearing rehabilitation with hearing aids. In a few days their son will start attending in a nearby preschool. The parents ask you whether– they should inform the preschool staff. What should be included in their instructions?	"Informing the staff is definitely needed. You need to explain the problem, emphasize how to approach and speak by standing in front, the child must be in close proximity to the speaker, the staff needs to notice if the child is not picking up information. Handling the hearing aids, and other issues (all that plus acoustically equip the room)".	"They should contact someone with authority, like a speech-language pathologist."	"They should say that the hearing aids are new to the boy and the staff should help him answer questions other kids might have."
In your opinion, which resources and skills are needed for the family of a hearing-impaired child to preserve his/her rights in the educational system (and other systems as well) throughout childhood and adolescence?	A lot of different resources of different types parents need to identify their child's needs and surround the child with professional therapies: speech-language therapy, psychotherapy, occupational therapy. matching hearing aid, close and careful hearing tracking, acoustically equipped classroom, and more.	Consistent involvement in the school and consultations with experts such as the speech-language pathologist, occupational therapist, and others.	A lot

The questionnaire went through the same validation steps as detailed for Stage 2. The questionnaire, which took 20-25 minutes to complete, was sent between June 2014 to February 2015 to 150 Hebrew speaking families of hard of hearing children age 6-15 from northern Israel. Twenty-four families returned full questionnaires: 9 were delivered and returned by rehabilitation center teachers, five were mailed, and 10 were answered and collected during face-to-face meetings (22% return rate). The respondents' demographics are presented in Table 5.

Paper and pencil open-ended questionnaire results

Parents with higher levels of education had a higher average score on contextual and general knowledge. Specifically, parents with a higher scientific background had a higher average score on general and contextual science knowledge – but not on advocacy knowledge and attitudes. Parents with higher incomes had better scores on the general and contextual science knowledge questions. Generally speaking, a higher than average income along with a higher level of education and science background characterized the participants with higher scores on general and contextual knowledge (Table 4). The results of the paper and pencil open-ended questionnaire should be interpreted with caution, however, given the small sample that precluded the assumption of a normal distribution. Nevertheless, the interactions between the variables were consistent with the results in Stage 4.

Table 4. Scores on General Science Knowledge, Contextual Science Knowledge and Parental Advocacy Knowledge and Attitudes for the Different Demographic Groups on the Paper and Pencil Open-Ended Questionnaire (N=24)

Characteristics	**Category**	**# of participants**	**Mean general science knowledge score ± SD**	**Mean contextual science knowledge score ± SD**	**Mean advocacy Knowledge and Attitudes ± SD**
Total sample		24	78.1±17.7	69.6±22.4	79.2±18
Gender	4	79.2±9.9	82.1±10.7	90.8±5	90.8±5
	20	77.9±7.8	67.1±5	76.9±4.1	76.9±4.1
Income †	5	75±15.6	54.3±2.8	74.7±16.4	74.7±16.4
	6	68.1±17.8	57.2±7.4	73.9±12.5	12.5±73.9
	13	83.9±17.2	81.3*±6.1	83.4±20.6	20.6±83.4
Level of education	16	71.4±4.4	62.5±4.9	76.9±4.9	76.9±4.9
	5	91.7*±2.6	85.7*±11.1	84.6±7.3	84.6±7.3
	3	91.7±4.8	81±12.6	82.2±5.5	82.2±5.5
Age	6	62.5±13.7	.595±10.6	77.8±16.5	16.5±77.8
	12	87.5*±13.1	73.8±6	75.1±21	21±75.1
	5	80±16.3	74.3±10.5	91.3±8.7	91.3±8.7
Formal Scientific background	15	69.4±16.8	63.7±23	79.1±16.4	79.1±16.4
	9	92.6*±5	80.9±22.5	79.4±21.5	21.5±79.4

Note: Normalized scores based on the percentage of correct answers. *Significant at the 0.05 level (2-tailed).
† compared to the average income in COUNTRY in 2015.

T test used for gender and scientific background. ANOVA and post-hoc Scheffé tests for income, age groups and years of education.

As shown in Table 4, the profile of the main advocate for a hearing-impaired child in this sample was most frequently an educated mother aged 41-46 with a higher than average income and good general and contextual knowledge.

Next, we ran multivariate linear regression analyses to test the predictive validity of the demographics on general science knowledge, contextual science knowledge, and advocacy attitudes and knowledge. Formal scientific background was a significant predictor of general science knowledge (p<.001) with 38% of the explained variance. Income and general science knowledge were the only predictors of contextual science knowledge (income: p<.01, general science knowledge: p<0.05) accounting together for 52% of the explained variance. Advocacy attitudes and knowledge did not emerge as significant predictors (Figure 3).

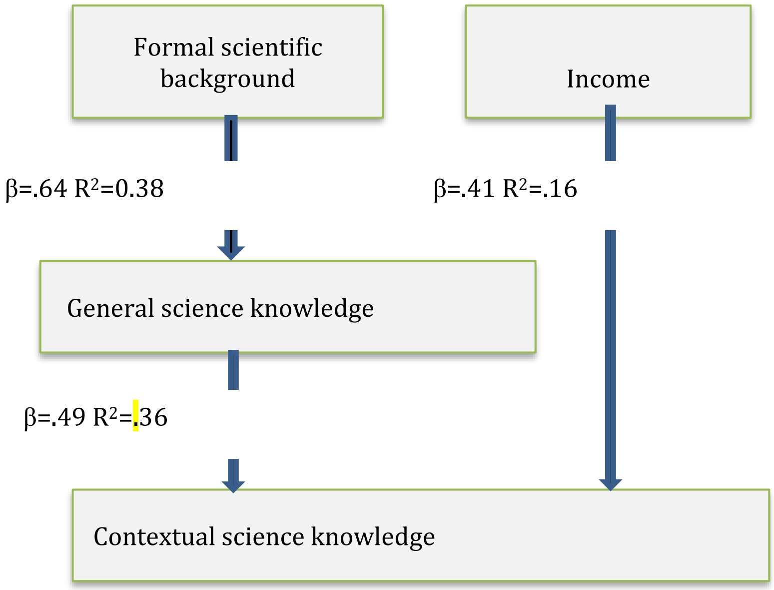

Figure 3. Interactions Between Socio-Demographic Characteristics, General Science Knowledge, and Contextual Science Knowledge Based on the Open-Ended Questionnaire (n=24)

Stage 4: On-Line Close-Ended Questionnaire

Due to low parental cooperation, probably because of the effort required to write answers to the open questions (Dillman et al., 1993), an online closed-ended questionnaire was developed. In the online questionnaire contextual science knowledge and parental advocacy knowledge and attitude were formulated as statements.

Contextual science knowledge was assessed on eight true/false statements (Table A2) based on the same terms as described earlier (Table A1). The resulting section was much shorter and less intimidating for parents. For example, instead of the open questions presented about the audiogram (Table 3 and Figure 3), the online questionnaire presented the same figure with the following True/False statement:

"An audiogram (a graphical summary of a hearing test) has two axes: The vertical axis (Y axis) represents the measurement of sound intensity and the horizontal axis (X axis) represents the measurement of frequency". (True)

The maximum score for this part was 8 points, which demonstrated acceptable internal consistency (α= 0.76).

Based on insights from Stage 3, Trainor's conceptual framework was used to develop the advocacy scale. Trainor (2010), based on focus groups of twenty-seven parents of children with various disabilities (autism, emotional or behavioral disabilities, cognitive disabilities and others), defined four types of parental advocacy: intuitive advocacy, information and knowledge-based advocacy, strategic advocacy and monitoring advocacy. She concluded that intuitive advocacy, which is based on the parents' personal insights about their child and on parental intuition, is usually the least affective form of advocacy and rarely promotes the exercise of the child's rights and needs. Information and knowledge-based advocacy is based on parental acquaintance with the specific information about their child's disability. Trainor (2010) pointed out that the more parental advocacy is supported by information and knowledge the more successful it is. Strategic and monitoring advocacy are characterized are not only by the knowledge and information parents have but also by the extent of their understanding of the laws and the special education system. These parents can combine their knowledge and understanding to achieve more effective advocacy. Parents applying monitoring advocacy use their social networking skills to promote systematic change and not only the changes needed for their children.

Sixteen statements were formulated corresponding to the four types of parental advocacy described in Trainor (2010) and Duquette et al. (2011) (Table 5). These statements were used to measure parental advocacy knowledge and attitudes on a Likert scale that ranged from 1-Strongly disagree to 4- Strongly agree, such as

"A parent does not need to know about the medical tests and treatment for hearing loss because the doctors provide the medical referral".

Table 5. Examples for Statements Reflecting the Four Parental Advocacy Styles

Intuitive advocacy	**Information and knowledge-based advocacy**	**Strategic advocacy**	**Monitoring advocacy**
Most of the parents of hard of hearing children are not aware of their children's rights	A parent of a hard of hearing child must acquire a lot of new knowledge in the field of hearing loss	A parent can feel safe and relaxed when his/her child is treated by educational rehabilitation centers	A parent must show a lot of tenacity to be sure his/her child can exercise his/her rights
Parents know their child best; they should tell the educational staff how to treat them	A parent needs to know how to read an audiogram to be able to support his/her hard of hearing child	Outreach and training of the educational staff is crucial for the child's integration	A hard of hearing child needs constant accompaniment and support from his/her parents because he/she will be treated differently

In addition to the validation steps described in the previous sections, the parental advocacy knowledge and attitude statements were also classified by science communication experts into four theoretical categories. Inter-rater reliability was acceptable (Cohen-Kappa 0.84). The responses were scored and normalized on a 0-100 scale, with an acceptable internal consistency (α= 0.7).

The questionnaire was disseminated through e-mail lists and *Facebook* pages of educational rehabilitation centers between March 2015 to August 2016. Ninety-one parents returned the questionnaires; their demographics are listed in Table 6.

On-line close-ended stage results

Parents with more years of education and higher levels of formal scientific background had higher mean general science scores. Specifically, parents with academic or high school-oriented science backgrounds did significantly better than parents who only took science up to 9th or 10th grade. Scores on the contextual science knowledge scale were lower for parents with fewer years of education. There were also significant differences for gender, with men doing better than women. However, it is worth noting that the number of male participants was much smaller, which may have biased the results (Table 6).

Table 6. General Science Knowledge, Contextual Science Knowledge and Parental Advocacy Knowledge and Attitudes for the Different Demographic Groups on the Online Close-Ended Questionnaire (n=91)

Characteristics	**category**	**# of participants**	**Mean general science knowledge score ± SD**	**Mean contextual science knowledge score ± SD**	**Mean advocacy Knowledge and Attitudes ± SD**
Total sample		91	80.4±16.7	73.2±20.9	79±9.6
Gender	**Male**	10	79.2±17.2	84.7*±12.2	78.8±5.7
	Female	81	16.8± 80.6	71.9±21.3	79.1±10
Income †	**Lower than average**	17	71.6±20.8	18.7±66.4	78.2±10
	Average	33	81.3±15.2	20.7±72.4	8.6±77.8
	Higher than average	39	82.7±15.2	22.1±76	80±10.3
Level of education	**Ara.14**	17	69.6±19.3	19.5±*61.7	74.6±8.5
	15-17	43	80.8±16	17.3±78.3	81.5±8.2
	≥18	31	85.8*±13.6	24±72.6	78.1±11.1
	Academic	25	10.6±*89.3	77±20.3	82.2±8.8
Age	**40-35**	32	77.6±17	73.4±23.4	9.5±76.2
	46-41	16	16.4±82.3	76.6±20.3	8.3±82.8
	60-47	8	77.1±19.3	19.9±67.2	7.7±78.9
Formal Scientific background	**Junior high (9th grade)**	16	17.5±.682	66.7±23.5	74.2±8.9
	High school-general (10th grade)	27	73.8±17.6	75±22.2	78.4±9.9
	High school-science oriented (12th grade)	23	87*±12.3	71.2±18.3	79.8±9.6

Note: *Significant at the 0.05 level (2-tailed). † compared to the average income in COUNTRY in 2015. T-test used for gender, ANOVA and post-hoc Scheffé tests used for income, age groups, scientific background and years of education.

In order to further explore these interactions Pearson and Spearman correlation tests were conducted (Table 7). As expected, income and level of education were significantly correlated with each other and with general and contextual science knowledge. In addition, parental advocacy knowledge and attitudes were significantly correlated with contextual science knowledge. Unexpectedly, however, it was also significantly correlated with formal science background and general science knowledge. However, once again, the small sample precludes the assumption of a normal distribution suggesting the results should be interpreted with caution.

Table 7. Correlations Between Sociodemographic Parameters, General Science Knowledge, Contextual Science Knowledge and Parental Advocacy Knowledge and Attitudes on The Online Close-Ended Questionnaire Stage (n=91)

	Gender	**Income**	**Level of education**	**Age group**	**Formal scientific background**	**Contextual science knowledge**	**General science knowledge**
Income	-.100						
Level of education	-.060	.233*					
Age group	-.081	.125	.121				
Formal scientific background	.004	.165	.353**	.006			
Contextual science knowledge	-.185	.163	.131	-.017	.149		
General science knowledge	.026	.221*	.325**	-.075	.478**	.329**	
Advocacy knowledge and attitudes	.010	.089	.077	.027	.254*	.258*	.234*

*correlation is significant at the 0.05 level (2-tailed); **correlation is significant at the 0.01 level (2-tailed) based on Pearson and Spearman correlation tests.

Next, we ran multivariate linear regression analyses to test the predictive validity of the different factors. Formal scientific background significantly predicted general science knowledge (p<.05) with 21% of the explained variance. General science knowledge was the only predictor of contextual science knowledge (p<.05) but only accounted for 9%

of the explained variance. Contextual science knowledge was the only predictor of advocacy knowledge and attitudes (p<.05) with only 5% of the explained variance (Figure 4). Sociodemographic characteristics other than formal scientific background did not predict any of the variables.

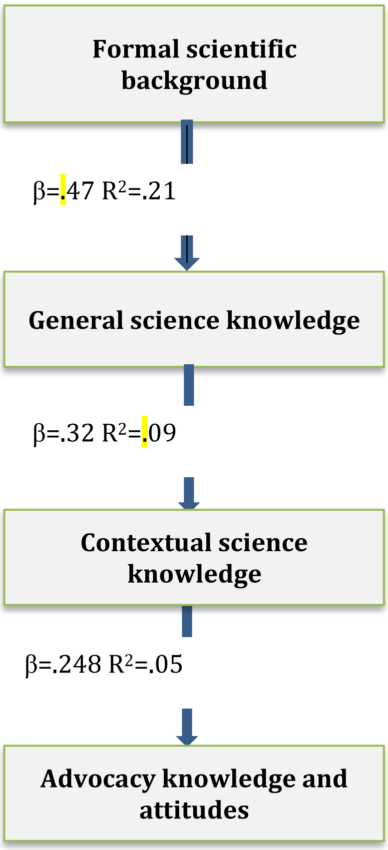

Figure 4. Interactions Between General Science Knowledge, Contextual Science Knowledge and Parental Advocacy Knowledge and Attitudes on the Close-Ended Questionnaire (n=91)

Discussion

This study aimed to develop and validate a contextual science literacy assessment tool. It describes the development, validation and adaptation process of a multifaceted science literacy questionnaire for parents of hard of hearing children. In so doing it empirically compared and contrasted measures of science literacy which corresponds to Vision I (GSS-NSF), vision II and III (contextual science knowledge and parental advocacy knowledge and attitudes).

The results (Table 4 and 6, Figures 3 and 4) suggest that general science knowledge, which is the focus of Vision I, enables the application of science to everyday science-related problems, which is the focus of Visions II and III. Kahan (2014) argued that there is no evidence that science knowledge as tested by the GSS-NSF scale can predict the ability of laypeople to resolve science- related daily problems. The results here however suggest the contrary.

However, it is important to note that general science knowledge only explained a small proportion of the variance in contextual science knowledge. Rather, the results point strongly to the importance of measuring science literacy among adults in a context that is relevant to them.

In addition, our results point to the disappointing outcomes of secondary science education. Formal scientific background predicted general science knowledge but did not account for the variance in contextual science knowledge at all. These results were consistently obtained in Stages 3 and 4 (Table 4 and 6). Furthermore, Table 6 shows no difference between adults who last studied science in 9th, 10th or 12th grade as regards their ability to use their science knowledge in a personally important science related context. Based on this small sample of 115 adults, our results may suggest that the school science these parents received as students, was not sufficient to develop their science literacy as expected by visions II and III.

This paper describes the development of a tool that may predict the practical relevance of science knowledge and literacy in one particular context of daily life; namely, parental advocacy for hard of hearing children. Some readers may argue that parents simply do not need science knowledge to care for their hard of hearing children. However, parents of deaf and hard of hearing children need to make many science-based decisions (e.g. type of rehabilitation), and use science knowledge to negotiate successful collaborations with the different professionals (e.g., hearing experts, doctors and educational staff). For example, a parent with a better understanding of an audiogram is able to better present the hearing difficulties of his/her child to the educational staff in school (Shauli & Baram-Tsabari, 2019). This duality is prevalent in the literature. On the one hand there is a body of scholarship pointing to the extremely attenuated effect of general science knowledge, per se, on various types of action in daily life contexts (Uğraş et al., 2017) . At the same time, case studies have shown that people acting in specific socio-scientific contexts are capable of taking informed actions that imply considerable knowledge of context-specific science (Bates, 2005; Trémolière & Djeriouat, 2021).

Learning theory, such as constructivism, clearly predicts and research generally confirms (Fosnot, 1996; Kennedy et al., 2015; Liu et al., 2014; Nivala et al., 2016 ; McCarthy & McNamara, 2021) that possessing a body of knowledge (i.e. “prior knowledge”) makes it easier to learn new related information. This interaction has also been suggested at the biological-neural level (Liu et al., 2019). Therefore, it is rather surprising that general science knowledge and more years of school science were not reflected in the parents' contextual science knowledge.

Conclusion

This study suggests a model for the development of a contextualized science literacy assessment for adults (Figure 1). This model can be used to develop contextualized questionnaires in other fields.

Recommendations

This study researchers suggest the key stages should include:

(1) Creating a pool of contextual terms and practical actions (e.g., advocacy) based on input from experts and engaged respondents (e.g. parents). (Table 1A)

(2) Narrowing the list based on the perceived importance of the concepts according to the views of the respondents (Table 1A)

(3) Develop a preliminary open questionnaire that addresses each of the concepts (Tables A2 and Table 2, Table 3)

(4) Conduct interviews and think aloud sessions with respondents, and adjust accordingly.

(5) Develop a close-ended questionnaire which corresponds to the narrow list and builds on insights from the preliminary version (Table A2, Table 5). On the theoretical level, this study also contributes to the literature on the usefulness of school level science knowledge in adulthood. One of the main justifications for emphasizing general science knowledge as an important component of science literacy is its potential role in facilitating the development of science knowledge that is relevant to a particular need or circumstance; i.e., contextual scientific knowledge.

Limitations

Several limitations of this study nevertheless constrain these conclusions. The main limitation was indirect assessment of aspects of Vision III of science literacy; i.e., the usefulness of science knowledge in daily life. We did not measure advocacy or its outcomes, we did not record rehabilitation or any other goal that the parents might have had. Instead, we used self-report knowledge and attitudes towards advocacy based on a specific expert opinion about what good advocacy looks like. It is very possible that parents had different ideas about the nature of good advocacy.

In this sense, this research tool is still in a preliminary and explorative phase in terms of assessing effective advocacy. Future research on measurement and a definition of "good" informed decisions and parental advocacy components as a proxy for usefulness will contribute to a better conceptualization of this highly complex issue.

One limitation which is more a positive than a negative component, in the case of measuring science literacy in context is the sample size and its local relevance. It is very possible that parents of hard of hearing children in another country, or parents from very different social demographic backgrounds would present different outcomes. In addition to these specific limitations, this study was affected by typical problems in questionnaire-based research: the issues of response bias, and the low response rate.

Ethics Statements

The study was approved by the Chief Scientist of the Ministry of Education in Israel (no. 8465; 19.10.14) and by the Institutional Review Board (21.05.14).

Authorship Contribution Statement

Both authors contribute equally to all aspects of the study.

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Appendix

Table A1. List of Contextual Science Knowledge Terms Rated According to Their Importance by Parents and Experts (N=20). Frequency Refers to the Number of People Who Rated the Term as One Of the Ten Most Important

Contextual Science Knowledge Term	Frequency
Hearing aid	18
Cochlear implant	17
Audiogram	17
Hearing test	16
Hearing threshold	14
Speech banana	12
Fluid accumulation	11
ABR test	9
Tympanometry test	9
Sound intensity (Decibel)	7
Sound frequency (Hertz)	7
Conductive/ Sensorineural hearing loss	6
Auditory nerve	6
Anatomy of the ear	5
Children's linguistic development	5
FM system	4
Mixed hearing loss	3
Eardrum (tympanic membrane)	2
Cochlea	2
Critical period	1

Table A2. List of Contextual Science Knowledge Terms and Corresponding Questions on the Close-Ended Stage 4 Questionnaire

Term	Questions
ABR test	The ABR test determines the type of hearing loss (conductive, sensorineural or a combination of the two) and its severity
Fluid accumulation	The phenomenon of fluid accumulation in the ears causes hearing loss
Tympanometry test	A tympanometry test assesses the level of hearing loss
Audiogram (sound intensity and sound frequency)	An audiogram (a graphical summary of a hearing test, figure 2) has two axes: The horizontal axis (Y axis) represents the measurement of sound intensity and the vertical axis (X axis) represents the measurement of frequency
Hearing threshold	A hard of hearing person's hearing threshold is above 20 Db
Speech banana	A hearing threshold below the speech banana means that spoken language cannot be understood
Hearing aids	Hearing aids are only suitable for people with a damaged auditory nerve
Cochlear Implant	A cochlear implant is only suitable for mild hearing loss

Table A3. List of Contextual Science Knowledge Terms and Corresponding Questions on the Closed-Ended Stage 2 Questionnaire

Term	Questions
ABR test	What is an ABR test? a. A hearing test for newborns. b. A hearing test that assesses auditory perception of sound and noise. c. A computerized hearing test that records electrical activity of the auditory nerve. d. A medical imaging technique of the inner ear In what cases is this test recommended?
Tympanometry test and Fluid accumulation	What is a tympanometry test? a. A hearing test for adults b. A hearing test for babies c. A flexibility test of the eardrum d. A test done under full anesthesia In what cases is this test recommended?
Audiogram (sound intensity and sound frequency) and speech banana	Based on figure 2: a. What does the vertical axis represent? b. What does the horizontal axis represent? c. Is the hearing shown in this graph normal? d. If not, please Indicate on the graph where normal hearing would be represented. e. Does the person described in this test hear and comprehend utterances?
Hearing threshold	What is the definition of normal hearing? a. Hearing that allows for normal functioning in daily life. b. Hearing at zero decibels in the range of observed frequencies. c. Hearing in the range of 0 to 15 decibels in the range of observed frequencies d. A normal hearing person is a person that doesn't use any kind of hearing aid.
Hearing aids	How does a hearing aid help to overcome a hearing loss? a. Hearing aid is amplifying sound intensity b. Hearing aid is attenuating sound intensity c. Hearing aid allows not to use the natural hearing at all d. Hearing aid transfers nerve stimulation directly to the auditory nerve
Cochlear Implant	How does a cochlear implant help to overcome a hearing decrease? a. Cochlear implant amplifies sound intensity and transfers the sign to the auditory nerve b. Cochlear implant bypasses the normal hearing and causes a direct nerve stimulation c. Cochlear implant changes sound frequencies and transfers it to the auditory nerve d. Cochlear implant changes sound frequencies and intensity and transfers it to the auditory nerve