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The usefulness of science knowledge for parents of hearing-impaired children

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Abstract

Hearing-impaired children's chances of integrating into hearing society largely depends on their parents, who need to learn vast amounts of science knowledge in the field of hearing. This study characterized the role played by science knowledge in the lives of nonscientists faced with science-related decisions by examining the interactions between general science knowledge, contextual science knowledge in the field of hearing, and parents' advocacy knowledge and attitudes. Based on six semi-structured interviews and 115 questionnaires completed by parents of hearing-impaired children, contextual science knowledge emerged as the only predictor for having slightly better advocacy attitudes and knowledge (5.5% explained variance). Although general science knowledge was the best predictor of contextual knowledge (14% of explained variance), it was not a direct predictor of advocacy knowledge and attitudes. Science knowledge plays some role in the lives of hearing-impaired families, even if they do not list it as a resource for successful rehabilitation.

Rationale

The hearing impaired child's ability to integrate into hearing society depends largely on developing efficient forms of communication (Most, Ingber, & Heled-

Ariam, 2012). This hinges on parental dedication to realizing their child’s potential (Nelson, Caress, Glenny, & Kirk, 2012). Most parents (over 90%) of deaf children are not hearing impaired, with little or no prior science knowledge of audiology (Northern & Downs, 2002). Thus, the moment of diagnosis is usually families’ first exposure to the world of hearing problems and their possible solutions (Vaccari & Marschark, 1997). Information on caring for a hearing-impaired child can take many forms, such as science 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, etc.). Parents need to find, read and assimilate copious, varied information, quickly (Fitzpatrick et al., 2008). They are not alone. Today's world is characterized by a growing need to implement science and technology in daily life, alongside much greater access to information on these topics (National Academies of Sciences, Engineering, 2016). Science educators argue that science literacy is a powerful tool for informed engagement in environmental, health and socio-political issues (The Organisation for Economic Co-operation and Development (OECD), 2016).

This study aims to bridge the disciplines of science education and science communication to examine the practical relevance of science knowledge in one particular daily life context using the methodologies and literature from both fields. It responds to the challenge raised by Kahan (2014) who deplored the absence of studies on the predictiveness of the US National Science Foundation (NSF) survey – a widely used research tool to assess public understanding of science (National Science Board, 2016) – concerning the ability to use and understand science in daily life.

The current study explored general science as well as contextual knowledge of parents of hearing-impaired children. It also examined the relationship between science knowledge, socio-demographic characteristics and parental advocacy knowledge and attitudes. Advocacy was defined by Wolfensberger (1977, in: Trainor, 2008) as the act of speaking and acting on behalf of another person or group of people to help address their preferences, strengths, and needs. Our purpose was to get one step closer to a measure of practical usefulness of science knowledge.

The idea of developing a measure of usefulness in public engagement with science is problematic because it assumes that an outsider can judge when success has been achieved, and that there is a single definition of success relevant across cases. We do not make these assumptions. Ideally, we could have operationalized "practical usefulness" as outcomes (such as effectiveness of rehabilitation), intentions or decisions to act (such as having implant surgery). However, these are influenced by many external and internal factors, and judging their success is highly subjective. Furthermore, the empirical literature offers little on factors that constitute a "good" informed decision, and there is a lack of research tools to measure the effectiveness of a "good" decision (Edwards et al., 2003).

For these reasons, we took a partially normative path. In environmental behavior research, "pro-environmental behavior" was defined as behaviors that consciously seek to minimize the negative impact on the environment (Kollmuss & Agyeman, 2002). Within advocacy scholarship, Trainor's (2010) classification of parents' advocacy ranks two patterns as more effective in helping their children. We followed Trainor's definition of effective advocacy in the operationalization of useful and effective advocacy knowledge and attitudes, since she did not propose a direct measure of success in advocacy. The resulting research tool is an effort to evaluate effective advocacy, but it is by no means complete or perfect. Future research on measurement and definition of "good" informed decisions and on parental advocacy components as a proxy for usefulness would certainly help the conceptualization and methodological aspects of this highly complex issue.

Literature review

Conceptual framework

The recent National Academy of Sciences report entitled "Science Literacy: Concepts, Contexts, and Consequences" (2016) notes that measures of science literacy in adults have traditionally focused on a limited set of content and procedural knowledge questions, recommending the research community "pursue new lines of inquiry around expanding conceptions of science literacy" (p.S-7). This study addresses the utility of science literacy and role of science literacy for citizens as decision makers.

When Paul de Hurd coined the term 'science literacy' in 1958, he was referring to new goals of science education in the USA after the Sputnik crisis, and defined it as knowledge about science and its implications for society. At that time Fitzpatrick

(1960) argued that science should not be taught solely for experts but rather "for all people". Many years and classifications later, Laugksch's (2000) differentiated two views of science literacy held by the "interest groups". One views literacy as content knowledge measured by survey questionnaires and is held mainly by the science education community and public opinion researchers. The second views it as the ways in which people understand science in daily life as measured through qualitative tools such as in-depth interviews and observations. This perspective is mainly held by sociologists of science and the informal science education community. Similarly, Roberts (2007) termed "Vision 1" the approach that defines science literacy as "the products and processes of science itself… At the extreme this approach envisions literacy within science" (p. 2). "Vision 2" corresponds to defining science literacy as skills and knowledge that students and lay people need, to deal with science related problems in daily life, such as Ryder's (2001) "functional science literacy". A recent definition published by the Programme for International Student Assessment, (OECD, 2016 p. 7) also adheres to Vision 2: “Scientific Literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen.”

These definitions of science literacy echo the ideological divide in theories and assessment of ‘public understanding of science’ and ‘public engagement with science’. Whereas PUoS aims at assessing the public's information gaps using standardized questionnaires, PES usually uses interviews and observations to chart the dialogue between science knowledge and the public's existing knowledge and how decisions about science related public issues are made (Nisbet & Goidel, 2007; Brossard & Lewenstein, 2009).

Contextualists criticize survey methodology for having low ecological validity, centering solely on missing knowledge, and oriented toward remedying education to overcome a "deficit". Toumey and colleagues (2010), for example, criticized surveys as a means of data collection, noting that science knowledge should be tested in the context of people's needs in daily life and their prior knowledge.

Conversely, survey researchers have criticized the low reliability and representativeness of ethnographic studies (Jerolmack & Khan, 2014; Nisbet & Goidel, 2007). Nevertheless, the two methodologies can be synergistic (Nisbet & Goidel, 2007; (Segev and Baram-Tsabari, 2012;). Ideally, triangulation of findings obtained using different approaches could lead to a better understanding of the role science knowledge plays in public life. Empirical triangulation could also help shed light on the relationships between the constructs of science literacy, public understanding of science, and public engagement with science.

Measures of Science Literacy

The best-known science literacy assessment tool for adults corresponding to the viewpoint of content knowledge as literacy was developed through collaboration between Miller (1998) in the US and Durant, Evans, & Thomas (1989) in the UK. These researchers developed a series of factual quiz type questions that tapped “textbook” knowledge known as the “Oxford Scale”. Miller (1983) suggested that civic science literacy involved three related dimensions: science vocabulary knowledge, understanding of science processes and understanding the impact of science on society. Since 1979, the US National Science Foundation (NSF) has based its large-scale surveys of public science literacy on this empirical operationalization of science literacy. The NSF survey is made up of a short battery of questions focused on factual science knowledge as well as an understanding of probability and basic constructs about enquiry (National Science Board, 2016). Similar batteries are used in other countries.

This survey has been criticized both ideologically (e.g., Ziman,1991, Wynne, 1992) and methodologically (Bauer, Allum, & Miller, 2007, Kahan, 2014). When Irwin and Wynne (1996) brought together different groups to discuss science issues that impact everyday life (e.g., air pollution), they found that most science knowledge is acquired outside the formal education system, supporting a sociological viewpoint of science literacy. However, this approach to science literacy tends to utilize contextual, small-scale, and interpretative studies. These may lead to broader conclusions but are not statistically generalizable.

The Programme for International Student Assessment (PISA) 2015 (OECD, 2016) assesses science literacy as the ability to explain phenomena scientifically, evaluate and design science enquiry, and interpret data and evidence scientifically. This conceptualization can provide a way to quantitatively measure science literacy in context.

Daily applications of science literacy

How do people use science knowledge and skills in everyday interactions? Research over the last twenty years has not yielded conclusive results (Feinstein, 2012; Irwin & Michael, 2003).

In their pioneering work, Layton, Jenkins, Macgill, & Davey (1993) summarized four case studies of varied citizens' groups, all of whom needed to deal with science to resolve problems in their daily lives, such as parents of Down's syndrome children. The researchers interviewed the participants about their science knowledge and the ways they used this knowledge to cope with problems they were facing. They concluded that practical science knowledge-in-action fulfils the following criteria: relevance to the person concerned, test of personal experience, related to other social knowledge, and derived from a trustworthy source.

Hilton, Hunt, & Petticrew (2007) found that when science knowledge is needed, for instance when parents have to decide whether to vaccinate their children, they do not always use science knowledge to make a decision. Parents' misunderstandings or gaps in knowledge about some vaccine-preventable diseases generally led to a lessened sense of need for vaccination. However, a recent study found that parents with relatively high scores on a health literacy questionnaire were more likely to be opposed to childhood vaccination (Amit Aharon, Nehama, Rishpon, & Baron-Epel, 2017). A study of polio vaccination discussions in a *Facebook* group found that although people debate science issues, their arguments are not based on empirical justifications, but rather on ungrounded claims (Orr et al., 2016). Therefore, the role of science knowledge in the context of the decision to vaccinate is complex. .

In a longitudinal study, Feinstein (2012) interviewed 10 families of children diagnosed with autism spectrum disorder (ASD). He found that although parents raised science-related questions about their children’s condition and used science resources, their concerns were not neatly bounded by science questions. Finally, an analysis of expressions of science literacy in readers' comments about online science related coverage showed that science knowledge may be used by the public in ways that were not envisioned or even desired, since science knowledge was used to express distrust in the science process and to oppose the scientific consensus (Baram-Tsabari and Laslo, 2014; Laslo et al., 2011).

These and other studies led Bromme and Goldman (2014) to argue based on the sociological theory of bounded rationality (Kahneman, 2003) that the public's limited understanding of science leads people to make science related decisions mostly by using quick heuristics, a phenomenon they called a "bounded understanding of science".

Informed parental advocacy

Children's key advocates are typically their parent(s) (Besnoy et al., 2015). Alper, Schloss, & Schloss (1995) described main five areas in which a disabled child might need advocative family support: physical-medical treatment, academic skills, social skills and friendships, integration in the community, and managing maturing and sexual development. Trainor (2010) described four kinds of parent advocates: the Intuitive advocate, a parent who uses personal insights derived from raising a disabled child, the Disability expert, a parent who uses information acquired from experts, the Strategist, a parent who uses personal insights and expert information, and an Agent for systemic change, a parent who uses personal insights, expert knowledge of the disability and the education system to advocate for a systematic change for his/her child and children with similar issues. The latter two groups have fuller and more varied information, and are generally more successful in their advocacy efforts (Trainor, 2010). Duquette et al. (2010) described four consecutive dimensions of advocacy: awareness (noticing the differences in development between a child and his/her peers), seeking information, presenting the case to educators, and monitoring (ensuring the fulfillment of rights and services).

Models of advocacy vary with respect to the number of strategies and the order of their steps, but the common thread is that informed parents are more successful advocates. Researchers have shown that most parents want to be effective advocates, but many are uncertain of rights, rules and regulations (Neumeister, Yssel, & Burney, 2013; Noh, Dumas, Wolf, & Fisman, 1989; Duquette, Orders, Fullarton, & Robertson-Grewal, 2011). Parents need to decide by themselves what constitutes required information (Duquette et al., 2010). Balcazar, Keys, Bertram and Rizzo (1996) compared the advocacy activities of parents before and after a training program that exposed them to information and leading organizations providing services to people with disabilities. The program was found constructive, regardless of parents' initial level of advocacy skills. However, the importance and usefulness of science knowledge for advocacy has been less well studied.

Advocacy by parents raises the problem of the unequal distribution of power. Bourdieu's (1986) notion of cultural capital is especially relevant here, since obtaining quality science education is a useful tool for enriching cultural capital (Claussen & Osborne, 2013). However, few studies have examined the effect of parents' science background when acquiring and applying new information.

Economic status and economic capital can also influence parental advocacy. High-income parents have access to superior resources and can pay for services that low-income families usually request from schools or health providers (Coots, 1998) or are asked to pay for (Resch et al., 2010).

Thus, there is a consensus among researchers regarding the major role of parents and parental advocacy in the successful integration of disabled children in society. However, the role of science literacy in informed advocacy remains unclear. This is specifically true in the case of parents of hearing-impaired children, who are usually first exposed to hearing-related information after their child is diagnosed, and need to quickly find, read and understand vast amounts of varied science information, and apply this newly acquired knowledge to advocate on behalf of their child.

Bass (2012) found that adult learning of new science knowledge is largely based on existing knowledge, not necessarily science knowledge. However, Ajzen, Joyce, Sheikh and Cote (2011) showed that degree of information accuracy fails to predict behavior.

Method

The objective of this study was to describe the interactions between general science knowledge, contextual science knowledge (both expressions of science literacy), and parents' advocacy knowledge and attitudes (enablers of effective advocacy). To achieve this goal, this mixed methods study had four stages (fig. 1):

[figure 1 about here]

(1) **Initial research tool development**, which involved interviews with four hearing rehabilitation experts and three parents of children with hearing loss. Interviews addressed the potential need for science-related knowledge of parents of hearing-impaired children for them to be in a position to advocate and promote their children's rights. Based on these seven interviews and the literature review, an open-ended questionnaire and interview protocol were developed to explore contextual science knowledge and parental advocacy knowledge and attitudes. These were inspired by the PISA 2015 (OECD, 2016) emphasis on the importance of assessing science literacy competencies in personal/local contexts.

The questionnaire's content was validated quantitatively using content validity ratio (CVR) (Lawshe, 1975), and qualitatively by audiology and science communication experts whose recommendations concerning grammar, vocabulary, word order and scoring method were adopted. Cognitive validity was established with two families of hearing-impaired children (Karabenick et al., 2007). The cognitive pretesting interview protocol consisted of three questions on each item in the questionnaire: reading aloud the question, explaining it in their own words, and answering the question. Unclear items were modified.

(2) **Study I** involved semi-structured interviews with 6 parents of hearing impaired children and 24 additional parents of hearing impaired children who

responded to an open-ended questionnaire (Appendix 1 online). They were recruited by sending a questionnaire and cover letter to 150 families via teachers from educational rehabilitation centers and distributed in parental meetings from June 2014 to February 2015.

(3) **Research tool development**. The open-ended questionnaire yielded many incomplete responses, probably because of the effort required to write out the answers (Dillman, Sinclair, & Clark, 1993). Therefore, a closed-ended version was developed probing contextual science knowledge (CSK) using true/false questions and parental advocacy knowledge and attitudes (PAKA) using agreement on a 1-4 Likert scale. The items in this version were based on the perspectives the parents raised during the interviews, to enhance ecological validity and allow comparable analysis. For example, one of the PAKA statements: "Most of the parents of hearing-impaired children are not aware of their children's rights" was integrated into the questionnaire following parents identifying lack of information about their children's rights, which they saw as preventing them from being good advocators. Validity was established in the same way as described in stage 1.

(4) **Study II** involved 91 parents responding to an online closed-ended questionnaire (Appendix 2). The online questionnaire was disseminated through e-mail lists of the educational rehabilitation centers and their Facebook pages from March to August 2016.

Research population. Over 4,500 hearing impaired children (ages 3 – 21) studying in various educational frameworks in Israel (0.3% of all the students in the country). Of these, about 75% were enrolled in inclusive education (Levy Goldman 2013). The sample was composed of hearing parents having only one hearing-impaired child aged 6-15 at the time in inclusion education (i.e. a mainstream school). This population was chosen since parents of children in inclusion education are confronted with a greater need to advocate on behalf of their children and to preserve their rights.

Sample. One hundred and fifteen participants completed the questionnaire. Most of the sample were women (88%), mainly in the age range of 23-40. Many had 15 years of education (indicative of a bachelor's degree) or more and a higher than average income. The level of science background was similar to the general population: about a quarter for junior high level science, general science in high school, advanced science in high school, and science at an academic level (Table 1).

Ethical considerations. 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).

Table 1. Sample demographics

Characteristic		**Number of participants (n=115)**	**Percentage of participants**	**Percentage in the general adult population***
Gender	Male	14	12	49.6
	Female	101	88	50.4
Age	22-34	36	31	28.6**
	35-40	37	32	28.1**
	41-46	28	24	23**
	47-59	13	11	20.3**
Education (no. of years)	12-14	27	23	39
	15-17	48	42	23
	18≥	40	35	28
Highest level of science education	Junior high	31	27	35
	High school-general	27	23	16
	High school-science oriented	24	21	12
	College and graduate level	33	29	38
Socio-economic status (income)	Income lower than average	22	19	26.2
	Average income	39	34	57.8

	Income higher than average	52	45	16

*based on the report of the *Israel Central Bureau of Statistics*, 2015 ** age distribution was calculated only for the 40.4% of the country's population who are in the 22-59 age range.

Research tools.

1. An open-ended questionnaire was designed to examine general science knowledge (GSK), science knowledge in the context of hearing impairment (CSK), advocacy knowledge and attitudes (PAKA), and to collect demographic and socio-economic data (see Appendix 1 for the full instrument). Respondents' answers on the CSK were content-analyzed and scored based on a rubric. Similar analysis was done for PAKA answers. The emerging categories were the basis for the CSK and PAKA statements in the closed-ended questionnaire. This procedure, used by mixed-method scholars (Arnon & Reichel, 2009; Kelle, 2001) enabled us to integrate the results of both questionnaires by grading both the open and closed ended questions in the same manner and statistically analyzing their results together.

General science knowledge (GSK) was tested in both Study I and II using 12 closed-ended true/false questions from the NSF's battery of factual knowledge questions (Table 2) (National Science Board, 2016). Questions were translated into Hebrew by the researchers and then back translated by an English teacher to confirm the quality of translation. Internal consistency of the GSK statements was satisfactory ($\alpha = 0.71$).

Table 2. Percentage of correct answers to general science knowledge questions in the research sample, adults in Israel (Ministry of Science, 2015) and American adults (National Science Board, 2016). The GSK results for Studies I and II did not differ statistically.

Question	% of correct answers in sample	% of correct answers among Israeli adults	% of correct answers among US adults
The center of the Earth is very hot (True)	92	84	84
All radioactivity is man-made (False)	85	76	72
It is the father's gene that decides whether the baby is a boy or a girl (True)	86	75	59
Lasers work by focusing sound waves (False)	60	64	50
Electrons are smaller than atoms (True)	65	60	51
Antibiotics kill viruses as well as bacteria (False)	71	53	55
The continents on which we live have been moving their locations for millions of years and will continue to move in the future (True)	89	86	82
Does the Earth go around the Sun, or does the Sun go around the Earth? (Earth around Sun)	83	69	76
How long does it take the Earth to go around the Sun?	59	64	55
A doctor tells a couple that their genetic makeup means that they have one in four chances of having a child with an inherited illness. Does this mean that if their first child has the illness, the next three will not? (No)	61	n.d.	84
Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many of them experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug? (The second way)	57	n.d.	53

Why is it better to test the drug this way? (Because a control group is used for comparison.)	49	n.d.	53
Average score	71.4	70.1	64.5

Contextual science knowledge (CSK). In Study I CSK was measured using nine open-ended questions based on issues hearing rehabilitation experts and parents of hearing impaired children had indicated as important for effective informed advocacy (e.g., Figure 2, Appendix 1). These included knowing about different medical tests (ABR, hearing test, tympanometry test), interpreting an audiogram (axis representation, hearing threshold, the speech banana), and knowing about the function of hearing rehabilitation aids. Qualitative verbal content was converted into quantitative binary data by identifying correct statements addressing the core issues. Correct answers received one point. Inter-rater reliability was established for the whole sample after shared construction of a rubric by two experts in the field of hearing with satisfactory agreement (Cohen-Kappa 0.87). Study I respondents were divided into three groups based on their CSK scores (high 100-87.5, mid-range 87-62.5, and low – below 62) to characterize the ways in which they used science in their answers.

Participants' answers were used as statements in the closed-ended questionnaire in Study II; e.g., a CSK statement in Study II: "Hearing aids are only suitable for people with a damaged hearing nerve" (True/<u>False</u>). On this basis, we integrated the results of Studies I and II for statistical analysis.

Internal consistency of the CSK statements was satisfactory, but not high (α= 0.68). A possible explanation for this level of reliability of the CSK and GSK questionnaires is the relatively small sample. In a subsequent study involving the same questionnaire with 297 responders in three different languages (Hebrew, Arabic and English), the reliability was higher (α= 0.73 unpublished data).

[Figure 2 about here]

Parental advocacy knowledge and attitudes (PAKA) measure was inspired by the four stages/types of advocacy suggested by Trainor (2010) and Duquette et al. (2011). In Study I PAKA was measured using three open-ended questions on topics that were highlighted by the hearing rehabilitation experts and parents; e.g.: "Are there good types of hearing rehabilitation you can recommend to other parents?" (Appendix 1). The same method used for scoring CSK was used to score PAKA: answers were content analyzed and scored based on the number of appropriate coping solutions suggested by respondents. Inter-rater reliability was established for the whole sample after shared construction of a rubric by two experts in the field of hearing with satisfactory agreement (Cohen-Kappa 0.87). In Study II, 16 closed-ended statements were used, based on parents' answers to the open- ended questions in Study I. These were ranked on a 1-4 Likert-scale with satisfactory internal consistency (α= 0.76) (Appendix 2).

2. Semi-structured 40-50 minute interviews were conducted with six families in their homes. The goal was to examine the same objectives in greater depth, by enabling respondents to express scientific related knowledge and lay expertise more freely. The protocol included all the questions in the open-ended questionnaire, and additional questions; e.g., "Over the past few years since your child was diagnosed, what kinds of new knowledge you have acquired? How did you do so?"

Statistical analysis. Correlational data and multivariate linear regression (stepwise method) analyses were used for each of the general science knowledge, science contextual knowledge and advocacy knowledge and attitude measures. Quantitative data were analyzed using SPSS 21.

Interview analysis. interviews were recorded, transcribed and analyzed using the thematic analysis method (Shkedi, 2003). At first reading, primary categories were developed based on the major themes emerging from the data; e.g., science knowledge emerging from parents' concerns, or hearing-impaired rights. These categories served as initial codes for classifying each of the text segments and were further revisited and developed throughout the analysis to form the final codes.

Results

Our analysis looked at interactions between demographics and types of knowledge, interactions between general science knowledge and contextual science knowledge in the field of hearing, and whether contextual science knowledge was a factor in parents' advocacy knowledge and attitudes, as a proxy for effective advocacy.

Parents' general science knowledge (GSK), contextual science knowledge (CSK), and advocacy knowledge and attitudes (PAKA)

General science knowledge (GSK) did not differ statistically between Study I and II ($F(1,113) = 0.343$, $p > 0.05$). General science knowledge was slightly higher on average than that of the general Israeli population (Table 2), but was not statistically significant. Contextual science knowledge (CSK) was not high on average and ranged from 12.5% to 100% correct answers. There was no statistically significant difference in averages in CSK score between Study I and II ($F(1,113) = 0.533$, $p>0.05$).

The combined results of Study I and II revealed complementary insights into the ways GSK supported CSK. The hardest questions for parents were those requiring the application of general science knowledge. For example, in Study I, parents found it difficult to explain the way hearing aids help hearing-impaired people. Most answers did not draw on science knowledge about the hearing process or ear structure. Many parents did not use content science knowledge to explain phenomena scientifically in this context.

The easiest question for parents was how to determine hearing loss based on an audiogram, where they could apply their visual memory of "good" or "bad" results of hearing tests without a full understanding of the graph. Once again, content and procedural knowledge were not utilized to interpret the data or evidence scientifically. Parents apparently relied on heuristics from their daily experience to answer correctly, since they were unable to explain the meaning of the axis or to interpret correctly the results, but were able to state whether the audiogram described a hearing loss.

Respondents in Study I were divided into three groups based on their CSK scores. Demographically there were no statistically significant differences between groups. Parents with the highest scores (100-87.5; n = 9) were able to utilize content and procedural knowledge and knew how to explain and interpret data scientifically. High achievers used science terms such as Db and threshold and used them correctly to interpret data.

Parents with midrange scores 87-62.5 (n =7), could usually name the right terms but did not know how to integrate this content knowledge into their procedural and interpretational skills. Parents with low scores (62-12 points; n=8) could explain and interpret the data using heuristics based on their daily experiences but usually could not explain or interpret them scientifically.

The average PAKA for Study I scores did not differ statistically from Study II ($F(1,112) = 0.05$, $p > 0.01$). Respondents were divided into two groups based on their PAKA scores: High scorers (n=58) – parents who agreed highly with effective advocacy statements, whose scores ranged from 80% to 100% and low scorers (n= 55), whose scores ranged from 79% to 60%. A T- test for independent samples was conducted to compare CSK and GSK in low and high scorers on the PAKA. A significant difference in CSK scores between high PAKA scorers ($M=77.5$, $SD=17.2$) and low PAKA scorers ($M=67$, $SD=24.2$) was found ($t\ (111) = 2.7$, $p < 0.05$). The effect of GSK was not significant. These results suggest that CSK may have an effect on parental knowledge and attitudes towards advocacy.

Interactions between general science knowledge, contextual science knowledge, and parents' advocacy knowledge and attitudes

Study I (n=24): A Pearson correlation analysis and Spearman nonparametric correlation analysis indicated that GSK was significantly correlated with scientific background and education level and age: participants with more years of education ($r_s = 0.643$, $p < 0.01$) and a better scientific background (for GSK $r = 0.64$, $p<0.01$) knew more, older participants succeeded better than younger ones ($r = 0.43$, $p<0.05$). CSK was significantly correlated with GSK ($r = 0.602$, $p<0.01$), scientific background ($r=0.43$, $p<0.05$) and income ($r = 0.543$, $p<0.01$).

Study II *(n=91):* Pearson and Spearman tests were consistent with the findings of Study I: GSK and CSK were significantly associated with years of education (for GSK $r = 0.304$, $p<0.05$ and for CSK $r = 0.25$, $p<0.05$). Scientific background was significantly associated with GSK ($r = 0.48$, $p<0.01$). In this study as well, GSK was significantly correlated with CSK ($r=0.33$, $p<0.01$). PAKA was significantly associated with CSK ($r = 0.26$, $p<0.05$) scientific background ($r = 0.\ 254$, $p<0.05$), and GSK ($r=0.\ 234$, $p<0.05$).

Combined analysis (n = 115): Pearson and Spearman tests revealed that GSK was significantly associated with years of education ($r = 0.354$, $p<0.01$), scientific background ($r = 0.518$, $p<0.01$) and income ($r = 0.231$, $p<0.05$). CSK was significantly correlated with scientific background ($r = 0.23$, $p<0.05$), income ($r = 0.25$, $p<0.01$) and years of education ($r=0.292$, $p<0.01$) and GSK ($r=0.394$, $p<0.01$). PAKA was significantly correlated with CSK ($r=0.26$, $p<0.05$).

Multivariate linear regression analyses were conducted testing the predictive validity of demographics on science knowledge, GSK on CSK, and on PAKA ($n= 115$). Scientific background ($\beta=0.414$, $p<0.01$) and years of education ($\beta=0.198$, $p<0.05$) were the only predictors of GSK with 28.8% of the explained variance. GSK predicted CSK ($\beta=0.387$, $p<0.01$) with 14% of the explained variance. CSK was the only predictor of PAKA ($\beta=0.252$, $p<0.05$) and accounted for 5.5% of the explained variance (Figure 2).

Low general science knowledge (GSK) may have limited parents' ability to acquire and understand contextual science knowledge (CSK). When divided into four groups by their GSK scores (low GSK 30-58 ($n = 22$); intermediate GSK 59-83 ($n = 42$); high GSK 84-92 ($n = 32$); excellent GSK 93-100 ($n = 18$)), parents at the lowest level were significantly inferior to all other groups on their CSK scores (one- way ANOVA ($F(3,110) = 8.344$, $p = .000$). Post- hoc comparisons using the Tukey HSD test indicated that the mean score for the low GSK ($M = 55.7$, $SD = 18.4$) was significantly different from the other groups ($M_{inter} = 70.3$, $SD = 22.5$; $M_{high}=74.7$, $SD=19.8$; $Mexc=85.8$, $SD=12.5$)).

[Figure 2 about here]

Illustrations of general and contextual science knowledge supporting parental advocacy in the Interviews

Five mothers and one father of hearing impaired children aged 8-14 were interviewed. Analysis yielded four major themes: (1) Difficulties accepting the diagnosis of hearing impairment, (2) Main sources of knowledge are relatives and medical doctors, (3) Previous science knowledge is used to comprehend contextual knowledge, and (4) Knowledge of difficulties and rights and contextual science knowledge drives parents to advocate for their children. Here we focus on evidence that previous science knowledge enriches the parental "tool box" and helps integrate new contextual science knowledge, and the ways in which science knowledge may support PAKA.

Previous science knowledge is used to comprehend contextual knowledge. Interview analysis revealed that parents with a scientific background were more likely to use science terms than other parents. For instance, Olivia the mother of 13-year-old girl with severe hearing loss, has a B.Sc. degree in Chemistry. When asked "Can the person described by this audiogram hear spoken words clearly?" she said:

"G. (her daughter), hears at 25 at all levels, the frequencies…..based only on this graph this child does not need an implant. This is a kid for a hearing aid. This is because he hears at 30 Db. In the case of an implant, it should be a straight line at 180". Using content knowledge, such as the terms decibel, frequency and a graph, helped Olivia interpret the data scientifically.

Nora, the mother of 14-year-old boy with a moderate hearing loss is a school graduate. She answered the same question in the following way:

"It is ABR. Here (pointing to the vertical axis) it's decibels, right? …I don't know what it is on this line (pointing to the horizontal axis)… The line means a decrease, increase. Decrease, right? "

Nora did not understand any of these basic science knowledge terms. Confusing general science terms (calling the axis 'decibels' and confusing the name of the medical test) prevented her from correctly interpreting the audiogram. Other parents with a basic scientific background also had problems understanding the meaning of the graph. They analyzed it more like a picture by talking about whether the line was in the upper or lower part of the drawing rather than extracting meaning from the different hearing measurements on a continuum of frequencies and volume levels. An example is Amanda's answer. Amanda, the mother of an 8 year old boy, who has a high school diploma and only a mandatory junior high school level scientific background, answered: "Audiogram? Audiogram is a graph, no? This graph represents the test of strengths. The high and the low. So they <u>actually draw</u> this graph, no?" Amanda used "drawing" in her answer supporting an interpretation of a painting rather than a graph.

General science knowledge supports contextual science knowledge and parental advocacy. The interviews also provided information on the role of content, procedural and epistemic science knowledge in supporting parental advocacy. Daniel, who has a B.Sc. in Electrical Engineering, is the father of an eight-year-old girl with a severe hearing loss. When asked: "can you please recall an example of a case when you used science in an advocacy situation?", he said "when we have to take M. (the daughter) to speech therapy and occupational therapy treatments and elsewhere my wife goes with her. However, all the medical testing and stuff is on me. I go with M. to the hearing tests, hospital, blood tests and everything she needs. I feel more comfortable than she does explaining the whole issue of the implant. When we had to explain to the children, teachers and staff about the implant at the beginning of first grade, I realized the meaning of science knowledge". Daniel's scientific background appears to make him feel more comfortable and confident in his understanding of medical terminology than his wife. His contextual science knowledge about the implant seems to help when he relates to his daughter's educational staff and peers. Olivia, who has a 13 year old daughter and science education at an academic level stated: "I read about the cochlear implant. I asked for extra explanations from the hearing rehabilitation center. At that point, I felt that learning the new hearing-related terms is useful…. I made the right decision for my daughter…" By contrast, a high school graduate, said:

"I actually did not understand the severity of my daughter's problem. I was told that my daughter hears at 40 decibels. I did not understand what that meant. I did not understand the severity. I did not understand what that number meant. I did not know that hearing on a level below 15 decibels is not O.K, and hearing on a level over 25 decibels means a hearing impairment. One day professor L. (her daughter's surgeon and the physician) told me 'you know how your daughter hears? Put your head into an aquarium full of water, and we will speak. That is the way A. (the daughter) hears.' Then I understood what my daughter's problem really was". Camilla also connected her contextual science understanding to the steps she took to get her daughter the help she needed: "… If not for professor L. I probably would not have gotten A. the help she needs".

Discussion

This study explored the role of science literacy in the daily lives of parents of children with a hearing impairment. We characterized the interactions between general and contextual science knowledge and parental advocacy knowledge and attitudes in a relatively small, educated research sample. The value of this study is more theoretical than practical. It suggests that improved measures might reveal a stronger link between general knowledge, context-specific knowledge, and practical outcomes and hints at what that relationship might be. Further research is needed for more practical implications.

In the current sample, the main caregiver of the hearing-impaired child, who is usually also the main advocate, was primarily an educated mother with higher than average income, who may feel more confident about her science knowledge than the average caregiver. The small sample and the fact that many participants shared a similar demographic profile (despite general science knowledge scores being comparable with representative Israeli adults, see Table 2) limits the generalizability of this analysis. Furthermore, specific wording of PAKA statements may have been too vague and answers could have been affected by the severity of the hearing-impairment.

However, the analysis suggests that engagement with science might be a factor in rehabilitation. In the interviews, parents demonstrated this point, which was substantiated by the statistical analysis of the questionnaires**.** Multivariate linear regression analysis showed that contextual science knowledge (CSK) emerged as the only predictor of parental advocacy attitudes and knowledge (PAKA), although only explaining 5.5% of the variance. Although general science knowledge (GSK) was the best predictor of CSK (14% of the explained variance), it was not a direct predictor of PAKA. These findings echo claims by Layton, Jenkins, Macgill, & Davey (1993) that lay people usually acquire science knowledge if it meets the criteria of personal and social relevance and personal experience.

Science background and education predicted GSK. This unsurprising finding echoes large scale surveys conducted all over the world (National Science Board, 2016; European Commission, 2005), thus enhancing the external validity of the questionnaires. This was also observed in answers provided by participants about different components of the audiogram. While both open and closed-questions probing a formal understanding of the graph (units, axis, the meaning of the curve) were mostly answered wrong, questions about interpretation of the results (normal or impaired hearing) tended to be answered correctly.

In spite of the high correlations, science background and education did not explain CSK or PAKA. This could have been expected in light of previous studies indicating parental level of education being a predictor of parental involvement in their children's school life (Waanders, Mendez, Waanders, Mendez, & Downer, 2007; Pickard & Ingersoll, 2016). Possibly a rich academic or scientific background is not enough for high CSK.

Parents with the lowest level of GSK were scored significantly lower than all other groups, suggesting that some parents cannot increase their understanding due to a lack of underlying concepts or skills. In addition, PAKA requires more than involvement. For example, for effective advocacy parents need contextual knowledge and advocacy related knowledge about relevant rights and laws.

Parents who displayed higher CSK emerged as having slightly better advocacy attitudes and knowledge. The small explained variance (5.5%) is consistent with previous research on environmental behavior (Ajzen et al., 2011). However, it is very possible that our operationalization of usefulness as parents' advocacy knowledge and attitudes was not comprehensive enough to include the range of situations in which science knowledge becomes a strong tool in parents of hearing impaired children. Thus, parents who have acquired contextual science knowledge may feel and may be more competent as advocates, but it is not the only or best factor to explain this feeling.

The findings also lend weight to the advocacy models suggested by Trainor (2010) and Duquette et al. (2010). Parents with fuller and more varied knowledge about the disability had slightly more effective advocacy attitudes and knowledge. Science knowledge plays a role in the lives of families of hearing impaired children, even if parents do not list it as a resource for successful integration of their children into hearing society. This is an important practical point for special education, since Gray (1994) showed that parents of autistic children made decisions about their child's treatment and rights with no clear correlation to medical models.

On a broader level, this study examined the role played by science literacy in lay people's daily lives. This issue was recently highlighted by the National Academy of Sciences report (2016) as having crucial importance not only on the individual level but also in terms of the community and society as a whole. Kahan (2014) argued that there is no evidence that science knowledge can predict the ability of laypeople to resolve science-related daily problems. However, Feinstein, Allen & Jenkins (2013) argued that when solving complex open-ended problems, people are supported by science knowledge and understanding, but this science knowledge seldom leads people to a full solution. The results of this study do lend some support to this claim in the tradition of vision 2 of science literacy. But is this enough? Science education in recent decades has become mandatory for all students in many countries, under the assumption that it has some value for their lives outside school. The communal disciplinary worldview is that science literate individuals make better, more logical, informed decisions. However, do people use science to make decisions? And if so, in what ways? Does using scientific ideas and ways of thinking to make decisions have beneficial consequences?

The usefulness of science education and background for the personal lives of non-scientists is not a yes/no question. There are levels of understanding, types of usages, and different consequences for different groups of people. Researchers have yet to identify the positive effects of science literacy on adults' lives, in the way health literacy does (e.g. improved quality of life).

This study sheds some light on the ideological and methodological question of the definition and measurement of science literacy. Data analysis of the interviews and questionnaires provides some evidence that general science knowledge, as measured by the commonly used NSF battery, can provide a better contextual understanding of science when needed. The results showed that sometimes parents used general science knowledge as a background for understanding contextual science terms (e.g., frequency, audiogram), procedures (e.g., ABR, tympanometry) and possible outcomes (e.g., fluid accumulation, rehabilitation path). Future research could further examine real-world effectiveness by looking for possible interactions between parents' science knowledge, declared feelings of effective advocacy and their children's feeling of integration into hearing society. This could further illuminate the contribution of science knowledge to non-scientists' well-being.

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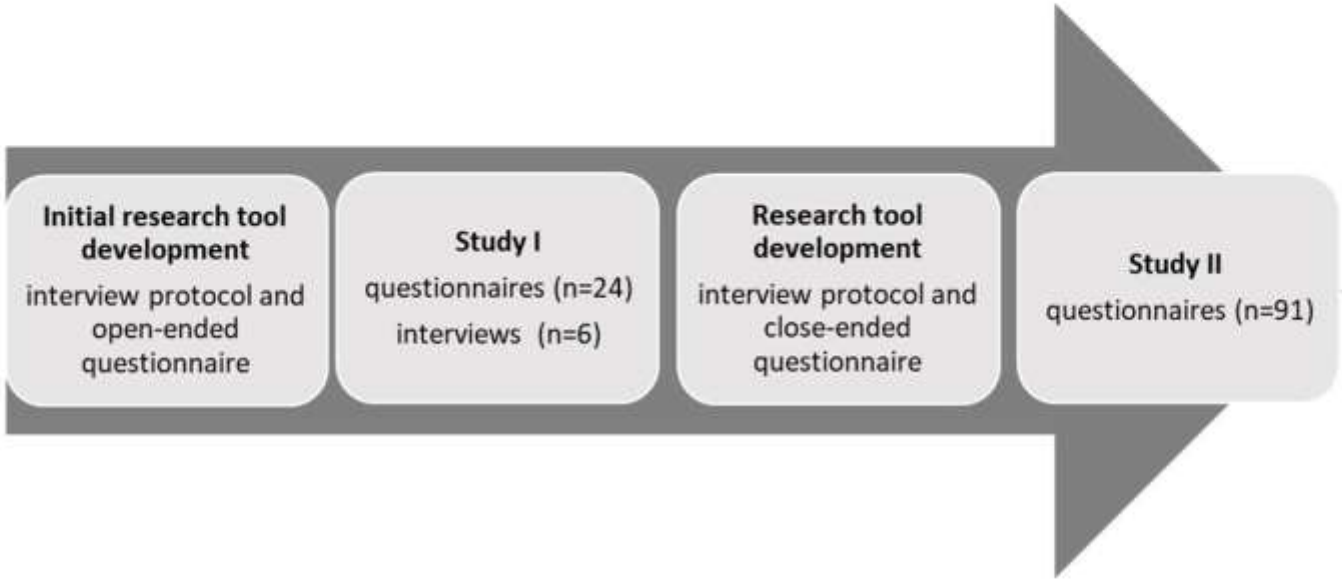
Figure Legends:

Figure 1. Research flow

Figure 2. Example of a contextual science knowledge (CSK) question. An audiogram is presented of the sort parents are given after a hearing test, and the following open questions are listed (answers appear in italics).

Figure 3. Interactions between general science knowledge, contextual science knowledge and parental advocacy knowledge and attitudes (n=115), based on multivariate linear regression analysis.

Figure 1. Research flow



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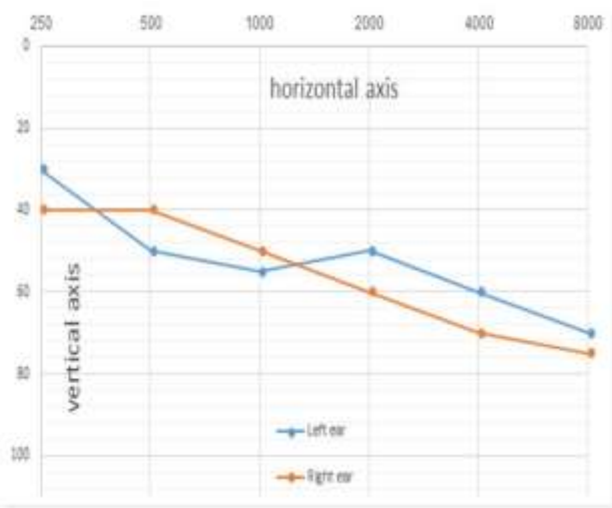

According to the following graph:

a. What does the vertical axis represent? *(the measurement of sound intensity)*

b. What does the horizontal axis represent? *(the measurement of frequency)*

c. Is the hearing shown in this graph normal? *(No)*

d. Does the person described in this test hear and comprehend utterances? *(No, some of the sounds s/he might not clearly hear and distinguish)*

Figure 3. Interactions between general science knowledge, contextual science knowledge and parental advocacy knowledge and attitudes (n=115), based on multivariate linear regression analysis.

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