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Student Perspectives on Learning Language Sample Analysis Using LENA

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Abstract

Language sample analysis (LSA) is valuable clinical tool and an important component of comprehensive language assessment. However, LSA is underutilized in real-world practice. SLPs have identified time constraints, insufficient training, and lack of confidence in LSA skills as barriers to regular LSA implementation. Communication science and disorders (CSD) programs have opportunities to provide LSA instruction to address these barriers and prepare students to reliably, feasibly, and confidently use LSA in clinical practice. This pilot study examined CSD students' perspectives on LSA instruction using the Language ENvironment Analysis System (LENA). Undergraduate students (n = 38) completed a series of two electronic surveys prior to and following LSA instruction using LENA. Changes in students' self-ratings of knowledge and skills in collecting and analyzing language samples, attitudes towards studying LSA and child language development, and critical thinking skills were assessed. Significantly higher student ratings were found for all items measuring language sampling knowledge and skills following digital LSA instruction compared to baseline. In addition, student ratings of enthusiasm for and confidence in studying LSA and child language development were also significantly higher. Students' self-ratings of critical thinking skills did not increase significantly following instruction in digital LSA. Implications for LSA teaching and learning are discussed.

Keywords

language sample analysis, LENA, students, SOTL, speech-language pathology

Cover Page Footnote

Thank you to Nicol Hernandez and the CMD students for their support of this study.

Introduction

Language sample analysis (LSA) is a valuable clinical tool and an integral component of comprehensive language assessment (American Speech-Language-Hearing Association [ASHA], 2018; Heilmann et al., 2010). LSA provides clinicians with a functional assessment of a child's language across all language domains, including syntax, morphology, semantics, and pragmatics. Collecting and analyzing samples of children's speech allows speech-language pathologists (SLPs) to identify communication impairments and determine eligibility for speech-language services (Dunn, et al., 1996; Heilmann et al., 2010). If deficits are identified, LSA can be used to establish a baseline of expressive communication behaviors, set treatment goals, and monitor progress over time (Barokova & Tager-Flusberg, 2018; Rescorla et al., 1997; Tager-Flusberg et al., 2009).

Learning to collect and analyze samples of child language are foundational skills for students in communication sciences and disorders (CSD) programs. For instructors of courses and labs that teach LSA, there are numerous valid approaches to consider. Currently, however, there is a dearth of research examining the perspectives and outcomes of students learning LSA. To our knowledge, only one study to date has reported outcomes of LSA training for students (Kroecker et al., 2010). For CSD faculty, it is not clear which instructional method(s) will result in optimal learning for students and, ideally, translate to continued use in clinical practice for professionals. CSD faculty need more data on students' experiences in learning and using various LSA methods. These data can inform teaching approaches that result in sustained behavior change in LSA implementation. Although research on student experiences in learning and using LSA are limited, numerous studies have examined the perspectives of practicing SLPs on implementing LSA in clinical practice over the past two decades. These studies have identified several barriers to regular LSA use.

Barriers to LSA Use Identified by SLPs in Clinical Practice

LSA is Time Intensive. One commonly cited barrier is that LSA is too time intensive (Kemp & Klee, 1997; Long, 2001; Pavelko et al., 2016). Long (2001) estimated the time necessary to complete manual analysis of a single language sample to take from 2.5 to 10 hours. If this is the case, it should not be surprising that LSA may not be feasible for most SLPs to implement regularly, given large caseload sizes and other work constraints.

Insufficient Training. A second identified barrier to LSA implementation in clinical practice is insufficient training and expertise (Bawayan & Brown; 2022; Kemp & Klee, 1997; Pavelko et al., 2016). In fact, 71 percent of the 938 practicing SLPs surveyed by Pavelko and colleagues (2016) indicated interest in receiving LSA training, particularly in the areas of analysis, interpretation, and development of treatment goals.

Lack of Confidence in LSA Skills. A third identified barrier to LSA use is SLPs' lack of confidence in their knowledge and skills to accurately and reliably use LSA (Bawayan & Brown, 2022; Heilmann, 2010; Kemp & Klee, 1997).

Efforts to Address Barriers to LSA Use in Clinical Practice

Concerns about underutilization of LSA in real-world practice have spurred efforts to address these barriers. Approaches include shortened language samples and the use of software to analyze language samples.

Shortened Language Sample. One approach to making LSA more efficient involves shortening the length of the language sample. For example, Pavelko and colleagues (2020) suggested that clinicians can use a sample of 25 to 50 utterances to obtain reliable measures of child language, including mean length of utterance (MLU), total number of words (TNW), clauses per sentence, and words per sentence. In contrast, other researchers have suggested that shortening sample sizes can result in invalid assessments of children's communication skills (Eisenberg & Guo, 2014; Guo et el., 2018). However, given the correct contexts and elicitation protocols, samples sizes of 50 child utterances are a generally acceptable minimum for reliable LSA (Pezold et al., 2020; Price et al., 2010).

LSA Software. Another approach to streamlining LSA is using software for analysis. There are currently several LSA software options available to clinicians, including the Systematic Analysis of Language Transcripts (SALT; Miller & Iglesias, 2018) and Computerized Language Analysis (CLAN; MacWhinney, 2000). Several studies suggest that LSA software programs can improve accuracy and reduce the amount of time to conduct analysis (Long, 2001; Miller & Iglesias, 2018 Price et al., 2010; Overton & Wren, 2014). However, other research suggests that use of LSA software can be similarly or, in some cases, more time intensive than manual LSA. For instance, in a recent focus group study of 11 Dutch SLPs, participants did not find the use of one language analysis software (i.e., CLAN) to be time efficient. In that study, researchers assumed clinicians would need less time than they did to complete the analysis, however participating SLPs spent around four hours analyzing 40-utterance samples.

To use LSA software, clinicians must first transcribe the sample and learn to format transcriptions to then be processed by computer. Different software programs offer different analyses, sampling contexts, and comparison databases (Pezold et al., 2020). This may partially explain why use of software for LSA does not seem to have increased measurably in the past two decades, despite wider availability of computers and software programs. For instance, in Kemp and Klee's 1997 study, eight percent of respondents indicated that they used computerized LSA methods. Almost two decades later, Pavelko and colleagues (2016) still reported that fewer than 10% of responding SLPs indicated regularly using LSA software (e.g., SALT).

CSD Student Instruction Can Address Barriers and Support Regular LSA Use

CSD undergraduate and graduate programs are a primary source of LSA knowledge and skills for practicing SLPs (Bawayan & Brown, 2022). Thus, they can play a critical role in addressing these barriers to LSA implementation and support a continuous cycle of improvement in clinical learning and efficacy. Towards this aim, the present study examined students' experiences in learning LSA using Language ENvironment Analysis (LENA; LENA Research Foundation, 2015). To our

knowledge, this study is the first to examine the perspectives of students in learning LSA using LENA.

LENA was chosen as an instructional LSA method because it may potentially address some of the LSA implementation barriers. First, as LENA does not require transcription or formatting of an analysis set, analysis with LENA is a less time intensive for students than using traditional LSA methods or other LSA software. Moreover, as students do not have to learn software-specific coding to complete analysis, LENA is relatively easy to learn and use (Gilkerson et al., 2007; Xu et al., 2009). Finally, compared to the 50 to 100 utterance sets typically analyzed when using traditional LSA methods and software, LENA can collect and analyze daylong recordings across multiple communication partners and settings. This may provide students with confidence in collecting a representative sample of child language.

In addition to addressing these identified barriers to LSA, training in LENA may also provide students with valuable clinical tools to assess and improve child language skills (Greenwood et al., 2011). For example, LENA has been used to share language environment data with parents (Sacks et al. 2014; Suskind et al., 2016. LENA language metrics have also been used to identify developmental risks and delays, challenges in language environment, and opportunities to enhance child-parent communication patterns. For example, LENA analysis of conversational turns has been used to identify deficits in initiations for children with autism spectrum disorder (Warren et al., 2010). LENA was also used to document that parents of children with Down syndrome spoke fewer words to children than parents of children who were developing typically (Thiemann-Bourque et al., 2014).

Features of Incorporating LENA in LSA Instruction

There are several unique features for instructors to consider when teaching students LSA using LENA. Here are some examples.

Automated Analysis. Analysis using LENA is automated. The LENA software uses algorithmic-based feature extraction and generates a segmentation map of the recording stream. Segments are matched statistically to LENA speech categories, including CH (key child), FA (female adult), MA (male adult), OL (overlap), TV (electronic media), NO (noise), and SIL (silence). Statistical modeling is also used to generate counts of automated speech variables, including adult word counts (AWC), child vocalization counts (CVC), and counts of conversational turns (CTC) – the back-and-forth alternations between the key child and an adult partner.

Core Reports and Metrics. LENA provides four core reports of these data (i.e., Adult Words Report, Conversational Turns Report, Child Vocalizations Report, Audio Environment Report) and a Composite Report that allow students to view graphs of sampled child language data in monthly, daily, hourly and five-minute time frames. Measures of background noise, electronic sounds, meaningful speech, and silence are reported as percentages of the total sound in the recording and are displayed in bar graphs along with the AWC, CVC, and CTC.

Additional Analysis. In addition to raw data counts, LENA's automatic vocalization assessment (AVA) generates a percentile score, estimated mean length of utterance (EMLU), standard score, and developmental age, for the sampled child, by statistically comparing features of the key child's acoustic signal to children of the same age and in the LENA dataset (Xu et al., 2008). Additional data can be extracted using LENA ADEX, allowing students to examine male and female adult word counts and initiations by key child with male and female adults, and vice versa (Van Dam, Ambrose, & Moeller, 2012). LENA speech variables examined by students in the present study are described in Table 1.

Table 1

LENA Variables

Acronym	Variable Name	Definition
CHN	Key Child Near	Near and clear speech signal produced by key child
MAN	Male Adult Near	Near and clear speech signal produced by adult male (e.g., father)
FAN	Female Adult Near	Near and clear speech signal produced by adult female (e.g., mother)
AWC	Adult Word Count	Estimated count of MAN and FAN vocalizations
CVC	Child Vocalization Count	Estimated count of non-vegetative, non-cry sounds of CHN
CTC	Communication Turn Count	Estimated count of turns between CHN and MAN or FAN
EMLU	Estimated MLU	Estimated mean length of utterance
AVA	Automatic Vocalization Assessment	Estimated scores of vocal maturity, generates a standard score and estimate of developmental age compared to other children of the same age and sex

Limitations of Incorporating LENA in LSA Instruction

Despite the unique features of automated speech processing with LENA, there are also notable limitations of the technology. Several limitations are described below.

LENA Does Not Transcribe Speech. First, LENA does not provide transcriptions of recorded speech. Rather, it analyzes the audio signal directly. As such, LENA's automated speech variables (e.g., AWC, CVC, CTC) are derived from the acoustic features of the signal, rather than semantic or syntactic rules.

Estimated MLU. LENA does not provide a count of true child utterances, as marked by semantic boundaries in manual transcription. Rather, LENA segments child vocalizations (CVs) by "breath groups", operationally defined as vocalizations followed by a 300 ms pause (Oller et al., 2010, supplemental material, p. 17). Estimated MLU provided by LENA is also generated from statistical

models by comparing features of the sampled child's speech signal to MLUs from children in the LENA database (Xu, et al., 2008). MLU is not calculated by averaging of morphemes across the number of utterances in a sample, unlike transcription-based LSA.

Common Language Metrics Not Available with LENA. LENA does not provide language measures commonly calculated in transcription-based LSA, including MLU, type-token ratio, and measures of clausal or lexical diversity. For students to calculate these measures, students must still generate transcripts and manually calculate measures or format them for analysis by other LSA software. Thus, LENA training enhances but does not replace learning of other LSA methods.

Limited Sampling Ages. Sampling age restrictions are another limit of LENA. For LENA language analyses to be valid, students must sample children under age 4 years. Given that acoustic features (e.g., fundamental frequency) of children's vocal output more closely resemble those of adults as they mature, LENA is less reliable in distinguishing between child and adult talk for older children and can erroneously include adult output in child vocalization counts and vice versa for children above the age of 4 years (VanDam & Silbert, 2016; Xu et al., 2009). Further, LENA's language sample analysis algorithms were originally trained on a sample of children ages one to four years who were learning North American English (Gilkerson et al., 2017; Xu et al., 2009).

Conservative Language Metrics. It is also important for CSD instructors and students to be aware that LENA's counts of language metrics are conservative when speech occurs in noisy environments or when speech occurs at low decibels or overlaps with other talk or noise (Canault et al., 2016; Xu et al., 2009).

Child-directed Speech. Additionally, although LENA can separate out speech signals from background and electronic noise (e.g., television or computer sounds), LENA does not currently differentiate between adult words that are said directly to the child and adult words that are said in range of the child but not necessarily directed to the child. For example, adult word count may include a parent talking on the phone spoken in range of the child's recorder. Thus, in interpreting these data, students should be aware that this may not be true child-directed speech.

LENA Does Not Include Video. Another consideration when using LENA is that students will not have video recordings of the child's interactions to reference when transcribing the language sample. LENA provides audio recordings that can be played back by students in five-minute segments by clicking on a waveform. However, without video, it can be difficult for students to know which communication partner is speaking on the playback, particularly when listening to discrete, five-minute recorded segments, which may start or end mid-utterance.

Cost. A final consideration is cost. Compared to other LSA software that is available for free (e.g., CLAN) or relatively low cost (e.g., SALT), instruction in LENA requires the purchase of digital language processors (DLPs) , adapted shirts, and software license subscriptions. Given the unique features and limitations of the technology, it is important to understand the perspectives of students in learning this approach.

Research Questions

The present study examined the perspectives of CSD undergraduate students on LSA training using LENA. Given that SLPs identified insufficient training as a barrier to regular LSA implementation, in the first and second research aims, we examined effects of LENA LSA instruction on student ratings of knowledge and skills in collecting and analyzing language samples. For the third research aim, given that SLPs reported lack of confidence in LSA as another barrier to implementation, we examined the impact of LENA LSA instruction on students' enthusiasm for and confidence in studying child language development and LSA. Finally, as a fourth aim, we also considered whether LENA LSA instruction impacted students' self-ratings of their critical thinking skills. Critical thinking skills are foundational for effective clinical work (Mok et al., 2008; Procaccini et al., 2016; Rehfeld et al., 2021). Training students to think critically about language data and child communication development can provide foundational clinical skills and give students a framework to adapt to inevitable future advances in LSA technology. Finally, we aimed to document students' qualitative opinions on what they most valued about learning LSA using a digital approach. Towards these aims, the present study examined the following research questions:

1. Are students' self-ratings of language sampling knowledge and skills higher following instruction in digital LSA using LENA compared to baseline?
2. Are students' self-ratings of language sample analysis knowledge and skills higher following instruction using LENA compared to baseline?
3. Are students' self-ratings of attitudes towards studying LSA and child language development higher following instruction in digital LSA instruction and analysis with LENA compared to baseline?
4. Are students' self-ratings of critical thinking skills higher following instruction in digital LSA using LENA compared to baseline?
5. What do students value about learning LSA with LENA?

We hypothesized that students would have higher ratings for items measuring LSA knowledge and skills following instruction with LENA compared to baseline. In addition, we hypothesized that students would have higher ratings for items measuring attitudes towards studying LSA and child language development, as well as higher self-ratings of critical thinking skills.

Method

Participants. Participants were recruited from students enrolled in the Language Development course. The Language Development course is typically taken by third-year undergraduate students majoring in communication disorders and by matriculated, out-of-field, graduate students meeting prerequisites before beginning graduate coursework. Students enrolled in the Language Development course have previously taken coursework on structural analysis of language and have experience in analyzing, but not collecting, short samples of child talk.

Approval for the study was granted by the university Institutional Review Board. All students enrolled in the Language Development course were invited to participate. Enrollment in the course was 47 students. Forty-one participating students completed the survey at baseline and 38 students

completed the survey following the LENA project. Data was only analyzed for students who completed surveys (n = 38). The mean age for participating students was 20.8 years. All participants were female Communicative Disorders majors. Across participants, 22 students reported having a cumulative GPA of 3.5 to 4.0, and 16 students reported having a cumulative GPA of 3.0 - 3.4.

LSA Training Module. The LSA module was taught using LENA in three to four lab-based sessions. Students were required to collect and analyze a language sample from a child (ages 1 to 4 years) using LENA technology. Students then completed a lab worksheet describing and interpreting language data and reflecting critically on the results, as well as the LSA method (Appendix A). The LENA Pro User Guide (LENA Research Foundation, 2015) was used to support student learning.

Student Learning Outcomes. Student learning outcomes for the LSA module included the following:

1. Students will understand how to collect representative samples of child language.
2. Students will analyze and evaluate child language data.
3. Students will effectively and confidently use technology in the sampling and analysis of child language.
4. Students will critically apply problem solving skills and knowledge of child language development to address fundamental questions in language sampling and analysis.

LENA Lab Session 1. To support students' knowledge and skills collecting language samples (Student Learning Outcomes 1, and 3), the first lab session focused on learning to operate the digital language processor (DLP). The DLP is approximately the size of a deck of cards (3-3/8" x 2-3/16" x 1/2") and weighs fewer than two ounces. Students learned to power the recorder on/off and to read the small screen that displays the status of the battery and indicates when the unit is sleeping or recording. Students also learned how to place the recorder in an adapted snap-pocket shirt to collect the sample. After demonstrating competency in using the recorder, students borrowed a DLP and adapted shirt to collect a sample of child language. The DLP allowed students to collect up to 16 hours of child language data per recording. As the recorder can be worn by the child throughout the day, students were able to collect child language samples across a variety of settings (e.g., playing outdoors, riding in cars, bicycling) and communication partners. Students were given the goal of collecting four-to-six-hour recordings of a child's language environment. Students either interacted with the child or asked the parents/caregivers to interact with the child for all or part of the recording time.

LENA Lab Session 2. In the second lab, students uploaded the audio data from the DLP to the lab computer to be processed by the LENA Pro software. (Student Learning Outcomes 2, 3, and 4). As upload times varied by length and amount of data recorded, students were given the option of returning to complete the analyses in a follow-up lab session.

LENA Lab Sessions 3 & 4. The final lab sessions focused on increasing students' knowledge of LSA and critical thinking skills (Student Learning Outcomes 2, 3, and 4). First, students visually examined the hourly Composite View Report showing bar graphs of each sampled hour for

LENA's automated measures, including audio environment, AWC, CVC, and CTC. Students then examined the Audio Environment Report and noted the amount of TV/Electronic time in the child's language environment during the sample. Next, students examined the 5-minute Composite View Reports for Adult Words, Child Vocalizations, and Conversational Turns. They identified three five-minute segments in their sample with the highest and lowest frequencies of AWC, CVC, and CTC variables. Students then clicked on the audio waveform for these segments to listen to the playback. Finally, students were given the option to either export the audio file to transcribe and analyze later or listen to the audio playback in the lab to complete a 50-utterance transcription and manually calculate MLU.

Students completed a lab worksheet to describe their sample and interpret the language data (Appendix B). Specifically, students answered following questions.

1. What were the child's peak talk times (i.e., 3 intervals with the highest CVCs) for the child you sampled?
2. What was happening in the language environment when the child used more vocalizations?
3. What were the child's low talk times (i.e., 3 intervals with the lowest CVCs) for the child you sampled?
4. What was happening when the child used fewer vocalizations?
5. When did your child have the most conversational turns? (i.e., 3 intervals with the highest CTC)?
6. Who did your sampled child talk with during intervals with the most conversational turns?
7. In considering the metrics (AVA, AWC, CVC, and CTC) and the audio-playback, do you think this was a representative sample of this child's language skills? Why or why not?
8. If you were going to take another sample of this child's language, what would you do differently and what would you keep the same?
9. How did the LENA estimated MLU compare to your manually calculated MLU?
10. Did you find anything surprising or interesting about the data you collected?

Survey Instrument. Using a series of two Qualtrics surveys, students' self-ratings were collected prior to instruction and following completion of the LENA LSA project. Student consent was solicited on the first page of the electronic study. Students who did not wish to participate were given the option of ending the study. Students were informed about the purpose, nature, design, and duration of the study. Demographic data (i.e., student age, year in school, major, grade point average) were also collected. To avoid any influence of student responses on course grades, survey responses were anonymous. At the end of the baseline survey, Qualtrics generated a random three-digit code for each participating student. Students were then prompted to enter their code on the second survey, to anonymously link responses from the same participant across the two surveys. Data collection using the questionnaires took about 20 to 30 min per survey. Prior to the current study, a trial survey was administered to four graduate students who had previously taken the Language Development course and were not involved in the study, to check for inconsistencies and to confirm understanding.

Survey Items. Survey questions were aligned with the instructional aims and student learning outcomes for the LSA module (Appendix B). The survey items were evenly divided to assess the impact of LSA instruction on students' perceived ability to collect representative language samples, ability to analyze those samples, attitudes towards studying LSA and child development, and impact on critical thinking skills. Students indicated responses on a Likert scale, ranging from 1 to 5, with 1 being the lowest level of agreement (i.e., "no gain") and 5 being the maximum level of agreement (i.e., "great gain"). Following the LSA project, students also provided qualitative responses to an open-text question prompting them to describe what they valued most about learning LSA using LENA.

Data Analysis. Data analysis was completed using IBM SPSS Statistics (Version 27). Descriptive statistics, including mean values for continuous variables and frequencies for categorical variables, were used to analyze demographic and response data. Paired samples *t*-tests (one-tailed) were run to examine any changes in students' self-ratings of survey items compared to students' self-ratings collected prior to instruction.

Written responses to the open text question were examined qualitatively. Students' comments were analyzed using grounded theory methods (Patton, 2002). After reviewing student comments, initial codes were developed by the author. A graduate research assistant read through and independently coded student comments. Through discussion, the author and research assistant compared and refined codes, resolved discrepancies, and reached consensus on a set of codes and relationships between codes (Creswell & Miller, 2000). Codes were then grouped into three thematic categories by the author (Birks & Mills, 2015).

Quantitative Results

Research Question 1. Are Students' Self-Ratings of Language Sampling Knowledge and Skills Higher Following Digital LSA Instruction Using LENA Compared to Baseline?

Compared to baseline, students' self-ratings were significantly higher for all five items pertaining to language sample analysis knowledge and skills. Increases remained significant with a Bonferroni adjusted alpha level of .010 per test (.05/5). These five items included: "I know how to collect a representative language sample", $t\ (37) = 12.27$, $p = < .001$; "I know the best settings to sample child language", $t\ (37) = 12.52$, $p < .001$; "I know the select optimal toys/materials to select for language sampling", $t\ (37) = 5.61$ $p = <.001$; "I know how to select optimal communication partners for language sampling", $t\ (37) = 7.45$, $p = < .001$; "I know how long it takes to collect a representative sample", $t\ (37) = 5.46$, $p < .001$. Table 2 describes the means, standard deviations, and paired sample *t* statistics for the survey item ratings assessing language sampling knowledge and skills prior to and following LSA instruction.

Table 2

Paired Samples T-Test Statistics for Language Sampling Item Ratings

Language Sampling Knowledge and Skills	Pre-Instruction		Post-Instruction		*t*	*p*
	M	*SD*	*M*	*SD*		
I know how to collect a representative language sample.	2.31	1.05	4.44**	1.04	12.27	<.001
I know the best settings to sample child language.	2.56	0.81	4.39**	.652	12.52	<.001
I know the optimal toys/ materials to select for language sampling.	2.75	0.93	4.11**	.979	5.61	<.001
I know how to select optimal communication partners for language sampling.	2.94	0.93	4.46**	.732	7.45	<.001
I know how long it takes to collect a representative sample.	3.00	1.09	4.23	.655	5.46	<.001

Note. *$p < .05$, **$p < .01$

Research Question 2. Are Students' Self-Ratings of Language Sample Analysis Knowledge and Skills Higher Following Digital LSA Instruction Using LENA Compared to Baseline? Student self-ratings for all five items assessing language sample analysis knowledge and skills were also significantly higher following instruction in digital LSA with LENA compared to baseline ratings. They remained significant with a Bonferroni adjusted alpha level of .010 per test (.05/5). These included the items: "I know how to calculate MLU*", t (37)* = 12.57, $p < .001$*; "*I know how to calculate total word count*", t (37)* = 3.62, $p < .001$*; "*I can identify patterns in the child's language*", t (37)* = 3.86, $p < .001$; "I can identify the child's peak talking times in the sample.", *t (37)* = 5.53, $p = < .001$*;* and *"*I understand how to compare a sampled child's language to language used by same-aged children*", t (37)* = 3.39, *p =.002.* Table 3 describes the means, standard deviations, and paired sample *t* statistics for the language sample analysis survey item ratings.

Research Question 3. Are Students' Self-Ratings of Attitudes Towards Studying LSA and Child Language Higher Following Digital LSA Instruction and Analysis with LENA Compared to Baseline? Students' self-ratings increased for two items assessing students' attitudes towards studying LSA and child language. These items included, "Enthusiasm for language sampling", *t (37)* = 3.01, $p = .005$ and "Confidence that I understand the course and project material", *t (37)* = 4.91, $p < .001$. Increases remained significant after Bonferroni correction to adjusted alpha levels of .0125 per test (.05/4). In contrast, there were no significant differences in students' self-ratings for the items: "Interest in taking or planning to take additional classes in

language development", *t (37)* = 1.47, *p* = .075; and "Comfort level in studying child language", *t (37)* = 0.86, *p* = 0.19. Table 4 describes the means, standard deviations, and paired sample *t* statistics for the attitudes towards LSA survey item ratings. Table 4 describes the means, standard deviations, and paired sample *t* statistics for the items rating students' attitudes towards studying LSA and child language development prior to and following LSA instruction.

Table 3

Paired Samples T-Test Statistics for Language Sample Analysis Item Ratings

Language Sample Analysis Knowledge and Skills	Pre-Instruction		Post-Instruction		*t*	*p*
	M	*SD*	*M*	*SD*		
I know how to calculate MLU.	2.23	1.03	4.29**	.071	12.57	<.001
I know how to calculate total word count.	3.37	.973	4.23**	.877	3.62	<.001
I can identify patterns in the child's language use.	3.00	.939	3.83**	0.78	3.86	<.001
I can identify the child's peak talking times in the sample.	2.57	1.20	4.11**	0.99	5.53	<.001
I understand how to compare a sampled child's language to language used by same-aged children.	3.06	1.51	4.09*	0.65	3.39	.002

Note. *$p < .05$, **$p < .01$

Table 4

Paired Samples T-Test Statistics for Attitude Item Ratings

Attitudes Towards Studying LSA and Child Language Development	Pre-Instruction		Post-Instruction		*t*	*p*
	M	*SD*	*M*	*SD*		
Enthusiasm for language sampling and analysis.	3.91	.070	4.43**	0.65	3.01	.005
Interest in taking or planning to take additional classes in language development.	4.06	0.80	4.34	0.73	1.47	.075
Confidence that I understand the course and project material.	3.43	0.78	4.29**	0.67	4.91	<.001
Comfort level in studying child language.	4.26	0.74	4.40	0.55	0.86	.19

*Note. *$p < .05$, **$p < .01$*

Research Question 4. Are Students' Self Ratings of Critical Thinking Skills Higher Following Instruction in Digital LSA using LENA Compared to Baseline?

Students reported higher self-ratings for three items assessing critical thinking skills following instruction. These items included: "Willingness to seek help from others (teachers, peers, TA) when working on academic problems", $t\ (37) = 2.38$, $p = .011$, "Connecting key ideas from the project with other knowledge from class", $t\ (37) = 2.22$, $p = .016$, and "Applying what I learned from doing this project in other situations", $t\ (37) = 2.11$, $p = .021$. However, after Bonferroni correction, increases in students' self-ratings were no longer significant at the adjusted alpha level of .010 per test (.05/5). In addition, there were no increases in students' ratings for two items designed to measure more broad application of critical thinking skills: "Using systematic reasoning in my approach to problems", $t\ (37) = 0.32$, $p = .318$ and "Using a critical approach to information I encounter in daily life", $t\ (37) = 0.30$, $p = .383$. Table 5 describes the means, standard deviations, and paired sample *t* statistics for critical thinking skills item pre-post LSA instruction.

Table 5

Paired Samples T-Test Statistics for Item Ratings Critical Thinking Skills

Critical Thinking Skills	Pre-Instruction		Post-Instruction		*t*	*p*
	M	*SD*	*M*	*SD*		
Willingness to seek help from others (teachers, peers, TA) when working on academic problems.	3.88	0.92	4.24*	.65	2.38	.011
Connecting key ideas from the project with other knowledge from class.	3.84	0.89	4.22*	0.71	2.22	.016
Applying what I learned from doing this project in other situations.	3.97	0.92	4.53*	0.79	2.11	.021
Using systematic reasoning in my approach to problems.	3.87	0.64	4.00	0.88	0.32	.318
Using a critical approach to information I encounter in daily life.	3.95	.074	4.00	.085	0.30	.383

*Note. *p < .05, **p < .01*

Student LSA Project Performance. In the present study, grades for the LSA project could not be correlated with individual students' survey responses, as responses were anonymous. However, aggregate LSA project scores for all students enrolled in the course ($n = 47$) were high (i.e., $M = 18.8/20$), suggesting that as a class, most students were successful in achieving targeted LSA learning outcomes.

Qualitative Results

Three themes emerged across submitted comments regarding what students most valued about learning LSA using LENA: (a) sophisticated language data output; (b) unobtrusive, representative sampling; and (c) ease and efficiency of language sample analysis. Themes, codes, and illustrative comments are described below.

Theme 1: Sophisticated Language Data Output. Students described valuing various features of the sophisticated LENA language data output. Codes within this theme included graphic data display, language metric counts, and audio environment analysis.

Code 1a. Graphic Data Display. Eleven students described that they valued the graphic display of language data**.** As one student commented, "Seeing the sample in a visual format on the computer made me realize how much of a pattern there may be for a child's language use and it was very interesting to see how their language changed in different settings and times of day." Another student wrote, "It was awesome to see when the child spoke the most and what she was doing at those times".

1b. Language Metrics. Three student comments described valuing the counts of language metrics provided by LENA. As one student wrote, "I enjoyed being able to see how much [name withheld] talked, and how many adult words were used, as well as the amount of conversational turns." Another student commented, "It was crazy that LENA could detect adult speech from child speech and count how many vocalizations/words were in them".

1c. Audio Environment Data. Three students described that they valued having data about the child's audio environment. As one student commented, "It was interesting to see the background noise picked up on the LENA. I was most interested in how the electronics program worked (it was very high tech)." As another student wrote, "LENA shows background factors effecting amount of language from client. This method helped me to look back and see what we discussed and how the child's language changed throughout the day."

Theme 2: Unobtrusive, Representative Sampling. Students described that they valued the unobtrusive, representative features of digital language sampling with LENA. Codes within this theme included: 1) representative language data sampled in the child's natural language environment and 2) comfort in sampling for both child and student.

2a. Representative Language Data Sampled in the Child's Natural Environment. Eight students commented that they valued the LENA LSA method for collecting representative language samples in the child's natural environment. As one student wrote, "I valued how natural it was to sample this way. My child went about his normal day; playing and running. While that would not happen in a traditional sample" Another student commented, "Sampling with the LENA made me realize how much more natural and comfortable the child's language was when he was able to go about his typical day instead of being videotaped." Another student commented, "I valued the fact that LENAs enable a fairly representative sample. It is unobtrusive, can record for up to 16 hours, and allows the child to interact with many people in a natural setting they feel comfortable in. The

child was able to move around and go about his daily routine, rather than sitting in one place like in the traditional sample". Two students commented more generally that they valued the representativeness of child language data collected by LENA in the child's natural environment. As one student wrote, "Sampling this way provides the ability to gather information in an everyday setting vs an artificial sample like in a clinic."

2b. Student and Child Comfort in Sampling. Two comments described that sampling with LENA was comfortable for both the child and student. As one student wrote, "I valued that the child and I both forgot that it was a project and continued throughout the day as we normally would.". As another student commented, "The thing I valued most about sampling this way, with the LENA, was that it felt as true and efficient as possible. I didn't have to sit there with a camera make him feel uncomfortable or act not true to himself."

Theme 3: Ease and Efficiency of Language Sample Analysis. Six students described that they valued using LENA for the ease and efficiency of language sample analysis, particularly compared to traditional LSA methods. Codes within this theme included transcription not required, and easy and efficient.

3a. Transcription not Required. Two students commented that LENA did not require transcription for analysis. As one student commented, "It was so quick and easy to obtain the data, without having to listen to hours of conversation and transcribe it all." Another student wrote, "This is a much easier and less time consuming versus writing every word, word for word."

3b. Easy and Efficient. Finally, three students described more generally valuing LENA for ease and efficiency of use. As one student commented, "I appreciated the method of sampling this way very much. It was very easy to do." Another student wrote, "I valued the simplicity of this type of sampling. The LENA did most of the work for me and provided a detailed summary of the child's language."

Discussion

This study adds to the limited research on students' perspectives in learning LSA. In addition, this study describes student experiences of LSA training using LENA, designed to address implementation barriers identified in the larger body of research that suggests using LSA in clinical practice is challenging. We anticipate that the findings of the present work can help guide teaching and learning efforts for undergraduate and graduate students in CSD programs. To that end, we discuss below several findings from the current study that advance our knowledge in teaching and learning of LSA with undergraduate students.

The first finding of note is that following LSA instruction using LENA, students had significantly higher ratings of knowledge and skills for collecting representative language samples, including identifying optimal settings, materials, communication partners, and sample length. In addition, students had significantly higher ratings for language sample analysis knowledge and skills following instruction in LSA using LENA, including calculating MLU and total word count, identifying patterns and peak talk times in the child's language, and comparing a sampled child's

language to language used by same-aged children. As insufficient training and lack of LSA knowledge and skills have been cited by SLPs as reasons for not implementing LSA in clinical practice, students' high ratings for items measuring LSA knowledge and skills are important outcomes of the present study (Klee & Kemp, 1997; Pavelko & Owens, 2016). Together with high student achievement on the LSA project, the finding of significantly higher student self-ratings for these items suggests that using LENA may be effective in supporting CSD students' learning of LSA knowledge and skills.

The second finding that we want to highlight is the significant increase in students' ratings of attitudes towards studying language sample analysis and child language development following instruction in digital LSA. Given that SLPs have described lack of confidence in LSA knowledge and skills as a barrier to implementation, increases in student confidence in understanding the course and project material are important outcomes of the present study (Heliman et al., 2010; Klee & Kemp, 1997; Pavelko et al., 2016). Early experiences of confidence in learning and using LSA may have long-term impacts on real-world LSA implementation as students transition to clinical practice. In the present study, students' self-ratings were significantly higher following digital LSA instruction for two of the four items. Specifically, students' enthusiasm increased for language sampling and analysis and confidence in understanding the course and project material after instruction.

Findings of increased confidence in students' LSA knowledge and skills in the present study may be attributed, at least in part, to the unique and user-friendly features of the digital LSA method. In other studies, SLPs reported limited use of LSA software and described software as too time-intensive to learn and use (Klatte et al., 2022; Klee & Kemp, 1997; Pavelko et al., 2016). In contrast, students in the present study did not describe the automated speech processing software as being time intensive to use. Rather, in qualitative responses to an open-text question, students described that they valued learning LSA with LENA for the sophisticated language data output, unobtrusive and representative child language sampling, overall ease and efficiency of digital language sample analysis. Given the capabilities of automated speech processing and portability of the digital recorder and software, students were able to collect four to six-hour samples of child language. Samples of this length allowed students to examine child talk across multiple contexts and communication partners. In addition, LENA software made it possible for students to quickly analyze hours of language data, including frequency counts of both child and partner speech metrics. Thus, the automated analysis of the digital LSA method likely contributed to increases in student's self-ratings of enthusiasm for and confidence in understanding the LSA project and the language development course. In contrast, no increases were found for two items that assessed students' attitudes towards studying language development more broadly (i.e., "interest in taking or planning to take additional classes in language development" and "comfort level in studying child language"). For these items, student ratings were high prior to digital LSA instruction (M = 4.06, M = 4.26, respectively) and remained high following instruction (M = 4.34; M = 4.40). As participating students in the present study were in their third year of the communicative disorders major, high ratings for these items at both timepoints likely reflects that prior to participating in the course and study, students were motivated to continue taking major classes and were comfortable in studying child language.

Another important finding of the present study was that LSA instruction incorporating LENA was associated with higher student ratings of some critical thinking skills. For example, students' ratings increased following digital LSA instruction for three items (i.e., "willingness to seek help from others when working on academic problems," "connecting key ideas from the project with other knowledge from class," and "applying what I learned from doing this project in other situations."). However, after Bonferroni correction, these increases were no longer significant. Given the small sample size (n = 38), increases in student self-ratings for these critical thinking skills may be significant in a future study with a larger sample of students. Critical thinking skills are integral for effective clinical work (Mok et al., 2008; Procaccini et al., 2016). Instruction that can enhance students' skills in thinking critically about language data may improve students' clinical efficacy and provide students with a framework to adapt to inevitable future advances in LSA technology.

In contrast, for two items designed to assess students' application of critical thinking skills more generally, no changes were found following instruction. Rather, for these two items (i.e., "using systematic reasoning in my approach to problems" and "using a critical approach to information I encounter in daily life"), students' ratings were low prior to digital LSA instruction (M = 3.87 and M = 3.95, respectively) and were not significantly higher following instruction (M = 4.00 and M = 4.00). These results suggest that although this instruction might increase specific application of critical thinking skills for LSA projects and the language development course, they may not generalize to contexts beyond the scope of the project and course. This finding is consistent with evidence across other studies of teaching and learning that suggest that acquisition of critical thinking skills may not transfer from specific content instruction to general approaches (e.g., Abrami et al., 2008; Saunders et al., 2000).

Limitations and Future Directions

Findings of this study fill a significant gap within the literature by examining students' perspectives in learning LSA using LENA. We anticipate that the results of the present work can help guide LSA instructional methods for incorporating automated speech analysis. However, there are several limitations. First, this study reported results from a small sample size of undergraduate students (n = 38) enrolled in a single CSD program. The experiences of these students may not generalize to all students in speech-language pathology programs. Further study, with a larger sample size of students across a variety of university CSD programs, is warranted to generalize results. In addition, the present study explored only one instructional method. It is not clear how LSA instruction using LENA compares to instruction in other LSA methods. For CSD programs with multiple sections of LSA courses or modules, instructors could collect data from random assignment of these sections to instruction incorporating traditional LSA, various language sample analysis programs, and automated speech processing. Another limitation of the current work is that student responses were anonymous to avoid any undue influence on participation. Thus, individual students' project or course performance could not be correlated with student survey responses. Future study that allows for correlations between individual students' ratings and assessment of LSA knowledge and skills, collected independently of a project or course project grade, would be valuable. Finally, future longitudinal study is needed to determine whether

training in digital LSA methods can result in continued LSA implementation as students transition to clinical practice.

Implications for LSA Teaching and Learning

Results of the present study will ideally stimulate increased attention to scholarship of teaching and learning in LSA and improve our understanding of instructional methods that can effectively support regular use of LSA by clinical SLPs. LSA is a valuable component of comprehensive language assessment but currently underutilized in clinical practice (ASHA, 2018). Thus, it is critical for CSD programs to develop instructional methods that can address identified barriers to LSA implementation and prepare students to reliably, feasibly, and regularly use LSA in clinical practice.

Specifically, coursework and labs should be designed to make LSA more time efficient and feasible for students to implement, while also supporting development of LSA knowledge and skills, self-efficacy, and critical thinking. Significantly higher student self-ratings found in the present study for child language sample collection and analysis suggests that instruction in digital LSA methods can support students' learning. Moreover, instruction in digital LSA methods may increase students' enthusiasm for and confidence in learning LSA, addressing an important barrier to implementation in real-world practice. Finally, instruction in digital LSA methods may improve students' critical thinking skills, particularly as applied to LSA. Overall, findings of the present study suggest that instruction in digital LSA incorporating LENA may offer one approach for CSD programs to bridge the gap between students learning LSA in school and actually implementing LSA in clinical practice.

Disclosures

Michelle Flippin is an Assistant Professor in the Department of Communicative Disorders at the University of Rhode Island. The author has no relevant financial or non-financial relationships to disclose.

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Appendix A

LENA Lab Worksheet

Student Name:
Child Sampled (First Name):
Age of Child (months):
Sample Date:
Sample Length (hours, minutes):

Describe Your Sample Child's Language Data

Audio Environment	
TV/Electronics Time	**Minute: % of Sampling Time:**
Hour 1	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
Hour 2	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
Hour 3	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
Hour 4	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
Hour 5	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
Hour	**Time:**
Adult Word Count	
Child Vocalization Count	
Conversational Turns	
AVA	
Standard Score	
Developmental Age	
EMLU	

Interpret Your Sampled Child's Language Data

1. When were the peak talk times (i.e., 3 intervals with the highest CVCs) for the child you sampled?
2. What was happening in the language environment when the child used more vocalizations?
3. When were the low talk times (i.e., 3 intervals with the lowest CVCs) for the child you sampled?
4. What was happening in the language environment when the child used fewer vocalizations?
5. When did your child have the most conversational turns (i.e., 3 intervals with the highest CTC)?
6. Who did your sampled child talk with during intervals with the most conversational turns?
7. In considering the metrics and the audio-playback, do you think this was a representative sample of this child's language skills – why or why not?
8. If you were going to take another sample of this child's language, what would you do differently and what would you keep the same?
9. How did the LENA estimated MLU compare to manually calculated MLU? If different, what do you think accounts for these differences?
10. Did you find anything surprising or interesting about the data you gathered?

Appendix B

Student Survey Items

1. I know how to collect a representative language sample.
2. I know the best settings to sample child language.
3. I know the optimal toys/ materials to select for language sampling.
4. I know how to select optimal communication partners for language sampling.
5. I know how long it takes to collect a representative sample.
6. I know how to calculate MLU.
7. I know how to calculate total word count.
8. I can identify patterns in the child's language use.
9. I can identify the child's peak talking times in the sample
10. I understand how to compare a sampled child's language to language used by same-aged children.
11. Enthusiasm for language sampling and analysis.
12. Interest in taking or planning to take additional classes in language development.
13. Confidence that I understand the course and project material.
14. Comfort level in studying child language.
15. Willingness to seek help from others (teachers, peers, TA) when working on academic problems.
16. Connecting key ideas from the project with other knowledge from class.
17. Applying what I learned from doing this project in other situations.
18. Using systematic reasoning in my approach to problems.
19. Using a critical approach to information I encounter in daily life.