EMPIRICAL MANUSCRIPT

Academic Achievement of Deaf and Hard-of-Hearing Students in an ASL/English Bilingual Program

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Abstract

There has been a scarcity of studies exploring the influence of students' American Sign Language (ASL) proficiency on their academic achievement in ASL/English bilingual programs. The aim of this study was to determine the effects of ASL proficiency on reading comprehension skills and academic achievement of 85 deaf or hard-of-hearing signing students. Two subgroups, differing in ASL proficiency, were compared on the Northwest Evaluation Association Measures of Academic Progress and the reading comprehension subtest of the Stanford Achievement Test, 10th edition. Findings suggested that students highly proficient in ASL outperformed their less proficient peers in nationally standardized measures of reading comprehension, English language use, and mathematics. Moreover, a regression model consisting of 5 predictors including variables regarding education, hearing devices, and secondary disabilities as well as ASL proficiency and home language showed that ASL proficiency was the single variable significantly predicting results on all outcome measures. This study calls for a paradigm shift in thinking about deaf education by focusing on characteristics shared among successful deaf signing readers, specifically ASL fluency.

Adequate literacy (reading and writing) skills are essential to being a successful participant in educational settings and subsequently in professional/employment opportunities (Lederberg, Schick, & Spencer, 2013). In most individuals, reading abilities start evolving in early childhood through development of preliteracy skills, advance with formal reading instruction in school, and expand as a result of higher education, social, and recreational experiences (Luckner, Sebald, Cooney, Young, & Muir, 2005). Without age-appropriate reading and writing skills, students cannot fully participate in classroom activities and are at risk for academic failure, leading to problems with employment and social adjustment (Moats, 2000).

Over the last 40 years, results from numerous studies have indicated that deaf children have significantly poorer reading comprehension, literacy skills, and overall depressed academic achievement in general when compared to their hearing peers (Qi & Mitchell, 2012; Wilbur & Quigley, 1975), decreasing the likelihood of enrollment in postsecondary education institutions (Garberoglio, Cawthon, & Bond, 2014). Numerous surveys (Allen, 1994; Traxler, 2000) report that approximately half of deaf students in the United States were reading below the fourth grade level at the time of their high school graduation (Cawthon, 2004), with only 7–10% of deaf high school graduates reading at the seventh grade level or above. In addition, studies reported that mathematical achievement of deaf students in various countries has been significantly poorer than that of their hearing peers (Pagliaro, 2010). Specifically, results showed that deaf high school graduates performed at fifth/sixth grade level in mathematical knowledge (Mitchell, 2008; Traxler, 2000), with the gap being evident already during preschool years (Kritzer, 2009). In a large-scale study by Marschark, Shaver, Nagle, and Newman (2015), performance of deaf and hard-of-hearing (DHH) secondary students on a mathematics subtest was better than on reading comprehension subtests of the Woodcock–Johnson Tests of Cognitive Abilities and Tests of Achievement, although both scores were significantly lower when compared to the hearing population. Despite reports of historically low and stagnant academic achievement, results of a study conducted by Antia,

Jones, Reed, and Kreimeyer (2009) shed a more positive light on deaf students' school achievement. During a 5-year period, scores on standardized assessments of reading, language, and mathematics, as well as demographic and communication data were obtained from 197 DHH students enrolled in mainstream classrooms for at least 2 hr daily. The results indicated that over that period, many students achieved average or above average levels. Of the students followed, 48–68% achieved average or above average levels in reading, 55–77% in language/writing, and 71–79% in mathematics. Furthermore, Spencer, Gantz, and Knutson (2004) assessed academic achievement of 27 deaf students who had cochlear implants using Woodcock–Johnson Tests of Achievement subtests. Achievement test results indicated that cochlear implant users' scores fell within 1 SD from normative data based on hearing peers, suggesting favorable academic performance of these cochlear implant users.

On the other hand, it has also been shown that the English literacy of deaf children is directly positively correlated with their sign language skills (Hoffmeister, 2000; Padden & Ramsey, 1998; Strong & Prinz, 1997). In order to be a successful reader and writer, it is necessary for a deaf child to "develop different linguistic mechanisms in order to map concepts onto meaningful forms of expression" (Wilbur, 2000). However, the relationship between deafness and low English literacy skills is complex and appears to be related to a variety of factors including language competence, academic achievement, cognitive abilities, and family background (Wilbur, 1977), as well as the manner in which the tests are constructed (Nolen & Wilbur, 1985). Many deaf children do not reach conversational proficiency in either a spoken or signed language, which means that they lack appropriate vocabulary size, sentence formation skills, and world knowledge that hearing children already possess by the time they start learning how to read. In contrast to their hearing peers, who learn to read and write in a language they already know, many deaf beginner readers have to cope with acquiring complex English language structures while being tasked to learn how to read in another language (Luckner et al., 2005).

However, there are deaf individuals who achieve excellent mastery of reading English (Goldin-Meadow & Mayberry, 2001; Miller & Clark, 2011; Prinz & Strong, 1998). Many of them are fluent in American Sign Language (ASL) and have extensive knowledge of written English (Hoffmeister, 2000). Research studies, using various reading comprehension tests and both receptive and expressive ASL assessments, have found that early acquisition of ASL and higher levels of ASL proficiency are strongly correlated with better reading skills in deaf signing children (Chamberlain & Mayberry, 2000; Hoffmeister, 2000; Padden & Ramsey, 1998; Strong & Prinz, 1997, 2000) and in deaf signing adults (Chamberlain, 2002; Chamberlain & Mayberry, 2008; Freel et al., 2011). Similar positive correlations between receptive and expressive proficiency have been shown for other sign languages and reading skills (Niederberger & Frauenfelder, 2005; Vercaingne-Ménard, 2002).

Consensus regarding optimal early intervention with the goal of developing adequate spoken language skills in deaf children has still not been reached, warranting detailed meta-analysis examining the effects of sign language in spoken language acquisition (Fitzpatrick, Stevens, Garritty, & Moher, 2013). Another body of evidence seems to suggest that knowing any language facilitates learning to read, even if that language differs from the one captured in print (Goldin-Meadow & Mayberry, 2001). Also, being proficient in ASL does not preclude nor interfere with learning to read, but rather supports it, which has been confirmed repeatedly by studies of skilled deaf readers who are proficient in ASL (Chamberlain & Mayberry, 2000, 2008; Hermans, Knoors, Ormel, & Verhoeven, 2008; Hoffmeister, 2000; Hoffmeister & Caldwell-Harris, 2014; Padden & Ramsey, 2000; Strong & Prinz, 1997).

The connection between these abilities appears to be based on a linguistic advantage reflected in a fully developed language base (ASL) that allows for normal cognitive development during the critical period for language acquisition. Deaf children of deaf parents are presumably exposed to a natural sign language such as ASL from birth and acquire it with ease and in the same developmental schedule, just like hearing babies acquire a spoken language (Lillo-Martin, 1999). Early linguistic experience, independent of sensory-motor modality, supports the development of ability to learn language(s) subsequently in life (including the development of linguistic devices), whereas the lack of this early language is strongly associated with long-lasting deleterious effects on the ability to learn any language, regardless of the length of linguistic exposure (Davidson, Lillo-Martin, & Pichler, 2013; Mayberry & Eichen, 1991). Neuroimaging studies lend further support for behavioral studies indicating benefits of early language exposure, demonstrating that access to complex linguistic stimuli regardless of the modality (visual or auditory) early in life is associated with engagement of specialized neural networks implicated in linguistic tasks (Malaia & Wilbur, 2010). Indeed, Mayberry and Lock (2003) showed that their adult participants (hearing and deaf) who acquired a language early in life, regardless of the modality (spoken or signed), performed significantly better on English (L2) grammatical judgment tasks and picture sentence comprehension tasks than deaf individuals without the experience of accessible language early in life. Their results show that deaf and hearing individuals with early language experience, who began learning English as L2 before the age of nine, independent of the modality, recognized different English structures (such as simple, dative, passive, conjoined, and relative clause sentences) more quickly on grammatical judgment response latency tasks than their counterparts without early language. Also, individuals with no early access to language responded more slowly on the grammatical judgment response latency task than all the other groups. These results suggest that "adults who acquired a language in early life performed at near-native levels on a second language regardless of whether they were hearing or deaf or whether the early language was spoken or signed" (Mayberry & Lock, 2003), reinforcing the notion that bimodal bilinguals, such as deaf individuals who acquire sign language (e.g., ASL) early and then learn English as a second language, achieve similar levels of English syntactic mastery as unimodal bilinguals (hearing individuals with early acquisition of a spoken language followed by learning English as L2).

Due to advanced communication abilities and metalinguistic skills attained through having a first language, formal reading instruction becomes more accessible. The ASL-signing deaf child can then be considered a member of a bilingual minority learning to read and write in English (Charrow & Wilbur, 1975/1989), a viewpoint reflected in the bilingual-bicultural (Bi-Bi) educational philosophy. Bilingual bimodal educational approaches, envisaged to support academic success of DHH children (LaSasso & Lollis, 2003; Strong, 1995), were first introduced in the late 1980s in the United States and in other countries such as Sweden (Svartholm, 2010), Denmark (Hansen, 1994), and United Kingdom (Swanwick & Gregory, 2007). The ASL/English bilingual programs aim to provide education to deaf

and hearing students that emphasizes language abilities across three domains—signacy, literacy, and oracy. This bimodal (manual/spoken) alternative model, presented by Nover, Christensen, and Cheng (1998), was developed within a three-tiered framework that includes signacy (receptive and expressive signing), literacy (reading, writing, fingerspelling, fingerreading, and typing for communication), and oracy (speaking, listening, and lipreading). Based on a theoretical model, bilingual practices that foster the development of ASL as the primary medium for discussing, analyzing, and mediating content and linguistic information found in English texts support advancement of English literacy skills in DHH students (Hoffmeister & Caldwell-Harris, 2014).

Wilbur (2000) argues that the hearing status of the parents does not necessarily determine ASL knowledge of the deaf child, as shown, for example, by Strong and Prinz (1997). The effect of inadequate signing skills of hearing parents can be alleviated by "providing deaf children with language-rich communication opportunities with other ASL-fluent members of the Deaf community" (Wilbur, 2000), fostering the cultural aspects of sign bilingualism. Various countries offering a bimodal bilingual approach differ in the ways that their respective sign language and spoken language experiences are organized in terms of the relative importance of print versus speech as the main vehicle for learning oral language as a second language (Arnesen et al., 2008; Moores, 2010; Preisler, Tvingstedt, & Ahlström, 2002; Svartholm, 2010). Nevertheless, the greatest difference between bimodal bilingual practices and the auditory-oral approaches, which use remedial strategies and attempt to raise spoken competencies through intense and structured teaching, is that the Bi-Bi education promotes a compensatory approach, trying to build an alternative language base through the unrestricted visual pathway to ensure full access to education facilitating age-appropriate language and cognitive skills of DHH students.

Despite the fact that bilingual programs have been established for 25 years, a scarcity of longitudinal studies examining their efficacy in raising the levels of deaf students' literacy achievements has been noted (Knoors & Marschark, 2012; Mayer & Akamatsu, 2003, Mayer & Leigh, 2010). Although Hermans et al. (2008) noted a lack of significant improvement of average reading ability in deaf children since the introduction of Bi-Bi ASL/English programs, Geeslin's (2007) study, comparing reading comprehension test performance of deaf students prior and after their schools' philosophical and educational shift to ASL/English Bi-Bi approach, indicated that older (13- to 18-year-olds) students' reading comprehension and language subtests scores significantly improved compared to their peers' scores attending the same school prior to the bilingual approach introduction. Lange, Lane-Outlaw, Lange, and Sherwood (2013) concluded that DHH students attending an ASL/English bilingual program caught up and outperformed a nationally normed comparison group (consisting primarily of hearing peers) after a number of years in the noted program, specifically after 8.2 years for reading and 2.5 years for mathematics. In addition, 41% of the participants were in the average or above average range in reading and 55% in mathematics after at least of 4 years of ASL/English bilingual program attendance, compared to these same students' initial assessment in the program when 29% of students on a reading test were in the average/above average range and only 19% scored in that range in mathematics. Overall, these findings support the efficacy of ASL/English bilingual educational approach in raising the levels of academic achievements of DHH students.

Aim

The goal of this project is to examine the linguistic and background variables that influence reading comprehension skills and academic achievement of deaf signing 6th–11th grade students. Moreover, the main focus is to determine the effects of ASL proficiency on reading comprehension abilities and academic performance. Therefore, the research questions of the present study are: (a) do deaf or hard-of-hearing (D/HH) students who are highly proficient in ASL perform significantly better than their less ASL proficient peers on reading comprehension tests (Northwest Evaluation Association [NWEA] Reading and Stanford Achievement Test, 10th edition [SAT-10] Reading comprehension performance); (b) do D/HH students who are highly proficient in ASL achieve significantly higher scores than their less ASL proficient peers on English language measures (NWEA Language Use subtests); and (c) are mean NWEA Mathematics scores of D/HH students who are highly proficient in ASL significantly higher than those of their less ASL proficient peers?

Methods

Procedures

Participants' background information and their scores on academic achievement tests used in this study were accessed through their school records after receiving IRB-approved written parental consent. In addition to educational scores, background information, such as primary and secondary diagnosis, audiological information, and home language, were obtained from school records. The ASL mastery information was obtained from the most recent assessment available from school records administered by ASL fluent examiners. All ASL proficiency assessments, which were conducted by different ASL-fluent school designated examiners and which varied in structure and linguistic complexity by students' age and ASL proficiency level, included examination of appropriate level conversational receptive and expressive ASL language skills (phonological parameters, fingerspelling, vocabulary, grammatical use of classifiers, use of space, nonmanual markers, and discourse-related markers). The current ASL proficiency rating for each eligible student was provided from these school records by the school psychologist. The participants' signing skills were dichotomously categorized as highly proficient and not highly proficient. The students whose ASL skills were judged to be nonexistent, poor, or medium were all labeled as not highly proficient. Only two students were labeled as not having any ASL knowledge. The majority of the students highly fluent in ASL were exposed to it earlier in life, at home or school.

Academic Achievement Measures

In order to assess reading comprehension, language skills, and mathematical knowledge, the NWEA Measures of Academic Progress (MAP) scores in Reading, Language Use, and Math scores as well as the SAT-10 Reading comprehension scores were obtained from the school and analyzed.

NWEA, a global, nonprofit educational services organization, has been developing adaptive assessments and conducting educational research for decades. NWEA MAP assessments are computer-based, adaptive, multiple choice tests that measure students' academic achievement and calculate academic growth in reading, language usage, and mathematics, aligned with the academic state contents standards in those areas (NWEA, 2013).

NWEA MAP assessments present each student with a unique test in each area, made of computer-selected test items from the 3,000 items bank (32,000 items for all subjects and levels) as the test is being administered. If the student answers correctly, subsequent questions become more challenging and vice versa. MAP tests are commonly administered several times a year (fall, winter, and spring). Typically, students complete 42–50 test questions in an untimed MAP content assessment, which takes about 1 hr. Results are reported in terms of RIT (Rausch Unit) scores, indicating the level of question difficulty a student is capable of answering correctly about 50% of the time, on a RIT scale, a stable equal-interval vertical scale. RIT scores, an estimation of a student's instructional level, range approximately between 100 and 300, as students typically score at the 180 or 200 level in the third grade and then progress to 220 or 260 level in high school. These scores are grade level independent. For example, a score of 220 on NWEA MAP Reading assessment achieved by a fourth grade and a seventh grade student indicates that these two students are at the same instructional level. The RIT score range is different for each subject area test. As a result, scores between content areas are not equivalent. Each test item on the assessment, based on its difficulty, corresponds to a value on the RIT scale, represented in 10-point intervals (for sample test questions, see https://www.nwea.org/content/uploads/2014/07/NWEA-RIT-Reference-Brochure-Digital.pdf).

In addition to providing accurate assessment of skills and concepts a student has learned and comparing each student's percentile ranking to the norming data, these assessments also provide normed information about students' academic growth in a specific tested area; however, trajectory data fall outside of the scope of this study. Achievement and growth norms are based on a nationally representative sample of MAP test scores from over 5 million students who have participated in nation-wide 2011 NWEA RIT Scale Norms Study (NWEA, 2011).

In this study, in addition to total scores and corresponding percentiles in NWEA overall MAP Reading, Language Use, and Mathematics, achievement information on each MAP subject subtests was obtained. The reading comprehension subgroup assessments used in the current study included scores for the following reading-related areas or goal strands: word recognition and vocabulary knowledge, comprehension of informational and literary texts, and knowledge of informational and literary text structure. Skills assessed in these areas include comprehending relationships between words and using lexical item component structures and clues from context to decipher word meaning; exhibiting literal comprehension of a variety of written materials by recalling, identifying, classifying, and sequencing details, facts, and main ideas as well as inferential reading comprehension by making reasonable predictions, drawing inferences necessary for comprehension and recognizing cause–effect associations, and synthesizing information from a range of written materials.

The language use main test areas include comprehension of the writing process, different types of written texts and their characteristics, English grammar conventions, and English language conventions (punctuation, spelling, and capitalization). It involves skills such as comprehending and applying correct basic sentence patterns, phrases and clauses, word forms, tense, subject–verb agreement, and pronoun–antecedent agreement, as well as obeying punctuation and capitalization rules.

MAP Mathematics RIT scores were used to assess academic achievement of deaf students. The main areas tested included: number sense, computation (solving problems using whole numbers, fractions, decimal, integers, rational numbers, and real numbers), algebra (simplifying expressions and extending patterns, solving equations and inequalities, using coordinate graphing, and solving functions and matrices), geometry (identification and classification of 2-D and 3-D objects, symmetry and transformations, similar and congruent figures, Pythagorean Theorem, and scale), measurement concepts (measuring and conversion using appropriate units, calculating various 2-D and 3-D objects values), statistics and probability (concepts of organizing, reading, and interpreting graphs, collecting and analyzing data), and problem solving (understanding and representing problems, developing solution strategies, verifying results, and explaining reasoning strategies and proofs).

Finally, reading comprehension subtest scores from the SAT-10, a commonly used assessment in reading and literacy studies, were also used in the current study. In this standardized test, student are presented with a variety of passages (fiction and informational texts) that need to be read independently, followed by multiple choice questions.

Participants

Background information and educational test scores of 171 students attending 6th–11th grade at a deaf school were obtained; however, only 118 of them had relevant sets of data for this project. Furthermore, after applying exclusion criteria, 85 students were determined to be eligible to partake in the study. Also, data regarding the age at hearing loss diagnosis were missing from 18 students and information regarding the age at first exposure to signing was not available for 16 students. Therefore, the number of scores varies across different dependent variables as not all participants had complete sets of data for all variables used in the study.

To be eligible, students had to have completed 6th–11th grade with individualized education programs indicating they were D/HH. Exclusion criteria were: home languages other than English and ASL; additional diagnoses of cognitive disability, specific learning disability, multiple disabilities, autism spectrum disorders, dual diagnosis of deafness and blindness, emotional disability, or orthopedic impairments. The only additional diagnosis participants may have had were language and speech impairment. All students attended a deaf school emphasizing a Bi-Bi educational approach, fostering the development of ASL skills as a linguistic foundation for literacy development in English. Despite varying ASL comprehension and production skills, all students had contact with and exposure to ASL, with 47 students rated as highly proficient and 38 as not highly proficient. Akin to many research studies in the area of deaf education, background variables of parental hearing status and home language were interconnected in this study, with the majority of students coming from families with one or both deaf parents using ASL as a home language. As expected, most participants raised in families with two hearing parents had English as the home language. Only one student with hearing parents was reported to use ASL at home. In addition, some participants received cochlear implants (13), out of which only 9 used them consistently. Genetic etiology of hearing loss was prevalent in the current study (57 participants). Twenty participants had a hearing loss of unknown origin and only eight participants exhibited hearing loss caused by environmental factors (ototoxic medication, trauma, or bacterial infection).

Data Analysis

One-way analyses of variance (ANOVAs) were carried out to examine differences between the two proficiency level groups on MAP Reading, Language Use, and Mathematics total scores.

In order to facilitate comparisons between grades as well as between MAP subtests, overall Reading, Language Use, and Math results have been converted to percentiles. Similarly, students' performance on all MAP subtests has been assessed in comparison to their grade peers' results included in the most recent NWEA RIT Scale Norms Study, which was based on the hearing student population. The school released data from MAP subtests coded as descriptors ranging from "1" to "5," with "1" representing low scores and "5" high scores, rather than as a raw score or a percentile. The possible descriptors, low or "1" (<21 percentile), low average or "2" (21–40 percentile), average or "3" (41–60 percentile), high average or "4" (61–80 percentile), and high or "5" (>80 percentile), were determined by NWEA through their norming study on a hearing population. Thus, data presented reflect how the deaf students' test outcomes in this study compare to national norms on comparable hearing students.

In order to examine differences between the two proficiency groups on MAP Reading, Language Use, and Mathematics subtest scores and SAT-10 Reading comprehension results, nonparametric Mann–Whitney *U* tests were used, due to violation of the assumption of normality of distribution and the ordinal nature of SAT-10 data. This assumption was tested using a Shapiro–Wilk test of normality of distribution, which was significant (*p* < .01) for all subtests and both subgroups, suggesting that MAP subtests and SAT-10 data were not distributed normally.

Regression analyses were carried out to predict reading comprehension and academic outcomes. We built a four-step hierarchical multiple regression models to predict scores on each of the three MAP tests—Reading, Language Use, and Mathematics. Regression diagnostic tests revealed that overall the data met the regression assumptions of normality, linearity, and homoscedasticity. Although correlation between two predictor variables was high (*r* = .84), tests for multicollinearity revealed low variance inflation factors (VIFs) for the independent variables (VIFs were less than 5.0 in all cases). All five predictor variables were statistically correlated with MAP Reading, Language Use, and Mathematics scores, indicating that the data were suitably correlated with the dependent variable in order for examination through multiple linear regressions to be reliably undertaken.

In the first step of this hierarchical multiple regression, two predictors were entered: age at enrollment at the current Bi-Bi school as a continuous regressor and having a cochlear implant as a nominal regressor. In the second step, we included a nominal predictor related to having a secondary speech and language impairment diagnosis. In the third step, we added a nominal variable identifying home language. Finally, in the fourth step, ASL proficiency as a nominal variable was included. The objective of this four-step approach was to assess the relative contribution of these four factor groups to the explained variance. We were particularly interested in the relative contribution of the last two variables, home language and ASL proficiency, as these two factors are often confounded in deaf education research.

In order to ascertain the amount of unique variance of three dependent variables that was accounted for by other variables after controlling for ASL proficiency, we performed a stepwise regression with ASL proficiency entered first, followed by other variables identified in the previous hierarchical multiple regression.

In addition to hierarchical multiple regression, we performed simple linear regression analyses for each the five selected predictor variables used in the hierarchical multiple regression for MAP overall Reading, Language Use, and Mathematics test scores. We reported the model including ASL proficiency as it explained the most variance in MAP Reading, Language Use, and Mathematics outcomes compared to other single-variable regression models.

Results

Detailed information regarding participants' background characteristics is summarized in Table 1. Distribution of speech and language impairment diagnosis per ASL proficiency is shown in Table 2. Group mean performances and standard deviations on

Table 1. Participants' characteristics

| | ASL proficiency | | | | | | |
| | Not highly proficient | | | Highly proficient | | | Total |
Variable	N	M	SD	N	M	SD	N
Home language							
ASL	4			44			48
English	34			3			37
Parental hearing status							
Deaf	4			43			47
Hearing	34			4			38
Hearing loss etiology							
Genetic	12			45			57
Environmental	7			1			8
Unknown	19			1			20
Additional diagnoses							
Language and speech impairment	24			4			28
Other health impairment	9			3			12
No	5			40			45
Cochlear implant							
Yes	13			0			13
No	25			47			72
Age at diagnosis (years; months)	34	1; 11	1; 7	33	0.6	1; 1	67
Age at first ASL exposure (years; months)	26	6; 5	6; 00	43	0; 2	0; 9	69
Age at enrollment at current bi-bi school	38	10; 8	4; 10	47	5; 10	4; 0	85

Note. ASL = American Sign Language.

predictor and outcome variable test results by ASL proficiency are presented in Table 3. Furthermore, regression model results predicting participants' academic achievement in reading, language use, and mathematics are presented in Tables 4 through 6.

Background Variables

Overall, a comparison of the two ASL proficiency groups revealed that fluent ASL users were on average diagnosed with hearing loss at an earlier age (M = 0.5 years, SD = 1.1) than their nonfluent peers (M = 1.9 years, SD = 1.6), experienced earlier exposure to ASL (M = 0.2 years, SD = 0.8) than the nonfluent participants (M = 6.4 years, SD = 5.9), enrolled in the current school for the deaf earlier (M = 5.9 years, SD = 3.9) than nonproficient peers (M = 10.7 years, SD = 4.8) and were less likely to wear their hearing devices (20% of ASL fluent wearers compared to 63% of wearers who were nonfluent in ASL).

Deaf students proficient in ASL differed from their peers who were not as fluent in several background variables, most notably in the presence of a secondary diagnosis of speech and language impairment. In the 2×2 contingency table (Table 2), the total number of students without speech and language impairment comprised of students with other health impairments not related to their linguistic abilities and students without any secondary exceptionality. Examination of the cell frequencies revealed that approximately one third of the participants were diagnosed with speech and language impairment (by ASHA-certified speech-language pathologists [SLPs]). However, the prevalence of that secondary diagnosis was higher (24 out of 28) in students who exhibited inadequate mastery of ASL than in those who were highly proficient in ASL (4 out of 28). A chi-square test of independence was calculated comparing the frequency of secondary diagnosis/impairment and ASL proficiency. An association between secondary diagnosis and ASL proficiency was found, χ^2(1, N = 85) = 28.406, p < .001, suggesting that ASL proficient participants were less likely to be diagnosed with a speech and language impairment than their less fluent peers.

NWEA MAP Reading

Available MAP Reading scores from 71 D/HH students were analyzed. One-way ANOVA results showed that deaf participants

Table 2. Distribution of frequencies of secondary speech and language impairment diagnosis and ASL proficiency

			ASL proficiency		
			Not highly proficient	Highly proficient	Total
Diagnosis	Speech and	N (% of total)	24 (28.2%)	4 (4.7%)	28 (32.9%)
	language impairment	Expected N	12.5	15.5	28.0
	No speech and	N (% of total)	14 (16.5%)	43 (50.6%)	57 (67.1%)
	language impairment	Expected N	25.5	31.5	57.0
Total		N (% of total)	38 (44.7%)	47 (55.3%)	85 (100.0%)
		Expected N	38.0	47.0	85.0

Note. ASL = American Sign Language.

Table 3. Group mean performances and standard deviation on outcome measures as a function of ASL proficiency

		ASL proficiency					
		Not highly proficient			Highly proficient		
Variables	Total N	N	M	SD	N	M	SD
NWEA MAP reading total	71	32	10.38	17.79	39	40.62	22.43
Vocabulary	69	30	1.30	0.84	39	2.54	1.39
Informational text structure	69	30	1.37	0.72	39	2.44	1.35
Informational text comprehension	69	30	1.17	0.59	39	2.33	1.13
Literary text structure	69	30	1.23	0.77	39	2.74	1.39
Literary text comprehension	69	30	1.63	1.19	39	2.92	1.48
NWEA MAP language use total	71	32	13.22	19.33	39	52.05	25.95
Writing processes	68	29	1.41	0.95	39	2.67	1.36
Types of writing applications	69	30	1.50	1.04	39	3.08	1.38
Grammar conventions	68	30	1.37	0.85	38	2.84	1.55
Language conventions	69	30	1.47	0.78	39	3.74	1.09
NWEA MAP mathematics total	63	29	14.90	19.93	34	55.21	25.80
Number sense	52	22	1.36	0.58	30	3.40	1.50
Computation	52	22	1.55	0.74	30	3.27	1.70
Algebra functions	52	22	1.55	0.86	30	3.47	1.41
Geometry	52	22	1.50	0.86	30	3.37	1.25
Measurement	52	22	1.32	0.78	30	3.03	1.45
Statistics and probability	52	22	1.27	0.55	30	3.43	1.48
Problem solving	52	22	1.27	0.46	30	3.07	1.48
SAT-10 total	56	24	2.75	0.61	32	2.19	0.97

Note. ASL = American Sign Language; NWEA MAP = Northwest Evaluation Association Measures of Academic Progress; SAT-10 = Stanford Achievement Test, 10th edition.

Table 4. Hierarchical regression model of MAP reading scores (N = 71)

Variable	B	SE	β	t	R	R^2	Adj. R^2	ΔR^2
Step 1					.438	.192**	.168	.192**
Age at current school enrollment	−1.689	0.569	−0.331	−2.967**				
Cochlear implant	16.290	8.075	0.225	2.017*				
Step 2					.513	.263***	.230	.071*
Age at current school enrollment	−0.650	0.683	−0.127	−0.951				
Cochlear implant	13.106	7.868	0.181	1.666				
Speech and language impairment	18.739	7.363	0.344	2.545*				
Step 3					.553	.306***	.264	.043*
Age at current school enrollment	−0.417	0.678	−0.082	−0.616				
Cochlear implant	6.829	8.295	0.094	0.823				
Speech and language impairment	13.186	7.705	0.242	1.711				
Home language	−13.850	6.848	−0.274	−2.023*				
Step 4					.613	.376***	.328	.070**
Age at current school enrollment	−0.072	0.660	−0.014	−0.110				
Cochlear implant	3.334	8.035	0.046	0.415				
Speech and language impairment	8.762	7.546	0.161	1.161				
Home language	2.894	9.032	0.057	0.320				
ASL proficiency	26.181	9.730	0.517	2.691**				

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.
*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5. Stepwise regression analysis for MAP reading, language use, and mathematics

Dependent variable	Model	Variable	R	R^2	ΔR^2
Reading	1	ASL proficiency	.598	.357***	.019
	2	Age at current school enrollment, Cochlear implant, Speech and language impairment, Home language	.613	.376	
Language use	1	ASL proficiency	.645	.416***	.019
	2	Age at current school enrollment, Cochlear implant, Speech and language impairment, Home language	.660	.435	
Math	1	ASL proficiency	.659	.435***	.055
	2	Age at current school enrollment, Cochlear implant, Speech and language impairment, Home language	.700	.490	

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.
***$p < .001$.

Table 6. Hierarchical regression model of MAP language use scores (N = 71)

Variable	B	SE	β	t	R	R^2	Adj. R^2	ΔR^2
Step 1					.399	.159**	.134	.159**
Age at current school enrollment	−1.906	0.691	−0.314	−2.759**				
Cochlear implant	16.172	9.799	0.188	1.650				
Step 2					.488	.239***	.205	.080**
Age at current school enrollment	−0.600	0.826	−0.099	−0.726				
Cochlear implant	12.170	9.514	0.141	1.279				
Speech and language impairment	23.554	8.903	0.364	2.646**				
Step 3					.537	.289***	.245	.050*
Age at current school enrollment	−0.302	0.816	−0.050	−0.370				
Cochlear implant	4.120	9.992	0.048	0.412				
Speech and language impairment	16.433	9.280	0.254	1.771				
Home language	−17.763	8.248	−0.295	−2.153*				
Step 4					.660	.435***	.392	.147***
Age at current school enrollment	0.294	0.747	0.049	0.394				
Cochlear implant	−1.922	9.088	−0.022	−0.212				
Speech and language impairment	8.784	8.535	0.136	1.029				
Home language	11.185	10.216	0.186	1.095				
ASL proficiency	45.261	11.006	0.752	4.112***				

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.
*$p < .05$; **$p < .01$; ***$p < .001$.

who were highly proficient in ASL (M = 40.6, SD = 22.4) outperformed their less skilled peers (M = 10.4, SD = 17.8) in overall reading comprehension ($F(1,69)$ = 38.34, p < .001). As shown in Figure 1, approximately 40% of the reading comprehension questions were answered correctly by participants who were highly fluent in ASL compared to only 10% of questions answered correctly by less ASL fluent students. Specifically, proficient ASL users ranged on average between 17th and 46th percentile across the grades on overall MAP Reading assessment compared to a notably poorer performance (2nd–19th percentile) of participants less fluent in ASL.

Mann–Whitney U tests were run to determine if there were statistically significant differences in MAP Reading subtest scores between highly proficient ASL signers and their less proficient counterparts. Due to between group comparisons on multiple subtests, alpha adjustment has been set to 0.01. Findings showed that the higher proficiency groups achieved significantly better scores in all MAP Reading subtests: vocabulary (fluent (Mdn = 3)/less fluent (Mdn = 1), U = 271.5, z = –4.18, p = .0005), informational text

comprehension (fluent (Mdn = 2)/less fluent (Mdn = 1), U = 217.5, z = –4.91, p = .0005), informational text structure (fluent (Mdn = 2)/less fluent (Mdn = 1), U = 316.5, z = –3.53, p = .0005), literary text comprehension (fluent (Mdn = 3)/less fluent (Mdn = 1), U = 296, z = –3.70, p = .0005), and literary text structure (fluent (Mdn = 3)/less fluent (Mdn = 1), U = 206.5, z = –4.97, p = .0005).

On average, students who are not highly proficient in ASL achieve scores ranging from "low" (1) to "low average" (2), whereas their ASL proficient counterparts tend to exhibit scores that fall between "low average" (2) and "average" (3) range on the MAP Reading subtests (Figure 2).

The hierarchical multiple regression model predicting MAP Reading achievement, presented in Table 4, revealed that at Step 1, background variables (age at enrollment at current Bi-Bi school as a continuous regressor and having a cochlear implant) contributed significantly to the regression model, ($F(2,68)$ = 8.08, p < .01) and accounted for 19.2% of the variation in reading achievement. After entry of speech and language impairment diagnosis at Step 2, the total variance explained by the model
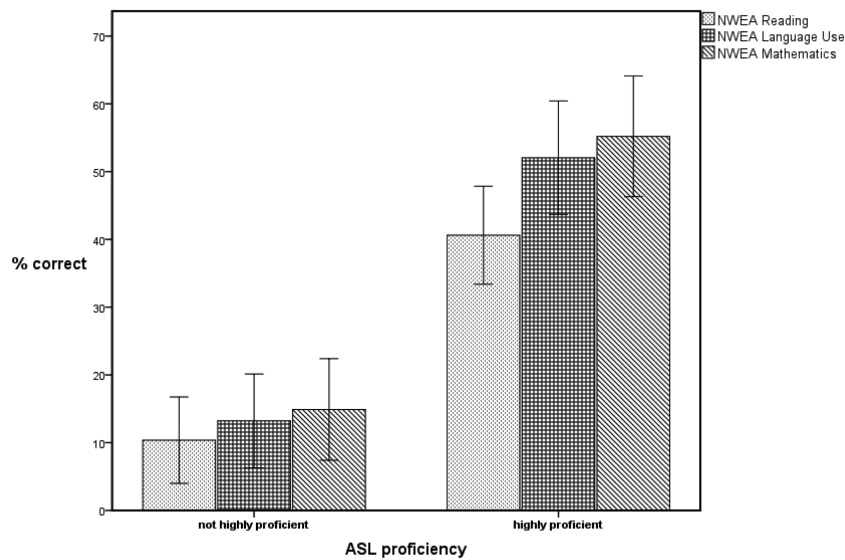

Figure 1. Mean total percent correct on Northwest Evaluation Association (NWEA) reading, language use, and mathematics tests as a function of American Sign Language (ASL) proficiency (error bars represent 95% confidence intervals).
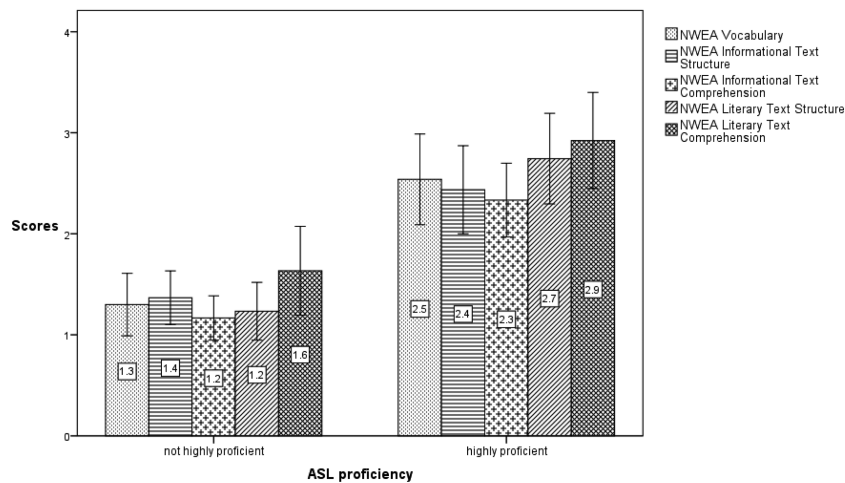

Figure 2. Performance on Northwest Evaluation Association (NWEA) reading subtests (error bars represent 95% confidence intervals). Y axis reflects mean score categories with "1" representing low scores, "2" low average scores, "3" average scores, "4" high average scores, and "5" high scores.

as a whole was 26.3% ($F(3,67) = 7.98$, $p < .001$). The introduction of speech and language impairment diagnosis explained an additional 7.1% variance in reading achievement, after controlling for age at enrollment at current school and having a cochlear implant (R^2 change = .071; $F(1,67) = 6.48$, $p < .05$). Adding home language to the regression model at Step 3 accounted for an additional 4.3% of the variation in the dependent variable, making this change in R^2 borderline significant ($F(1,66) = 4.09$, $p = .047$), so the total variance explained by the model was 30.6% ($F(4,66) = 7.28$, $p < .001$). Finally, after addition of ASL proficiency in Step 4, which increased the explained variance in reading scores by 7% ($F(1,65) = 7.24$, $p < .01$), the final regression model accounted for 37.6% of variance in reading scores ($F(5,65) = 7.83$, $p < .001$). In the full model, consisting of five predictors, the only significant predictor was ASL proficiency, showing that, after controlling for other factors, better ASL proficiency was positively related to NWEA Reading scores ($\beta = 0.517$, $p < .01$).

Furthermore, we performed a single-predictor regression model containing only ASL proficiency (see Table 5), which by itself significantly accounted for 35.7% of variance in reading scores ($F(1,69) = 38.34$, $p < .001$). Similarly, results of a stepwise regression analysis (see Table 5) suggested that ASL proficiency accounted for the majority of explained variance of MAP Reading results. After controlling for ASL proficiency, addition of other background variables as well as the presence of speech and language diagnosis did not significantly improve prediction (R^2 change = .019; $F(4,65) = 0.48$, $p > .05$). What this indicates is that many of the variables that are often pointed to as relevant to reading and other academic outcomes for deaf students are not as important, even combined together, than ASL proficiency on its own. This finding suggests that some traditional practices may need to be reconsidered.

NWEA MAP Language Use

Performance on English language usage tests reveals a pattern akin to reading comprehension performance. One-way ANOVA results revealed a significantly better performance of ASL proficient students ($M = 52.1$, $SD = 26$) than their less proficient peers ($M = 13.2$, $SD = 19.3$) on the MAP overall language use test ($F(1,69) = 49.21$, $p < .001$). Deaf participants attending 6th–11th grade who were highly proficient in ASL scored on average between 30th and 62nd percentile in language use compared to their classmates with poorer ASL fluency whose results fell between 2nd and 18th percentile. The lack of overlap between mean percentiles of the two groups corroborates other findings suggesting superior achievements of fluent ASL participants. The results of Mann–Whitney U tests, administered to examine differences between highly fluent ASL participants and those exhibiting lower proficiency levels on Language Use subtest scores, indicate statistically significant higher achievement of more fluent signers on all subtests (alpha levels have been adjusted to 0.0125): comprehension of writing processes (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 269$, $z = -3.99$, $p = .0005$), different text types comprehension (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 190.5$, $z = -4.97$, $p = .0005$), English grammar conventions (fluent ($Mdn = 2.5$)/less fluent ($Mdn = 1$), $U = 238$, $z = -4.41$, $p = .0005$), and English language conventions (fluent ($Mdn = 4$)/less fluent ($Mdn = 1$), $U = 73.5$, $z = -6.35$, $p = .0005$) (Figure 3).

Again, we conducted hierarchical multiple regression to predict variance in MAP Language Use scores, in the first step using both age at enrollment at current school and having a cochlear implant, which accounted for 15.9% of variance in language use scores ($F(2,68) = 6.43$, $p < .01$). Introducing the presence of speech and language diagnosis at Step 2 contributed an additional 8% of explained variance ($F(1,67) = 6.99$, $p < .05$), resulting in a three-predictor regression model accounting for 23.9% of variance in scores ($F(3,67) = 7.00$, $p < .001$). At Step 3, adding home language accounted for additional 5% of variance in scores ($F(1,66) = 4.64$, $p < .05$), so the explained variance of the model as a whole after the addition of home language was 28.9% ($F(4,66) = 6.69$, $p < .001$). Finally, the addition of ASL proficiency in Step 4 contributed 14.7% to the explained variance in scores ($F(1,65) = 16.91$, $p < .001$), raising the final regression model explained variance to 43.5% in MAP Language Use scores ($F(5,65) = 10.03$, $p < .001$). After controlling for other factors, higher ASL proficiency was positively related to language scores ($\beta = 0.75$, $p < .001$), whereas none of the other factors revealed themselves as being significant factors. As detailed in Table 5, modeling only ASL proficiency as a single factor in a simple linear regression of MAP Language Use resulted in 41.6% of variance in language use
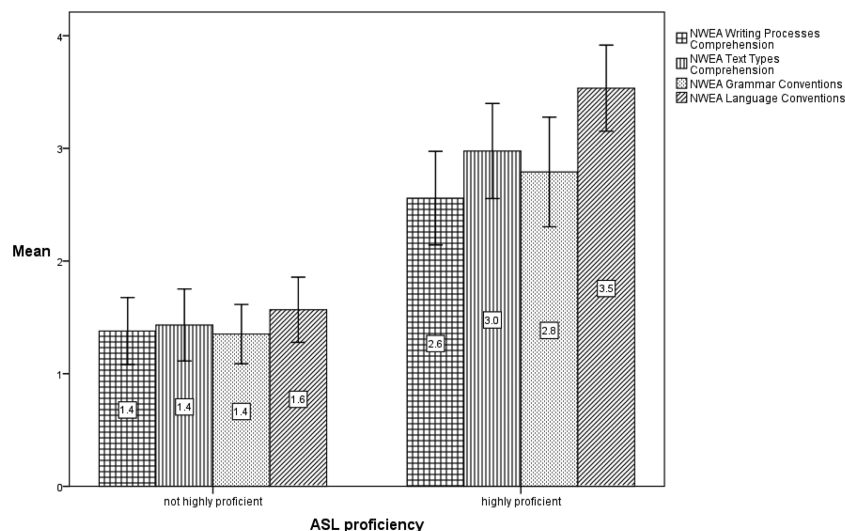

Figure 3. Performance on Northwest Evaluation Association (NWEA) language use subtests (error bars represent 95% confidence intervals). Y axis reflects mean score categories with "1" representing low scores, "2" low average scores, "3" average scores, "4" high average scores, and "5" high scores.

scores explained ($F(1,69) = 49.21$, $p < .001$). Addition of the other background and additional impairment variables after ASL proficiency is accounted for did not contribute significantly to the variance explained by the full model (R^2 change = .019; $F(4,65)= 0.55$, $p > .05$). This finding is parallel to the results on reading comprehension above.

NWEA MAP Mathematics

Mathematical skills were assessed by the MAP Math subtests. Students who were skilled in ASL achieved significantly higher scores, between 17th and 63rd percentile ($M = 55.2$, $SD = 25.8$), again a difference of almost 4 times higher than those with low ASL proficiency ($M = 14.9$, $SD = 19.9$), ranging between 4th and 23rd percentile on overall math assessment ($F(1, 61) = 46.89$, $p < .001$). Assessment of differences between two ASL proficiency groups on Mathematics subtest was carried out using multiple Mann–Whitney U tests (hence alpha level has been corrected to 0.007). Findings, presented in Figure 4, indicated that highly fluent participants performed significantly better than their less proficient peers on all subtests: number sense (fluent ($Mdn = 4$)/less fluent ($Mdn = 1$), $U = 93.5$, $z = -4.56$, $p = .0005$), computation (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 144.5$, $z = -3.59$, $p = .0005$), algebra functions (fluent ($Mdn = 4$)/less fluent ($Mdn = 1$), $U = 91$, $z = -4.56$, $p = .0005$), geometry (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 73$, $z = -4.89$, $p = .0005$), measurement (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 99$, $z = -4.51$, $p = .0005$), statistics and probability (fluent ($Mdn = 4$)/less fluent ($Mdn = 1$), $U = 73.5$, $z = -4.96$, $p = .0005$), and problem solving (fluent ($Mdn = 3$)/less fluent ($Mdn = 1$), $U = 97$, $z = -4.54$, $p = .0005$).

The amount of variance in the MAP Mathematics scores that could be predicted by independent predictor variables was examined using hierarchical multiple regression model. At Step 1, background variables explained 28.3% of variance in mathematical test scores ($F(2,60) = 11.84$, $p < .001$). After the introduction of the speech and language diagnosis variable at Step 2, contributing an additional 6.6% ($F(1,59) = 5.99$, $p < .05$) to the explained variance in test scores, the variance explained by the model was 34.9% ($F(3,59) = 10.54$, $p < .001$). Furthermore, the home language variable, included at Step 3, explained an additional 2.8% of the variance in mathematical test scores, but this change was not

significant ($F(1,58) = 2.6$, $p > .05$), resulting in 37.7% of the total variance explained by the model ($F(4,58) = 8.77$, $p < .001$). Finally, inclusion of ASL proficiency at Step 4 uniquely accounted for 11.3% of the total variance in test scores ($F(1,57) = 12.6$, $p < .01$), yielding the final model, consisting of five predictor variables, which accounted for 49% of the variance in MAP Mathematics test scores ($F(5,57) = 10.94$, $p < .001$). Again, akin to the results for the Reading and Language Use, the only significant predictor in the final, full model was ASL proficiency ($\beta = 0.67$, $p < .01$). Similarly, entering ASL proficiency as a single predictor in a simple linear regression model (see Table 5) accounted for 43.5% of variance in MAP Mathematics scores ($F(1,61) = 48.89$, $p < .001$). Inclusion of other predictor variables after unique contribution of ASL proficiency has been accounted for did not significantly improve prediction power of the full model (R^2 change = .055; $F(4,57) = 1.54$, $p > .05$) (Table 7).

SAT-10 Results

SAT-10 Reading comprehension data from 56 participants attending 8th–11th grade was analyzed. The sample consisted of 32 students highly fluent in ASL and 24 of their less fluent classmates. Results were provided in grade-equivalent values that have been converted into grade-independent values, coded as three possible descriptors indicating below grade level (1), at grade level (2), and above grade level (3) performance, with higher scores suggesting better performance.

A Mann–Whitney U test was run to determine if there were differences in SAT-10 Reading comprehension test performance between highly proficient participants and less proficient ones. Distributions of the SAT-10 score categories for two groups were similar, as assessed by visual inspection. SAT-10 Reading comprehension performance of highly fluent ASL students ($Mdn = 1$, mean rank = 32.1, $M = 1.8$, $SD = 0.61$) was significantly better than the performance of less fluent students ($Mdn = 1$, mean rank = 23.8, $M = 1.3$, $SD = 0.97$) on SAT-10 Reading comprehension assessment ($U = 270$, $z = -2.30$, $p = .021$). The percentage of students at the above-grade performance level who are highly proficient (37.5%) is nearly 4.5 times that of those who are not highly proficient (8.4%). Similar trend can be observed at the below-grade performance level, where there is a higher percentage (83.3%) of not highly proficient students
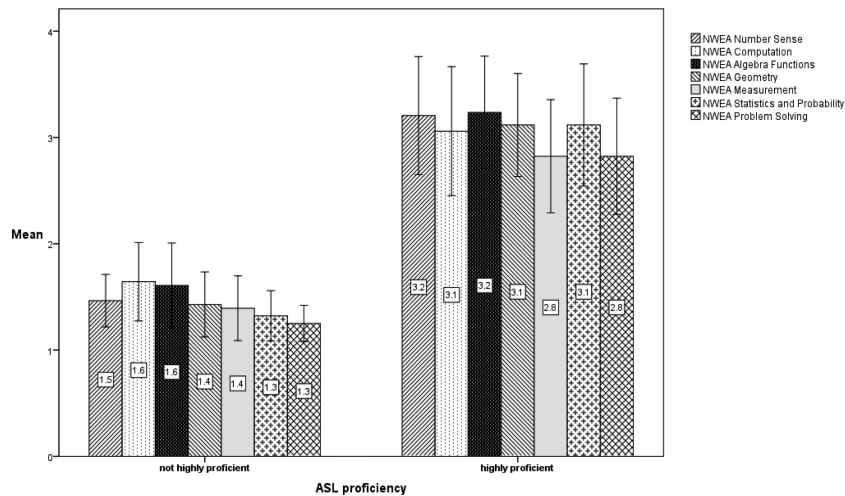

Figure 4. Performance on Northwest Evaluation Association (NWEA) math subtests (error bars represent 95% confidence intervals). Y axis reflects mean score categories with "1" representing low scores, "2" low average scores, "3" average scores, "4" high average scores, and "5" high scores.

Table 7. Hierarchical regression model of MAP mathematics scores ($N = 63$)

Variable	B	SE	β	t	R	R^2	Adj. R^2	ΔR^2
Step 1					.532	.283***	.259	.283***
Age at current school enrollment	−2.674	0.681	−0.446	−3.929***				
Cochlear implant	16.825	9.889	0.193	1.701				
Step 2					.591	.349***	.316	.066*
Age at current school enrollment	−1.520	0.807	−0.253	−1.884				
Cochlear implant	12.483	9.667	0.143	1.291				
Speech and language impairment	21.795	8.909	0.333	2.446*				
Step 3					.614	.377***	.334	.028
Age at current school enrollment	−1.345	0.803	−0.224	−1.674				
Cochlear implant	7.435	10.038	0.085	0.741				
Speech and language impairment	15.854	9.530	0.242	1.664				
Home language	−13.346	8.271	−0.219	−1.614				
Step 4					.700	.490***	.445	.113***
Age at current school enrollment	−0.670	0.757	−0.112	−0.884				
Cochlear implant	2.759	9.258	0.032	0.298				
Speech and language impairment	12.460	8.752	0.190	1.424				
Home language	14.748	10.938	0.242	1.348				
ASL proficiency	41.102	11.579	0.672	3.550***				

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.
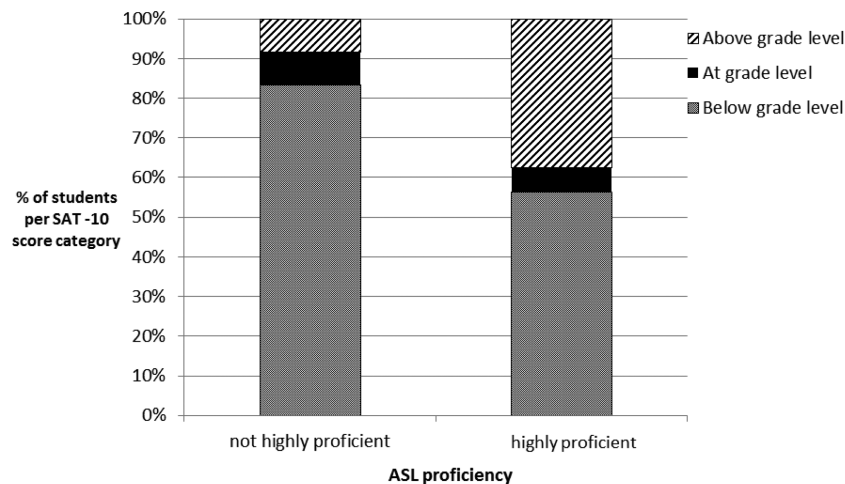*$p < .05$; ***$p < .001$.

Figure 5. Students' Stanford Achievement Test, 10th edition (SAT-10), performance as a function of American Sign Language (ASL) proficiency.

in comparison to highly proficient ones (56.3%). This reflects the obvious fact that high proficiency in ASL does not guarantee successful performance but does significantly increase the likelihood of successful performance on standardized tests (Figure 5).

Discussion

The results of the study support the hypothesis that deaf students who are highly proficient in ASL perform better than their less fluent peers in English reading comprehension tests and assessments of English language use but also in other areas of academic achievement, such as mathematics knowledge. Although both subgroups of students have had access to ASL in an educational setting, it can be assumed that students who use it at home may have started acquiring it at an earlier age, possibly resulting in higher ASL fluency. However, statistical analysis was used to demonstrate that the only variable in models significantly predicting reading, language, and mathematics scores was ASL proficiency. Other potential factors, such as home language or age

at enrollment in current school, did not contribute significantly to any of the three dependent variables after ASL proficiency was controlled. Also, when entered as a single term in a simple linear regression for each of the MAP tests, models containing only ASL proficiency accounted for almost as much total variance as the full regression models that included other regressors such as home language, presence of a secondary speech, and language impairment diagnosis, having a cochlear implant and age at first enrollment at current school. The importance of ASL knowledge for reading comprehension was also shown by Novogrodsky, Caldwell-Harris, Fish, and Hoffmeister (2014). They suggested that ASL vocabulary knowledge appeared to be the strongest predictor of reading comprehension, above and beyond parental hearing status, which is often/can be considered a proxy for home language.

These findings support the importance of ASL proficiency in academic achievement of DHH students in ASL–English Bi-Bi programs, above and beyond familial linguistic status (English vs. ASL). Namely, although additional studies are warranted to determine other factors contributing to the regression models

of reading and academic achievement of deaf signing students, this study shows that ASL fluency is undeniably one of them, indicating that, in a Bi-Bi educational setting, highly fluent deaf signing students outperform their less fluent peers on literacy and academic assessments.

Controversy about deaf education has continued for centuries, with debates often primarily focused on method (especially presence or absence of sign language use or tolerance) rather than appropriate language outcomes and academic success, despite many other factors influencing educational success. When focused on method, evaluations have been designed to compare the programs, methods, or groups, rather than the factors contributing to success. Thus, there are often no transparent descriptions of age of first exposure to the pedagogical method and the amount of time it has been implemented, nor how it is ensured that every child is getting only the best implementation of that method. Schools are understandably shy of agreeing to participate in studies comparing their methods, and as a result, few studies are conducted to evaluate methods in actual implementation. Beyond that, many students experience different educational programs, alternating between various special classes and programs and regular mainstreamed programs. In contrast, the present study not only considers the contributions of a variety of variables, the student population in the study are educated in a school that tests and requires ASL proficiency of all teachers, aides (including interns), and staff, eliminating that as a source of unknown variance.

Given the number of remaining uncontrollable variables involved, we suggest thinking about the problem of educating deaf children in a different way. For example, if we can find a group of deaf children who are performing well according to standard assessment tests, and another group that is falling behind, then the educationally relevant key questions are: what do the children in the successful group have in common and what can parents and educators do to increase the probability of placing any random student into the successful group? Naturally, in order to validate the results reported here, further large-scale research studies including students from a number of various educational settings are needed. However, this suggested way of thinking about the problem preserves the traditional measurements (school achievement tests) but does not focus on educational method or curricular implementation. Rather it focuses on factors that correlate with successful children, such as high level of (modality independent) language proficiency. In the Bi-Bi context, the correlation includes ASL proficiency.

As seen in the present study, the majority of deaf signing students in the academically successful group were highly fluent in ASL. In contrast, only one student with comparable good reading scores did not have a high level of ASL proficiency. Similarly, only three students who were not highly ASL proficient achieved average or better scores in mathematics. These students all have hearing parents and English as home language but differ among themselves (?) in other variables (presence of cochlear implant, age of enrollment at current school, age at diagnosis). Although our findings indicate that ASL proficiency is not the only factor determining academic success, it is clear that high levels of ASL proficiency increase the probability of achieving grade-appropriate literacy skills and overall academic achievement (Tables 8–10).

A possible limitation of the current study is that the sample comes from a single school for the deaf employing an ASL–English bilingual educational approach. However, it was our intention in the reported study to perform a post hoc analysis of the students' data obtained from a school for the deaf that

Table 8. Participants' MAP reading proficiency scores as a function of ASL fluency

	ASL proficiency	
	Not highly proficient (N)	Highly proficient (N)
Reading proficiency < 40%	31	18
Reading proficiency ≥ 40%	1	21

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.

Table 9. Participants' MAP mathematics scores as a function of ASL fluency

	ASL proficiency	
	Not highly proficient (N)	Highly proficient (N)
Mathematics < 40%	26	11
Mathematics ≥ 40%	3	23

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.

Table 10. Participants' MAP language use scores as a function of ASL fluency

	ASL proficiency	
	Not highly proficient (N)	Highly proficient (N)
Language use < 40%	29	14
Language use ≥ 40%	3	25

Note. ASL = American Sign Language; MAP = Measures of Academic Progress.

is an exemplary model of ASL–English bilingual education philosophy. Further studies encompassing other schools with the same educational approach are warranted, although in order to ensure the optimal assessment of the efficacy of this approach, researchers are encouraged to include schools providing the best implementation of this method.

Finally, the data presented here do not indicate that it is impossible to achieve at grade or above grade performance on nationally standardized tests of reading, language use, and mathematics without high ASL proficiency nor do they diminish reported successes in other educational settings for DHH students, such as general education or mainstream settings (Antia et al., 2009). Rather they indicate that the odds of achieving success on such tests are significantly enhanced by factors of 7–20 when high ASL fluency is present. In fact, the percentage of students highly proficient in ASL in the current study scoring at or above average level (more than 40th percentile) in reading, language and mathematics are comparable to percentage of general education students from Antia et al. (2009) study performing at or above average level in those content areas (for reading, 54% of high ASL students compared to 48–68% of mainstream DHH students; for language, 64% of ASL proficient students in comparison to 55–77% general education classroom deaf students; and for math, 68% of ASL fluent participants compared to 71–79% of students in Antia et al. study). The percentage of students scoring at or above average in our study decreased when the whole sample

was included in the computation, including those less proficient students. This finding adds support to importance of developing a high level of ASL proficiency for students in Bi-Bi programs.

These facts, which have important academic implications, need to be provided to parents when they make educational decisions for their children. Similarly, such information needs to be included in presentations of evidence-based practices for training SLPs, audiologists, pediatricians, teachers of deaf students, and administrators of educational programs that include DHH children. Finally, education about ASL itself is provided to the students in the program from which our population is drawn, in a manner that is parallel to providing English classes to native speakers of English. The profession of teachers of ASL is rapidly developing on a par with teachers of English, wherein Master's degrees are offered at increasing numbers of universities, and national certification testing and standards are overseen by a national organization of ASL teachers. To achieve high proficiency in ASL for deaf students, the people who teach them need to be better trained than is generally the case at the present time.

Conflicts of Interest

Funding

Acknowledgments

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