



The LENA Research Foundation develops advanced technology for the early screening, research, and treatment of language delays and disorders in children and adults. In early 2009, philanthropists Terrance (Terry) D. and Judith (Judi) A. Paul established the not-for-profit organization with a gift of \$32 million, which included the assets of Infoture Inc. Funded by the Pauls, Infoture developed the breakthrough LENA System in a five-year research and development effort. (Terry is the principal inventor of LENA.) The Pauls' donation to establish the LENA Research Foundation included the LENA technology, a multimillion-dollar supercomputer, and a natural language corpus of over 75,000 hours of natural language audio recordings. The foundation employs a team of scientists and engineers who are skilled in computerized speech and speaker recognition, microelectronics, statistical research, and children's language acquisition and development; they are passionately devoted to helping the foundation enhance language development worldwide.

The LENA System is the core technology and focus of the foundation's research and development program and is currently available in two versions—one for parents and one for professionals such as clinicians and researchers. LENA provides more than 25 different metrics on the natural language environment of children, including estimates and percentile scores for adult words spoken to the child, conversational turns, and child vocalizations. Meanwhile, two LENA products in particular enable parents and speech-language professionals to facilitate the early detection of language delays and disorders. The LENA™ Language and Autism Screen (LLAS) analyzes child vocalizations to automatically and objectively calculate the risk of autism, identify the presence of language delays, and assess the quality of a child's natural language environment. And the LENA™ Developmental Snapshot easily and confidentially assesses a child's expressive and receptive language skills, generating a standalone score and developmental age based on a parent questionnaire administered online.

Many researchers have hailed LENA as a paradigm shift in the diagnosis and treatment of language delays and disorders. The breakthrough technology has the potential to help parents, clinicians, and researchers close the gap in language development between advantaged and disadvantaged children and improve the language development of children with hearing loss and language disorders such as autism. LENA also has the potential to help adults struggling with language disorders, such as stroke victims. For example, stroke victims and other adults suffering from aphasia could one day use LENA to accelerate their re-acquisition of speech.

Although LENA was just introduced in 2007–2008, researchers have been using the technology to investigate many aspects of children's natural home language environments. Their findings have revealed important information on the effects of gender differences, birth order, and TV viewing habits on language development, and have provided new information on autism and the correlates of language delay. In 2009, LENA research studies were published in the prestigious peer-reviewed research journals *Pediatrics*, *Archives of Pediatrics and Adolescent Medicine*, and the *Journal of Autism and Developmental Disorders (JADD)*. Moreover, speech-language pathology graduate school departments have begun to train their students to use LENA in clinical settings, and speech-language pathologists have begun using LENA as a diagnostic and treatment tool.

To see a summary of the foundation's research findings, please visit <http://www.lenafoundation.org/Research/TechnicalReports.aspx> and download a PDF of *The Power of Talk*.

The Pauls planted the seeds for the development of the LENA System and the LENA Research Foundation in 1986, when they founded Renaissance Learning Inc. in the basement of their home in Port Edwards, Wisconsin. They created the company to market their Accelerated Reader™ (AR) reading management software, which was based on a system that they had developed to motivate their own children to read more books. At the same time, the Pauls made the acceleration of learning for all children worldwide the company's corporate purpose. From these inauspicious beginnings, Renaissance

Learning grew quickly; it went public in 1997, and Accelerated Reader is now the most popular software program of all time in K12 schools. Over 65,000 schools and roughly 15 million students in the United States and several thousand schools abroad use AR software each day, making Renaissance Learning one of the leading technology companies in the K12 market.

Visiting schools on Renaissance Learning business, Terry and Judi came to realize that teachers lacked the information and tools necessary to make data-driven decisions and to personalize the learning process. They discovered that almost the entire burden of improving student achievement is placed on the shoulders of the teachers, who are expected to prepare and instruct classes, control classrooms, grade papers, and assess students. They realized that very little of the information teachers collect gets out of the classroom, making it difficult for principals to provide coaching and supervision. (Educational research supports these observations.) Terry and Judi could see that although Renaissance Learning products helped teachers to manage and motivate student book reading something more was needed to help close the gap in reading and math achievement. In addition to using Renaissance Learning software to improve students' reading, writing, and math skills, teachers needed progress measurement tools that were easy to use and affordable.

Understanding teachers' need for more information to improve learning and close the gap in student achievement, Terry led the development of four additional computerized assessment tools: Accelerated Math, Star Reading, Star Math, and Star Early Literacy. Together with the Accelerated Reader software, these products have become the five leading computerized assessment products used in K12 schools today. In addition, Terry—focused on the mission to accelerate learning for all children—led the development of the reading and math intervention programs Reading and Math Renaissance, which have been successfully adopted by several thousand schools nationwide to help close the gap in student achievement. Today, Renaissance Learning has 950 employees, and the Pauls retain a 70 percent ownership in the company. Terry is the chief executive officer (CEO) of Renaissance Learning and the president of the LENA Research Foundation, to which he devotes 15 percent of his time.

Although the Reading and Math Renaissance intervention programs had helped many thousands of teachers and schools to close the gap in student achievement, Terry realized that even with the most intensive intervention teachers and schools were limited in terms of what could be achieved. The problem was particularly acute for the ability to read, the foundational skill for all other subjects and entrance to and success in college.

Schools can certainly help to close the reading gap, but they are unable to completely close it because of the huge disparity in receptive vocabulary with which students enter school. Some advantaged students enter first grade knowing the meaning of 10,000 or more words; however, other disadvantaged students may know only 2,500 words. Consequently, when both sets of students are formally taught how to read, the advantaged students with the 10,000-word receptive vocabulary quickly learn how to read and rapidly jump from reading at the first grade level to the third or fourth grade level. Meanwhile, the disadvantaged students learn to read more slowly and even when they do learn to read they struggle at the first or second grade level. Unfortunately, this gap caused by the early home language environment continues and often gets worse during subsequent school years. Terry realized that the early language environment sets the learning trajectory for students, making it almost impossible for schools to close the gap entirely. And he concluded that in order to close the achievement gap one must close the home language environment gap.

In 1998, Terry started searching for ideas for improving the home language environment and came across the groundbreaking book *Meaningful Differences in the Everyday Experience of Young American Children*. The authors, University of Kansas professors Betty Hart, Ph.D., and Todd Risley, Ph.D., had spent 10 years on the study. As part of this extensive undertaking, Drs. Hart and Risley collected one-hour recordings each month for three years for 42 children from 8 months to 40 months of age. The families came from a variety of socio-economic conditions—some families were on welfare, some were the families of university professors. Each recording was carefully transcribed through an excruciating three-year long process to determine and count every word and syllable spoken to the child and the number of interactions between adults and child, called conversational turns.

Hart and Risley discovered that the number of adult words spoken to the children from birth to three predicted almost all of the variance in the children's language ability and IQ at age three and—in a follow-up study—their reading and math achievement at age 10. More amazing, after considering the quantity of talk, socioeconomic status (SES) and mother's education accounted for none of the

difference in language ability and IQ. Talk and only talk made the difference. In fact, just plain talk has a more powerful impact on language and cognitive development than any combination of flashcards, computer programs, TV, or DVDs.

Meaningful Differences sparked the idea for the LENA (for “language environment analysis”) System. The difficulty of the Hart and Risley study had been the time and expense of the transcription process. But Terry realized that with the statistical techniques used in automatic speech recognition technology it might be possible to develop a computer program and means to automatically count the number of words spoken to young children and conversational turns. If the words and interactions between parents and children could be automatically measured and reported on, he reasoned, parents and caregivers would be able to change their behavior and increase the words and conversational turns. In turn, their child’s receptive vocabulary, language ability, and IQ would increase, and the language gap would close. Subsequently, closing the home language gap would eventually close the school achievement gap. Furthermore, Terry realized that if an inexpensive automatic means could be developed to measure the natural language environment of children, it could lead to all kinds of discoveries and perhaps make it possible to develop automatic methods for measuring language development and language disorders such as autism.

Seized with the idea for LENA, Terry and Judi founded Infoture in 2004, and recruited a team of scientists and engineers and an outstanding scientific advisory board to help make Terry’s vision for LENA a reality. Todd Risley, the co-author of *Meaningful Differences*, became one of Terry’s main boosters and advisors. Risley was able to see the first prototype version of LENA and some of the preliminary research results before his untimely death in November 2007.

Initially, Terry thought it might take two years and \$5 million to develop LENA. Instead, it required nearly five years and the Pauls’ personal investment of \$30 million. To build the algorithms and norm tables incorporated in the software, LENA scientists first collected thousands of hours of recordings from over 300 families and administered several thousand child language assessments. Today, LENA Research Foundation has the largest corpus of processed child speech in the world, a significant value to researchers. Once collected, the recordings were fed iteratively through a supercomputer consisting of 148 parallel processors with 27 terabytes of hard storage to develop the algorithms, norms, and software needed to provide reports for parents and researchers.

Although it took longer and cost more to develop than expected, LENA is already more accurate at measuring word counts, conversational turns, and many other important metrics of the natural language environment than Terry expected. In the beginning, Terry was not confident that it would be possible to automatically measure a child’s language development based on his or her voiceprint or that LENA would be capable of automatically determining the probability of risk of autism. In these and other respects, LENA has already far exceeded Terry’s expectations. Amazingly, it is now clear that by collecting even more recordings of children it is possible to make LENA even more accurate, affordable, and useful for additional clinical and research applications.

In 2008, Terry and Judi realized that for LENA to reach its full potential in terms of closing the language and achievement gap and make a difference in the diagnosis, treatment, and research of language delay and disorders, it should be part of a non-profit organization. Having a non-profit oversee LENA would make it possible to attract the grant money needed to further LENA’s development and to work in a more cooperative way with leading researchers throughout the world. Therefore, Terry and Judi established the LENA Research Foundation in early 2009 by dissolving Infoture and donating \$2 million in cash plus the assets of Infoture, including the LENA technology, supercomputer, and 75,000 hour home language corpus, to the foundation. The Pauls are confident that this change in organizational structure puts the LENA development on a course that will make a significant contribution to improving the screening, diagnosis, treatment, and research of language delays and disorders, and help close the gap between the haves and have nots that frequently divides this country and the world.

