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Assistive Technology Outcomes: Meeting the Evidence Challenge

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Meeting the Evidence Challenge

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Editing policies of this issue are based on the *Publication Manual of the American Psychological Association* (6th ed.) and may be found online at: www.atia.org/atob/editorialpolicy. The content presented herein does not reflect the position or policy of ATIA and no official endorsement should be inferred.

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Assistive Technology Outcomes: Meeting the Evidence Challenge

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Assistive Technology Outcomes and Benefits Editorial Policy

Aim and Scope

Assistive Technology Outcomes and Benefits, published by the Assistive Technology Industry Association, is an open access, peer-reviewed journal that publishes articles specifically addressing the *benefits* and *outcomes* of assistive technology (AT) for Persons with Disabilities across the lifespan. The journal's purpose is to advance the AT industry by (a) fostering communication among stakeholders interested in the field of AT, including manufacturers, vendors, practitioners, policy makers, researchers, consumers with disabilities, and family members; (b) facilitating evidence-based demonstrations and case-based dialogue regarding effective AT devices and services; and (c) helping stakeholders advocate for effective AT devices and services.

Assistive Technology Outcomes and Benefits invites for consideration submissions of original papers, reports and manuscripts that address *outcomes and benefits* related to AT devices and services. These may include (a) findings of original scientific research, including group studies and single subject designs; (b) marketing research related to AT demographics, or devices and services; (c) technical notes regarding AT product development findings; (d) qualitative studies, such as focus group and structured interview findings with consumers and their families regarding AT service delivery and associated outcomes and benefits; (e) project/program descriptions in which AT outcomes and benefits have been documented; (f) case-based reports on successful approaches to service delivery; and (g) consumer perspectives on AT devices and services.

Submission Categories

ATOB welcomes scholarly contributions. However, many stakeholders engaged in the field of AT do not have an academic background. ATOB offers a unique opportunity for these stakeholders to contribute their expertise and experience in the context of achieving successful outcomes and beneficial impacts. ATOB understands that many potential authors may lack experience in authoring papers for peer-reviewed journal publication. Therefore, the ATOB Editorial Board is pleased to offer assistance in preparing and refining relevant submissions.

Articles may be submitted under three categories—

Voices from the Field

Articles submitted under this category should come from professionals who are involved in some aspect of AT service delivery with persons having disabilities, or from family members and/or consumers with disabilities. Submissions may include case studies, project or program descriptions, approaches to service delivery, or consumer perspective pieces. All submissions should have a clear message and be written with enough detail to allow replication of results.

Voices from the Industry

Articles submitted under this category should come from professionals involved in developing and marketing specific AT devices and services. Case studies, design, marketing research, or project/ program descriptions are appropriate for this category.

Voices from Academia
Articles submitted under this category should come from professionals conducting research or development in an academic setting. Submissions are likely to include applied/ clinical research, case studies, and project/ program descriptions.

Types of articles that are appropriate include
Within each of the voices categories, authors have some latitude regarding the type of manuscript submitted and content to be included. However, ATOB will only accept original material that has not been published elsewhere, and is not currently under review by other publishers. Additionally, all manuscripts should offer sufficient detail to allow for replication of the described work.

*Applied/Clinical Research***.** This category includes original work presented with careful attention to experimental design, objective data analysis, and reference to the literature.

Case Studies. This category includes studies that involve only one or a few subjects or an informal protocol.

Design. This category includes descriptions of conceptual or physical design of new AT models, techniques, or devices.

Marketing Research. This category includes industry-based research related to specific AT devices and/or services, demographic reports, and identification of AT trends and future projections.
Project/Program Description. This category includes descriptions of grant projects, private foundation activities, institutes, and centers having specific goals and objectives related to AT outcomes and benefits.

Approaches to Service Delivery. This category includes descriptions of the application of assistive technology in any setting (educational, vocational, institutional, home-life) to improve quality of life for people with disabilities.

Consumer and Caregiver Perspectives. This category offers an opportunity for product end users, family members, and caregivers to share their experiences in achieving successful outcomes and benefits through the application or use of AT devices and services.

Mandatory Components of all articles

- Authors must include a section titled *Outcomes and Benefits* containing a discussion related to outcomes and benefits of the AT devices/services addressed in the article.
- Authors must include a short description of the article's target audience, and indicate the article's relevance to that target audience. Authors may describe their work as it relates to more than one audience, and should specify the value that each group may derive from the work.

Publishing Guidelines

- Each manuscript must reflect the style guidelines of the Publication Manual of the American Psychological Association (6th edition, 2009).

- Manuscripts should be no more than 25 pages in length (double-spaced), including references, tables, and figures. Due to the electronic format of the journal, all submissions should be submitted as email attachments in a Microsoft® Word format.
- See detailed *Manuscript Preparation Guidelines for Authors* for more information on formatting requirements and submission instructions.

For More Information

- Please see ATOB's *Editorial Policy* at http://www.atia.org/at-resources/atob/ for details regarding the submission and review process, ATOB's copyright policy, and ATOB's Publication Ethics and Malpractice Statement.

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Introduction to ATOB Volume 10: Assistive Technology Outcomes: Meeting the Evidence Challenge

Jennifer L. Flagg, ATOB Editor-in-Chief

If you attended the Assistive Technology Industry Association (ATIA) 2015 conference, you may have participated in Assistive Technology (AT) Outcomes Day, a collaborative event, jointly hosted by the Research Committees from ATIA and the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA). The AT Outcomes Day included three sessions: two focused on industry's perspective, while the third addressed academic models for data collection.

If you missed this significant event, the *Assistive Technology Outcomes and Benefits* (*ATOB*) Editorial Board is pleased to offer you a second chance, by continuing the Outcomes Day discussions through six articles on the topic of "Meeting the Evidence Challenge" in the arena of AT outcomes.

Several of the AT Outcomes panelists expand on their presentations, while others add new perspectives drawn from academia, industry, and the field. Collectively these articles attempt to improve the quality of life for people who use assistive technology. However, the avenues pursued to that end vary significantly. Read on for details about the contents of this Volume 10, Issue 1 of *ATOB*.

Voices from Academia

This issue begins with two scholarly articles reviewing some of the long-standing issues in the area of assistive technology outcomes measurement. First, Ben Satterfield considers current and past efforts geared towards improving the collection and analysis of AT outcomes measurement data. His "History of Assistive Technology Outcomes in Education" presents an overview of outcomes measurement projects, programs, and tools that have been implemented over the past 25 years. Readers will find this discussion useful in orienting themselves in the work that has been completed, and in identifying the challenges that still persist.

Roger Smith then extends that discussion in his contribution titled "The Emergence and Emergency of Assistive Technology Outcomes Research Methodology." In this piece, Dr. Smith considers the ways that outcomes measurement has been approached by the medical field and how those advancements could be applied to assistive technology. In doing so, he describes the problems with attempting to conduct randomized controlled trials related to AT use, and touches upon solutions that would help AT prescribers and payers to accept other forms of evidence.

Voices from the Field

In an article of practical interest to therapists, AT specialists, educators, and administrators, Chris Bugaj and Beth Poss present a practical and informative discussion of tools that can be used for outcomes data collection and analysis. Their article, "Multiple Means of Measurement: Tools for Collecting and Analyzing Evidence of Student Progress," describes the movement towards digital data recording, including details regarding several tools for capturing, displaying and analyzing evidence of outcomes.

Voices from Industry

The article "Supporting Literacy Achievement for Students with Intellectual Disability and Autism through Curricular Programs that Incorporate Assistive Technology" is geared towards AT service providers, administrators, and special education professionals. Authors Carol Stanger, Pamela Mims, Leah Wood, and Lynn Ahlgrim-Delzell describe ten related research studies, each of which considered the efficacy of one of five Attainment Company products. Gains in English language arts skills were demonstrated by study participants, who were students with developmental disabilities and autism. This work is married to the Volume 10 theme in two ways. First, it demonstrates the efficacy of the products being studied, giving service providers the evidence they may need to recommend these products to their clients. Second, it presents a sample of studies that contain protocols that could be applied to measuring AT outcomes for other products.

Russell Cross and Bob Segalman collaborate to describe the value of using automated data logging in speech-generating devices in their article "The Realize Language System: An Online Speech Generating Device Data Log Analysis Tool." Parents, service providers, and educators will appreciate the detailed discussion of state of the art technology in automated data logging, as well as the in-depth look at the application of data logging technology in Prentke Romich Company's Realize Language system.

In their article, "Measuring Assistive Technology Outcomes: A User Centered Approach," Adam Kinney, Dianne Goodwin, and Lynn Gitlow describe the inclusion of AT device users in the design and development of Blue Sky Design's Mount'n Mover product. A retrospective study evaluating this product demonstrated positive client outcomes. The authors then attribute the successful outcomes to the user-centered process applied to design the product's features and functions. AT developers and service providers will likely find value in the process description, as well as the resulting outcomes, which both provide valuable insights into the wants and needs of users of the Mount'n Mover.

Make Your Voice Heard

While these articles offer many suggestions and solutions related to achieving positive outcomes for people with disabilities, significant work remains to be done. Models and methods for data collection and analysis have the potential to shape the way we view outcomes, not only in relation to health and function, but also in terms of community participation, and ultimately, life satisfaction. Collaborations between manufacturers and researchers offer great potential for providing practical solutions with proven efficacy. It is our hope that these articles will help spur continued communication and further action that enables all stakeholders to advance the AT field towards quality of life improvements for those we are here to serve.

ATOB welcomes continued discussion on these issues, as well as the many other facets involved in the development and use of assistive technology for and by people with disabilities. If you are a prospective author, we encourage you to visit the *ATOB* webpage at http://www.atia.org/at-resources/atob/ to review open calls for papers, and to learn more about how you can make your voice heard.

Declarations

The content is solely the responsibility of the author and does not necessarily represent the official views of ATIA. No financial disclosures and no non-financial disclosures were reported by the author of this paper.

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History of Assistive Technology Outcomes in Education

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Abstract

The idea of identifying and measuring Assistive Technology (AT) outcomes seems at first to be simple. However, AT is part of a larger process that includes AT implementation services and the intervention of which AT is itself a part. Given the expansion of AT options available today, we also must examine the question of which AT solution best meets a client's needs.

While rehabilitation and other medical fields have sought to measure outcomes for some time, concern for AT outcomes in education began to emerge in the mid 1990's. Consensus as to what outcomes should be measured has remained elusive. Several federally funded projects, professional surveys, and summit discussions have provided a context for examination of the collection of AT outcomes data.

Recent developments have rekindled discussion of outcomes by demonstrating that the field remains unprepared with regard to producing AT outcomes evidence. An historical context for addressing these current challenges is described.

Keywords: assistive technology, outcomes, educational measurement, special education

Introduction

According to the Individuals with Disabilities Act of 1997, assistive technology (AT) refers to "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of children with disabilities." In education, AT serves to enhance learning and support classroom performance and participation. AT can range from pencil grips and raised-line paper to screen reading software and high-tech speech generating devices.

The law also defines AT services to encompass and support the selection, acquisition, and use of AT including evaluation and training for student, family and professionals. Edyburn (2004b) suggests that while these definitions of AT and AT services are important, they represent only two legs of a three-legged stool. The third leg should address AT outcomes. Without greater definition, educational professionals have little on which to base instructional and purchasing decisions regarding AT.

Simply put, an assistive technology (AT) outcome is the impact of an AT intervention (Scherer, 1998). Teachers, administrators, and families all have an interest in discovering how well AT is helping students to achieve their personal and academic goals. Publishers, manufacturers, and researchers all seek evidence of the impact of specific AT upon learning and classroom performance. While this seems straightforward, there are several challenges associated with measuring AT outcomes in education.

Among these challenges has been the task of determining the impact that AT has played, apart from other influencing factors (Smith, 2000). A lack of validated data collection tools for measuring outcomes has frustrated outcomes research (Edyburn & Smith, 2004; Watson, Ito, Smith & Andersen, 2010). From this has emerged the undertaking to address the need for a model or framework for conceptualizing outcomes in education (Bromley, 2001; Edyburn, 2001; Lenker & Paquet, 2003). Complicating matters further has been the diversity of the students whose progress is being measured (Smith 1996; RESNA, 1998a, 1998b, 1998c ; Watson, Ito, Smith & Andersen, 2010) and the lack of agreement as to what specific data to collect, (Smith, 2000; Parette et al., 2006).

The study and discussion of outcomes has been prevalent in the medical and rehabilitation fields since the mid 1980's (Assistive Technology Outcomes Measurement System, 2004). Concern for the importance of AT outcomes in the field of education developed in the next decade as the number of AT solutions increased. Parents and administrators alike wanted to understand "what works?" (Smith, 2000). After a flurry of attention and activity throughout the first decade of the new century, the field still lacks outcomes data to support the use of specific AT and agreement as to how best to collect such data. The goal of this article is to set an historical context for future discussion of AT outcomes in education.

Over the past two decades in education, there has been broad acceptance of the notion that AT use will positively impact students with disabilities (Ashton, 2005; Edyburn, Higgins, & Boone, 2005; Smith & Smith, 2004). Today, as budgets remain tight, schools and systems are being urged to look at the outcomes research behind the AT in which they invest (Satterfield & Smith, 2015). Guidelines for this process have been vague and limited (Parette, Peterson-Karlan, Smith, Gray, Silver-Pacuilla, 2006). These problems persist today for reasons that will be explored in the next section.

The Complexity of Measuring AT Outcomes

A shortage of definitive research on AT use and AT outcomes in Education (Watson, Ito, Smith, & Anderson, 2010) perhaps can be understood given the diversity of individuals in the population under study (Smith 1996; RESNA, 1998a, 1998b, 1998c; Fuhrer, 2001). Beyond this, it has been acknowledged that the process of measuring student classroom performance, functionality of the AT and changes in student well-being must take into account all the support, therapy, and other interventions (besides classroom use of AT) that an individual receives (Smith, 2000). These factors have proven difficult to isolate. While the use of subjective measures of success has been considered to be inadequate for measuring some aspects of AT (Fuhrer, 2001; Watson, Ito, Smith & Anderson, 2010), Smith (2000) has shown how subjective measures of perceived value of AT and AT services and self-satisfaction of the school, student and family with AT and AT services can be a significant element in AT outcomes measurement. Beyond this, Smith (2000) also stresses the importance of considering cost when measuring outcomes because the school systems that are purchasing assistive technology are looking for ways to make their funds go further.

In contemplating the measure of AT Outcomes, the full set of stakeholders and their perspectives must be considered (Rust & Smith, 2006) because their viewpoints are often different. Parents are looking for positive impact upon the student both in the classroom and overall. While teachers, therapists, and administrators anticipate achievement of academic goals, administrators also must consider the costs of AT. Manufacturers and publishers of AT consider user satisfaction, usage, cost, improved student function, and classroom results. These considerations have sometimes extended beyond academic performance alone. Scherer (1996) reviewed research on AT use and concluded that AT choice and decision making should be focused upon the individual beyond the classroom and how that specific selection of AT will enhance the student's quality of life. DeRuyter (1998) contended that AT outcomes should incorporate quality of life measures, achievement of objectives and performance targets, student satisfaction with the AT, and the expense involved. Enhanced community involvement also has been suggested as an important measure (Fuhrer, 2001).

Early History of AT Outcomes in Education

The first scholarly discussions of outcomes with regard to AT emerged in the mid 1990's (DeRuyter, 1995) and were broadly focused but nevertheless influential with regard to education. The first peer-reviewed journal with an issue which was dedicated to AT Outcomes (*Assistive Technology*; Smith, 1996) followed quickly thereafter. The first textbook on AT, *Assistive Technologies: Principles and Practice* (Cook & Hussey, 1995) was published at this time. In 1998, the Rehabilitation Engineering Society of North America (RESNA) published an extended three-part discussion of AT Outcomes, including the first national survey of AT outcomes practices (RESNA 1998a, 1998b, 1998c). The turn of the century saw the creation of the National Assistive Technology Research Institute (NATRI) and a second journal with an issue which focused upon AT Outcomes (*Diagnostique*; Edyburn, 2000a).

Studies Related to AT Outcomes in Education

Early studies related to AT outcomes focused upon device abandonment (DeRuyter, 1997; Riemer-Ross & Wacker, 2000; Scherer, 1996) revealing that the rate of abandonment ranged from 8% to 75% of AT in the field. These studies relied heavily upon customer satisfaction surveys without establishing goals or anticipated results (Watson, Ito, Smith & Andersen, 2010). Riemer-Ross and Wacker (2000) explored the factors related to AT use that served to decrease abandonment. Their results suggested to the field that the centrality of the student in the consideration process, the appropriateness of AT selected for use, and the advantages that the specific AT provided the student all had a positive impact.

A limited number of studies sought to examine the changes in functional performance of AT use by students in public schools (Smith, 2002).

It was difficult to generalize from the several studies of AT and students in school (Campbell, Milbourne, Dugan, & Wilcox, 2006; Evans & Henry, 1989; Gerlach, 1987; Hall, 1985; Hetzroni & Shrieber, 2004; Higgins & Raskind, 2004; Wallace, 2000) as these studies involved small groups of diverse students or focused upon specific AT or strategies involving AT.

The AT Infusion Project under the Ohio Department of Education (Fennema-Jansen, 2004; Fennema-Jansen, Smith, & Edyburn, 2004), however, did feature a large group (just under 3000) of students. The study attempted to examine the effect of a broad spectrum of AT upon these students. This project demonstrated how collection of AT outcomes data might be done on a large scale. In the process, a tool for collecting information about the impact of AT in an educational setting was developed, the Student Performance Profile (SPP; Fennema-Jensen, Edyburn, Smith, Wilson, & Binion, 2005; Watson, Ito, Smith, & Andersen, 2010).

Another study of younger students with Cerebral Palsy (CP) was conducted by Ostensjo, Carlberg, and Vollestad (2005). While this was a descriptive study, it involved 95 students and employed the Pediatric Evaluation of Disability Inventory (PEDI) tool to measure mobility, self-care, and social function. It was the social function scale of this tool that looked at aspects of learning and intellectual growth.

Watson, Ito, Smith, and Anderson (2010) suggest that many of these early studies were narrowly focused or methodologically limited, that others were qualitative or non-experimental, and that the field suffers from a scarcity of well-conceived studies that address AT outcomes. Lenker et al. (2005) called for future research to be more deliberate and suggested the need to include a rationale for the instruments used and more detail about the sample, the length of the study, and the sites involved.

Process: Setting the Stage for Good Decisions

While these studies were under way, other efforts were taking place to establish a framework for good decision making with regard to AT. In 1999, Dave Edyburn (2000b) launched a series of annual reports to the field, known as "What have we learned lately?" Each year, he identified a set of key articles appearing the previous year in journals that addressed AT research in education. He identified the trends that were represented in AT research that year and summarized the highlights from the articles. He especially pointed to evidence of AT outcomes where they appeared in the literature, and provided observations as to how the approaches to research represented in these articles could be made stronger (Edyburn, 2002, 2003, 2004a, 2006). In recent years, Edyburn has developed visual mappings to illustrate how published research has clustered around specific themes (Knowledge by Design, Inc., 2015). These articles were broadly read by educators, administrators, and researchers in the field.

In 2005, RESNA announced the launch of its certification process to identify and establish qualified practitioners for the field. The Assistive Technology Professional (ATP) certification was designed to establish a standard of professionalism for the field and foster increased confidence among those who use AT products and services (RESNA, 2014). While AT certification is generally not required in educational circles, it does provide an opportunity for educators who work in AT to obtain credentials that highlight their skills.

In 2000, the National Assistive Technology Research Institute (NATRI) was launched to explore AT and AT services in schools and to discover what practices were most effective. The NATRI team examined planning and implementation of AT in K-12 schools as well as professional development in AT. The Institute produced the Status of AT Use Survey (Quinn et al., 2008) which helped inform the field of the breadth of AT use in K-12 schools as well as the locus and contexts in which AT was being used, pointing to a need to broaden AT use to general education settings and beyond communication and access. NATRI also launched a study of state and local level policies with regard to AT and the Individualized Education Program (IEP) process (Bell, 2001) which suggested that, while many agencies had AT policies in place, awareness at the teacher level remained limited. An investigation of AT and IEP process (Bausch, Quinn, Chung, Ault, & Behrmann, 2009) revealed that some districts had more explicit and complete directions and policies regarding AT and the IEP than others. The study highlighted areas where a lack of information regarding AT could jeopardize some students' academic success. This study also revealed a lack of planning for AT implementation. Bausch, Ault and Hasselbring (2006) developed the *AT Planner*, a set of materials to guide this process including the monitoring of progress related to AT use.

NATRI also sought to explore the impact of AT upon academic progress. Using interviews of teachers, students and families, NATRI discovered frequent reports of positive results. However, teachers reported cases of device abandonment relating to student dissatisfaction with the device chosen for them (either the AT was stigmatizing or it was not their choice), that inadequate training was provided, or the AT provided was inappropriate relative to the student's needs (Bausch, Ault, & Hasselbring, 2015). A NATRI study of institutions of higher education illustrated the limits of the preparation of pre-service teachers and therapists for implementation and effective use of AT (Bausch & Alt, 2012), reporting that many professionals had only a general awareness of AT as they entered the field. While the NATRI project ended in 2006, its studies have highlighted issues that persist today and raised questions that continue to be relevant.

Simultaneously, a series of conceptual models were being articulated for the field. There were several models for AT Consideration. The ultimate goal of these models was to connect the person with appropriate AT by exploring the individual, the setting, and function (Bromley, 2001). These models attempted to lay out a set of considerations to aid AT teams to choose appropriate tools for individuals (Edyburn, 2001; Lenker & Paquet, 2003). Among these were: the Lifespace Access Profile (Williams, et.al, 1995); the SETT Framework (Zabala, 1995); Education Tech Points (Bowser & Reed, 1995); Chambers Consideration Model (Chambers, 1997); Matching Person and Technology (MPT) Model (Scherer 1998b); AT CoPlanner Model (Haines & Sanche, 2000); and the Wisconsin Assistive Technology Initiative (WATI, 1998). A common feature of these models is their emphasis upon student outcomes. By exploring the student's strengths and needs and by defining the context and activities in which the student needs to perform, appropriate AT can be identified. Each model calls for the collection of data related to the AT introduced and the gains made by the student involved.

There were other technology-enhanced performance models that sought to define technology's role in improving individual functioning (Edyburn, 2001). These included: the Model of Human Performance technology (Wile, 1996); Baker's Ergonomic Equation as adapted by King (1999); the Human Activity

Assistive Technology (HAAT) Model (Cook & Hussey, 2002); and the Human Function Model (University of Kentucky Assistive Technology (UKAT) project, 2002) which incorporates principles of Melichar and Blackhurst's (1993) Unifying Functional Model. While these models brought renewed focus upon the individual, they conceptualized successful AT as fitting into specific contexts and situations in which the individuals find themselves. In general, these models did not attempt to isolate AT from other factors. In fact, in some cases, adherents to these models have made the case that it may not be necessary to isolate AT from the constellation of other interventions and factors in order to conclude that a positive outcome related to AT has been achieved. If the student previously could not read, but through introduction of a screen reader is now reading, then from the perspective of the student, the functionality sought has been achieved. Even if it was not the sole factor, AT was part of what made the positive outcome possible. Nevertheless, Edyburn (2015) has noted that the standard of evidence in AT outcome research has become more exacting as the field has matured.

There were also a series of developmental models that emerged. These models described how delivery of AT services in school environments contributed to individual progress and development (Edyburn, 2001). These included: the QIAT Consortium – Quality Indicators for Assistive Technology (1998); the Model of Technology Integration Process (Edyburn, 1998); STAGES (Pugliese, 2001); and the A3 Model (Schwanke, Smith & Edyburn, 2001). These models served as a basis for development of "Best Practices" for AT implementation as the field began to mature by bringing clarity and definition to the steps involved in integrating AT in the classroom such that positive outcomes could be achieved.

Still other models were appropriated from other fields and examined for their applicability as tools to explore how AT might reshape our conceptualization of the challenges surrounding the individual with a disability (Lenker & Paquet, 2003). These models included: the Social Cognition Model (Carter, 1990); the Perceived Attributes Theory (Rogers, 1995); the Career Path Model (Gitlin, 1998); and the International Classification of Functioning for Disability and Health (ICF) Model (WHO, 2001). These models have implications for the measurement of AT outcomes, especially regarding the challenges in the larger environment in which the student operates, the changes that take place in the environment over time, and individual perceptions of the value of the AT to be used.

Lenker and Paquet (2004) expanded upon Rogers' Perceived Attributes Theory to outline a predictive person-centered conceptual model. The authors sought to relate the use of AT to how the client perceives the relative advantage of using that AT. While developed with the rehabilitation environment in mind, this model has implications for collection of information on AT outcomes in education.

Federal Projects

Also at the turn of the new century, two federal projects were launched to address the questions and obstacles relating to AT outcomes. These were five-year research programs that sought to improve the field's measurement capability with regard to AT and AT outcomes and to reduce barriers to the use of AT outcome measures.

One project was the Assistive Technology Outcomes Measurement Project (ATOMS). The goals of this project included finding the relationships among AT outcomes factors to help create a better understanding of AT use and disuse, identifying and developing data collection instruments for AT outcomes, and, through the Ohio Project, developing experience collecting data on AT Outcomes in education (Assistive Technology Outcomes Measurement System, 2005a). The project, which ended in 2006, laid a foundation for future AT outcomes research in education by producing a range of technical reports on the current collection and use of AT outcomes data and by developing a set of patterns for measurement tools to help collect outcomes data on AT use (Assistive Technology Outcomes Measurement System, 2005b).

The second federal project was the Consortium for Assistive Technology Outcomes Research (CATOR). This project sought to bring conceptual clarity to the field on the topic of AT outcomes measurement, identify barriers and factors contributing to AT abandonment, improve platforms for acquiring AT outcomes data, and understand the processes for AT use and disuse (Consortium for Assistive Technology Outcomes Research, 2011a). Among the achievements of this project were the establishment of a common set of terms and definitions for collecting outcomes data from mobility-related AT interventions and the development of tools and procedures for administering and measuring AT in seating and mobility clinics. The project's ongoing work currently addresses the development of more precise measurement tools for evaluating the effectiveness of mobility-related AT devices and how such AT can support, enhance and impact the assistance provided by individual caregivers (Consortium for Assistive Technology Outcomes Research, 2011b). Aspects of these tools may provide elements that can be grafted into instruments used in the measurement of educational outcomes.

AT Outcomes Summit 2005

In 2005 a summit on AT outcomes in Education was held in Chicago, IL. AT professionals from all aspects of the field gathered to discuss questions relating to assessment. Specifically, the summit explored the difficulties in the incorporation of AT into educational assessment and how these challenges affected the assessment of content area learning for students who use AT. Beyond this, the group considered what would be required to determine the influence of AT on student progress. (Parette et al., 2006)

Participants were concerned that the technology that was being approved for use on standardized tests might be influencing purchase and policy decisions for instructional classrooms: If the AT cannot be used for the test, then it should not be used in the classroom. This would have the effect of denying students tools that could assist them in making academic progress. Attitudes persist among the educational leadership that AT use is "cheating." The summit participants suggested that Universal Design principles (including access through technology) should be incorporated into assessment models (Parette et al., 2006). Concerns remain as the PARCC and Better Balanced national testing consortia have sought to include students with disabilities in their online testing environments. (Marachi, 2015).

The summit called for the field to encourage the growth of research that makes evident the impact of AT upon educational progress. This requires that data collected be amassed and combined around a set of agreed upon outcomes measures. Access to these data needs to be open to teachers as well as researchers. Participants also proposed that professional preparation be overhauled such that the emphasis would be upon strategies for implementation of AT rather than the AT tool and its operation. Instructional environments and curriculum need to reflect the technology that is a core component of 21st century life and business (Parette et al., 2006).

The summit pointed to the trend that technology is becoming generalized. What once was technology reserved for accommodation of a few students is becoming the pathway to curriculum access for all students. They suggested that there is too little focus upon the skills that are required for proficiency with the emerging technology (Parette et al., 2006).

Thurlow et al. (2007) further explored the implications for large scale testing upon the role of AT and found that there were wide differences among states in how they addressed the needs of students for accommodations on state-wide testing. The application of AT, which has been commonly understood as an individual accommodation, to large-scale testing argues for a broader perspective on its applicability which now involves staff resources from instructional technology, assessment, and administration. In the process, several issues are raised which include accessibility to the testing format and how test security can be maintained while students are given access to the test content. In many states these issues have been passed on to the national testing consortia (PARCC and Better Balanced) to address. States such as Georgia, who have developed their own online test (Georgia Milestones Assessment), assert that their testing is accessible to all students (Georgia Department of Education, 2014), but the ability to implement accessible testing across the state has encountered challenges (Waylock, 2015).

Questions Regarding the Collection of AT Outcomes Data

Several questions emerge when we seek to measure AT outcomes by making use of data currently being collected. Can we get visibility into what data is being collected by existing systems? Each system that is currently collecting data has established its data set based upon its most significant needs. Billing requirements are significant to private practice and clinical settings. Some schools bill today for speech and occupational therapy services. These may collect some data relative to AT usage, but do they collect enough information to draw conclusions as to efficacy of AT solutions and strategies? Can we assume quality of life issues are being addressed by currently collected data? When privacy concerns are considered, what data *can* we obtain?

With regard to schools, we assume that data is maintained on students who have Individualized Educational Plans (IEPs). As schools employ the AT consideration models (mentioned above) in the selection of AT for student use, what is done with the data that is collected on AT trials? Many schools make use of online IEP systems today. What data are these systems currently collecting? What data elements might be used to provide some insight into AT use and its impact?

Several important questions asked by the Outcomes Summit of 2005 still remain unanswered. What should be the standards we are looking for? What outcomes should be tracked? Are there some that would be elective and others that would be required? Who decides this? How would the various perspectives of the students and their families, the research community, the manufacturers and publishers, and the schools be addressed?

One particular challenge that remains unresolved is how to determine the relative impact of the various therapies and interventions that are taking place with an AT user. In many cases individuals who use AT are also receiving other services. We can assess a desired outcome to some degree, but can we isolate the impact of AT hardware or software? Indeed, do we have to separate AT from the other services and therapies provided if we can establish a positive result in student performance? Clearly, as the range of AT options grows, manufacturers, publishers, teachers and administrators want insight into what AT might be most appropriate and effective. However, this "black box" effect, in which observers lose the granularity with which to distinguish the effect of specific elements in an intervention, will create impediments to measuring outcomes of specific AT use (Smith, 2000).

Conceptualizing a Framework for Measuring AT Outcomes

A call for a theoretical framework for measuring AT outcomes in education has been issued. Fuhrer, Jutai, Scherer, and DeRuyter (2003) contributed a model for measuring AT outcomes that incorporates both objective and subjective measures, includes data that addresses concerns of various stakeholders, gives primary consideration to the goals and needs of the individual (student), addresses the need for common definitions (ICF), and provides visibility to mediating and moderating factors. The model specifically identified effectiveness and efficiency of the AT, satisfaction with the AT itself, and how well the AT contributed to the individual's feelings of competence and sense of well-being as critical aspects to be measured. The authors called for examination of these factors in both the short and long run, listing a number of moderating factors such as comorbidities, environmental factors, other simultaneous treatments, and expense.

Lenker and Paquet (2004) assert that without a predictive conceptual model, professionals will find it difficult to apply research to practice. The authors have developed a model for conceptualizing AT outcomes as relating to the AT user's perception of the relative advantage of the use of the AT in question. This model employs AT usability (duration, frequency, environments, contexts, and tasks) and quality of life (health and well-being, quality of social relationships, and ability to perform in social roles) as outcomes indicators. While conceptualized as a model for AT in rehabilitation settings, it would be instructive to explore how this might guide the development of a predictive model for education. Clearly some redefinition of the quality of life measures would be required. As a student-centered model, some study must be given to how to capture the student perception of relative advantage as opposed to projection of teacher-perceived advantage (although such a model may want to find a place for teacher and parent perceptions of relative advantage).

Edyburn (2015) observed that little has been accomplished with regard to developing AT outcome measurement tools. He suggests two possible reasons for why the field has not yet developed AT outcome measurement tools. First, the field is still in the early stages of integrating AT into instruction and has not had sufficient time to establish a core research base. Edyburn points to an evolving criteria for quality of evidence regarding AT outcomes as the second reason. Where a case study may have been perceived as indication of efficacy in the early days of AT, now teachers and administrators are expecting more robust research with regard to outcomes.

There is tremendous diversity among the persons with disability who use AT (Smith 1996; RESNA, 1998a, 1998b, 1998c; Watson, Ito, Smith & Andersen, 2010). This makes it challenging to produce randomized controlled trials. The field has been seeking to make its research more rigorous by using methods such as single subject design and seeking to apply the principles of treatment integrity to studies which are of necessity small in scope (Smith, 2015).

Perspective from the Field

In an attempt to sample the thoughts of professionals in the field regarding a framework for measuring AT outcomes, the ATOMS project (Edyburn & Smith, 2004) conducted a survey of 80 AT conference attendees (including individuals with a broad range of roles and professional duties related to

AT) to discover what the practitioners believed was of greatest importance with regard to a framework for measuring AT outcomes. Agreeing that a framework was needed, the participants explored the extent to which expertise and training should be required of those administering AT outcomes data collection systems. Several points of agreement emerged. The survey indicated a preference for instruments that are easy to administer and could be employed by many practitioners in the field, as opposed to being administered only by those steeped in AT outcomes theory.

Regarding data collection techniques, the participants in the survey indicated a desire to preserve the option to employ paper-based as well as web-based instruments, suggesting a desire to maintain the flexibility that paper-based instruments provided, and possibly reflecting the level of technical sophistication of much of the field at that time. One wonders if a more current set of survey participants would be more inclined to accept web-based instruments.

Concerning the integration and analysis of data, participants indicated a preference for using data that can be obtained from multiple current data sources, including both new specialized data collection tools and data culled from existing data collection mechanisms. When considering the process of constructing meaning from data results, the survey asked about the desirability of simplification and visual representation as opposed to the need for drill-down visibility and granularity of collected data. The survey indicated a preference for simple and visual interpretation.

Edyburn and Smith (2004) also suggested the possibility of "dynamic norming" of the data being gathered. Given the limitation of the size and diversity of the population involved and the breadth of AT products and services, it would be difficult to establish a group against which to compare changes. Would a web-based, real-time database to provide normative comparisons be important? Respondents indicated that a system that provides "dynamic norming" would be of significant value. No such process has been established to date.

The survey asked how the data might be used for decision-making. Would different users of the same data arrive at similar conclusions? Would there be a need for training for the field in how the data might be viewed and interpreted? Should the system support decision-making on the basis of data? Specifically, should the system include nuanced inferences about services and products and implications for implementation strategies? The survey indicated that such a feature would be valuable, but to a lesser degree than other factors (Edyburn & Smith, 2004).

Edyburn and Smith (2004) highlighted the need for validated instruments for measuring AT outcomes and observed that the field lacks the consistency and skill in its practice that would permit effective collection of AT outcomes data. Further, they identified concerns about the readiness of the field to collect, analyze, and interpret AT outcomes data.

Where Do We Go From Here?

There remains no consensus relative to a model for defining and anticipating AT outcomes. Some suggested starting points and tools have been proposed that are worthy of the field's consideration. Research is needed to help frame the collection of outcomes data and to establish a foundation for predictive models to emerge.

After examining AT outcomes studies in the rehabilitation field, Lenker et al. (2010) assert that the field needs to approach AT outcomes research in more systematic ways. Specifically, clearly articulated theories of treatment that specify the philosophy and methodological underpinnings of the research are needed. These theories will serve as guides for teachers as they seek to apply outcomes data to their classroom. There is need for greater specificity regarding the intervention so that consumers of the research can understand not only what AT was involved, but what was done with the AT (strategies, usage, application, and how the AT was integrated into instruction). Lastly, greater attention to treatment integrity is needed so that readers may have certainty that treatment was carried out in accordance with the stated research protocols.

Smith (2000) has posited that in order to be comprehensive and efficient, AT outcomes measurement in education must be student-centered, incorporate measures of AT use across different contexts, be consistent in measurement approach across student populations, be inclusive of subjective information about quality of education and impact upon quality of life, and discern the impact of AT on the student from among multiple interventions. One instrument which attempted to incorporate many of these elements was the Student Performance Profile (SPP) which was developed in conjunction with the Ohio Assistive Technology Infusion Project (Fennema-Jensen, Edyburn, Smith, Wilson, & Binion, 2005). The SPP employed individual student IEP goals as outcome measures to provide an approach that was student-centered and consistent across populations. Rating scale questions were asked of case managers as to the relative impact of AT compared to that of other therapies and treatments. Watson, Ito, Smith and Andersen, (2010) were able to develop a study from a subset of this data (13 students with a variety of disabilities) to analyze the effectiveness of the AT used upon the IEP goals of the students involved. Among the 11 of 13 students who made progress on IEP goals during this study, AT was identified as one of the factors contributing most often to the improvement made. This was a small study, but it provides one example of how AT as an outcome among a number of interventions and factors may be measured.

Edyburn, Fennema-Jansen, Hariharan, and Smith (2005) have pointed to the fact that IEPs are most often generated online. They suggest that this fact may open the door for the collection of information about AT outcomes. They describe how online IEP systems might be modified to collect data on how well individual goals are met when AT is involved. Such a view would be of particular value to teachers and systems as it helps connect the outcomes information with the planning and instructional process. The availability of data that was de-identified and aggregated would help researchers provide the field with useful insight into how AT might be effectively applied with different students.

Another possible strategy for collecting AT outcomes data might be to examine the data collected for AT trials (Edyburn, Fennema-Jansen, Hariharan, & Smith, 2005). When data collected on a student's trial use of a particular AT tool, is used for a decision as to whether the student might use that tool on an on-going basis, what happens to that data? Could it be aggregated with data from other student trials?

Data is also kept on AT inventory use. Generally school systems collect items at the end of the school year so that they may be inventoried and refreshed over the summer for use the next fall. How might we collect data on which students have used which AT items? Could we use this as an opportunity to include a survey which might help us also discover how successful or satisfied the student and teacher (maybe parent) were with that tool (Edyburn, Fennema-Jansen, Hariharan, & Smith, 2005)?

The changes and developments in technology itself may have the effect of hastening a solution. The ease of collection of survey data today, for example, may make it easier for us to collect and analyze outcomes information (Smith, 2000). The proliferation of polling and survey tools, such as SurveyMonkey.com (SurveyMonkey, 2015), have made collection of data such as customer satisfaction with a product or service an easier and much less expensive task.

As the technology progresses, will we soon see the capability of such data being gathered by the AT tool itself? An increasing number of AT products incorporate some form of data collection in their design. Almost all speech generating devices (SGDs) collect information about client usage in a data logging tool that is resident in the device. Apps for the iPad tablet such as LAMP: Words for Life (Prentke Romich Company, 2015) are emerging that are able to collect usage data. Tools such as the AAC Performance Report Tool (Romich et al., 2003) and the Realize Language web site (Cross, 2013) provide visibility to this usage data (once extracted and uploaded) and allow some analysis of outcomes. Instructional software tools such as Classroom Suite (Ablenet, 2015) have the capacity to collect and analyze student responses (Parette, Blum & Boeckmann, 2009). This trend may provide another source of data by which outcomes may be measured.

Target Audience and Relevance

This article has described the contributions of many to further professional awareness of AT outcomes and how they might be collected and applied. And yet, well into the second decade of this discussion, the field of education has reached little consensus in defining the outcomes it values most and still has no valid accepted instruments for collecting data regarding these outcomes. Much information is collected on students who use AT, but little has been done to compare or aggregate this information. While the field is still maturing, the pressure from limited budgets, questions about standardized testing accessibility, and curriculum policy decisions demand that we rapidly address the need for AT outcomes data. This article has identified several concepts relating to outcomes measurement from the perspective of rehabilitation that can offer guidance to researchers as they craft the theories, framework, and tools for measuring AT outcomes in education.

Manufacturers and publishers may look at AT outcomes somewhat differently from other stakeholders, but still have a strong interest in providing information that addresses concerns of the field. This article has identified ways that outcomes data is already being collected within apps, computer software and hardware devices. As technology advances, industry members can look for ways to build data collection features into new product designs. At minimum, these tools may help the field establish sources of information on elements of usage such as frequency, duration, and contexts.

Administrators have the responsibility to make wise and effective decisions with regard to AT implementation, especially relating to cost. The literature has suggested that they may find in their backyards a potentially significant amount of data relevant to outcomes. Beyond the data collected in online IEPs and testing data, this article has asked about other information which is currently being collected that might inform not only administrative policy and purchasing decision, but also instruction. Administrators can make an important contribution to the field by exploring these sources of data and how they can be enhanced to be more informative. Privacy is always a valid concern, but well planned data collection and storage can de-identify data while retaining the features needed to support decision making and research. The ideas presented in this article can serve as a starting point.

The agencies that fund AT purchases in the rehabilitation field (Medicaid, Medicare, private insurance, etc.) want to have confidence that the resources they are devoting to AT purchases for their clients have a likelihood of success. In education, these agencies play a peripheral role with regard to AT. Nevertheless, dependable AT outcomes data would provide a framework for making decisions about AT for their clients. The federal Department of Education and the state education agencies could serve a pivotal role by providing leadership and by supporting, encouraging, and helping to resolve problems and issues with outcomes data collection, especially by helping find ways to combine data from different sources.

Classroom teachers and therapists in the school setting also have a role to play in the development and application of AT outcomes data. This article has identified the importance of accurate application of treatment theory and of attention to treatment integrity. Also, parents and professionals who together make up the IEP teams in the local setting, are in position to examine AT outcomes data as they are collected and make judgments as to how to apply AT in the specific cases of the students they serve.

Outcomes and Benefits

While there remains a great deal of work to do to establish a system for measuring AT outcomes in education, those engaged in the field would benefit from reviewing the work of those who have preceded us in wrestling with outcomes measurement. Their contributions to the discussion of AT outcomes have laid the groundwork and shaped the questions that we must face if we are to develop an effective system for collecting and analyzing outcomes data.

Declarations

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The Emergence and Emergency of Assistive Technology Outcomes Research Methodology

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Abstract

Assistive technology (AT) outcomes in rehabilitation made major strides in the early 2000s. However, despite major advancements in the technology environment, AT devices, and rapid advances in outcomes methodology, outcomes never seemed to charge into the mainstream of AT research. This has turned into a significant field-wide problem as evidence-based funding has become a reality. This paper summarizes the history of AT outcomes to highlight continuing methodology issues and opportunities in rehabilitation to create systems and research methodologies more conducive to measurable AT outcomes and disability research than traditional randomized controlled trials. The health and medical outcomes fields have matured to include registries, acceptance of small studies as key steps in measuring outcomes, and mHealth to leverage the capabilities of mobile interventions and data collection. AT and rehabilitation engineering professionals, researchers, and policy makers must take advantage of these new methods and engage in a new level of defined research that includes these emerging techniques. Without this investment in outcomes research, the budgetary constraints of evidence-based funding will continue to leave the field in a state of marginal financial support.

Keywords: assistive technology, outcomes measurement, rehabilitation, methodology

The Emergence of Assistive Technology Outcomes Research

Research in assistive technology (AT) outcomes has a historically strong foundation, a weak current focus, and major potential to contribute to improving future AT services and the lives of people with disabilities. However, documenting AT outcomes is challenging. This is in part because AT outcomes are multifaceted as a key interest of many stakeholders, each having their own reasons for wanting to know about outcomes (DeRuyter, 1995, 1997, 1998). Basic researchers want to understand foundational factors explaining why AT works and the related causes and effects. People with disabilities and service providers want to know which AT devices work and under what real-life conditions. Manufacturers and developers want to demonstrate that their products work. Funders want to know what functional improvements are made with which devices and services and at what costs. Moreover, the concept of "outcomes" and the varied domains of outcomes are a terminology debacle. People with disabilities even have difficulty relating to the word "outcomes". People with disabilities want products that work. Outcomes are an abstract construct (Lenker, Harris, Taugher & Smith, 2013). The context describing "outcomes" emerged from conversations among service providers trying to describe what they thought third-party payers needed.

This complexity around outcomes must be organized and simplified. The consequence of any confusion around outcomes is a disservice to the field. This paper focuses on the outcomes that service providers, manufacturers, and people with disabilities must document so that funders can understand. At its core, if the field fails to deliver practical outcomes data on this level, current and future funding of AT devices and services will continue to be in jeopardy.

To better understand the current state, where the AT field fundamentally lacks evidence of AT outcomes, it is helpful to examine the history of outcomes in rehabilitation and AT, review the unique methodology challenges encountered by the field, and highlight the implications of inaction. This background will help explain what the communities of AT consumers, practitioners, educators, researchers, and industry need to do.

Historical Need for Measuring Outcomes in Rehabilitation

The need for measuring outcomes in rehabilitation has existed and been documented for many decades. Understanding the path that medical rehabilitation outcomes research took as it matured informs new directions for managing AT outcomes research. Early on, researchers and clinicians acknowledged the need and prompted publications that created new assessments for disability outcomes measurement (Granger & Gresham, 1984; Keith, 1997; Fuhrer, 1987). Many new functional assessment instruments were created during this time and standards for developing instruments were articulated (Johnston & Graves, 2008). In the 1980s, work supported by the National Institute on Disability and Rehabilitation Research (NIDRR, now the National Institute on Independent Living, Disability and Rehabilitation Research - NIDILRR) through a field-initiated project, spawned the Functional Independence Measure (FIM) as a simple 10-20 question outcome measure. The foundational questions heavily overlapped the Barthel Index (Mahoney & Barthel, 1965). The FIM development process created a consensus through a multi-disciplinary and substantial national effort with stakeholders across rehabilitation service provider sectors.

What resulted was not only the development of the FIM (Stineman et al., 1996), but also the creation of the Uniform Data System (UDS) (Fiedler & Granger, 1996; Uniform Data System, 2015) that later evolved into being embedded in several national data collection systems such as the Centers for Medicare and Medicaid Services' (CMS) Minimum Data Set 2.0 Resident Assessment Instrument User's Manual for nursing homes (CMS, 2008), and the NIDRR Burns national registry (Klein et al., 2007). Eventually, this FIM initiative provided the foundation for the current rehabilitation and disability funding system based in the CMS (Clayback et al., 2015). This system, called the Inpatient Rehabilitation Facility Patient Assessment Instrument (IRF-PAI) (CMS, 2016), highly resembles the early work in the 1980s and is a direct descendent of the 18-question, seven- point FIM scale. The researchers in medical rehabilitation realized that aggregating data into field-wide data sets was necessary to demonstrate positive outcomes and to help direct the funding systems to support successful practice. As a relatively defined area of practice, medical rehabilitation has been able to successfully focus its methods. National outcomes data systems have resulted.

Historical Need for Assistive Technology Outcomes Measurement in Rehabilitation

While the AT community began paying attention to outcomes after the efforts in the general rehabilitation community, by the 1990s it was clearly acknowledged that a focus on AT outcomes measurement and research was needed (Smith, 1996). At that time, many AT outcomes researchers were predicting that if the profession did not seriously begin developing and using outcomes measures, AT funding would be in peril. As part of a field-driven response, the Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) developed an active Special Interest Group on AT outcomes in the late 1990s and 2000s. Al Cook, then president of RESNA, created an ad hoc Committee on Quality Assurance that actively participated in the efforts to develop service provider credentialing in AT to facilitate competent service provision and the resulting outcomes. Key to this process was the writing and compilation of a three-volume resource on AT outcomes published by RESNA (1998). Additionally, during this project, RESNA brought together expert groups to create taxonomies of the skills and knowledge related to best practices that served as the core for the development of the Assistive Technology Professional (ATP) credentialing and targeted future specialty credentialing areas (RESNA, 1996).

In 1996, a special issue of the journal Assistive Technology was devoted to outcomes. The focus revolved around methodology. In 2004, the e-journal of Assistive Technology Outcomes and Benefits (ATOB) was launched with support of the Assistive Technology Industry Association. ATOB went dormant for two years in 2013 and 2014. While this could be due to factors specific to the journal and editorial support, it is also a historical indicator that runs parallel to the national funding of AT outcomes initiatives in the United States. NIDRR actively funded AT outcomes research projects as earmarked activities in the early 2000s for about a decade (Schwanke & Smith, 2005; Smith, Schwanke, & Rust, 2006; CATOR Project, 2004). The Satterfield (2016) paper in this issue details this further. When the funding for these activities was discontinued, the attention to developing AT outcomes systems also languished. A historical overview of the history of AT outcomes measurement is presented as a chronological chart on The Assistive Technology Outcomes Measurement System (ATOMS) Project (2015) website, and highlights the impact of legislation, leading AT outcomes research, and related activity (Smith, Rust, Lauer, & Boodey, 2004).

Interestingly, during these NIDRR focused Disability and Rehabilitation Research Projects (DRRPs), several instruments specific to AT assessment were devised or further developed. Three well known instruments are the Psychosocial Impact of Assistive Devices Scale (PIADS) (Day & Jutai, 1996), the Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST) (Demers, Weiss-Lambrou, & Ska, 2000), and the Matching Person and Technology (MPT) (The Institute for Matching Person & Technology, Inc., 2015). These instruments are heavily documented and have been actively used in research since their inception. None of these instruments have become widely used as outcomes instruments, in part due to the domains of each of their focus which are identifiable in their names. The PIADS examines an important domain of AT use, being the psychosocial perception of the device when it is used. The QUEST focuses on the user experience as determined by their satisfaction with the device. The set of instruments surrounding the MPT assessment process was designed to help identify acceptance of devices as they were being selected by the consumer and service provider to better identify devices that would be accepted by the user.

Each of these instruments elevates and assesses an essential domain of AT device use, the subjective experience of the user or prospective user. These instruments have been critical for understanding what devices and critical features of designs are considered of value to the ultimate consumer of the device. Researchers interested in understanding the successful application of AT devices have widely deployed these data collection tools and acquired substantial information about the nature of the interactions between devices and their users. This has led to a better understanding of device abandonment, improved procedures in the selection of devices so the consumer is involved, broadly informed designers that the perspectives of people with disabilities matter when developing new devices, and, importantly, documented the internal experiences that people with disabilities have encountered when they consider a device, use a new device, continue using, or discard a device. These instruments, however, did not document functional performance or health-related quality of life domains that funding agencies have seemed to adopt as essential domains for rehabilitation and health-related interventions.

Other work from these DRRPs attempted to focus more on performance outcomes. For example, researchers extended the work of School Function Assessment (SFA) into the SFA-AT that added an Assistive Technology Supplement (Silverman & Smith, 2006; Watson, Ito, Smith & Anderson, 2010) and the School Performance Profile (SPP) focused on AT outcomes of K-12, comparing AT to other interventions (Fennema-Jansen, 2004; Edyburn, Fennema-Jansen, Hariharan, & Smith, 2005; Fennema-Jansen, Edyburn, Smith, Wilson, & Binion, 2007; Watson & Smith, 2012). Plus, in the vocational rehabilitation domain, the Isolating the Impact of Intervention (I3) was created by Johnson (2006) as a self-administered survey. While the SFA-AT, SPP, and I3 all demonstrated some success in measuring AT outcomes, like the MPT, PIADS and QUEST, they were not promoted for widespread use as outcomes instruments and none were adopted widely as an ongoing outcomes data collection methodology.

Historical Intersection of Medical Rehabilitation, AT Outcomes, and Medical Records

As documenting outcomes has increasingly been accepted as an essential task for rehabilitation service provider accountability, regulations have structured what data must be collected and how to collect it. This transition of medical and health records to electronic data collection, storage, and access was intended for increasing efficiency and data sharing for those in the need to know. While outcomes documentation has not been a driver of the move toward electronic records, it has been swept along. As one can ask almost any hospital or medical service today about the headaches of "going live" with e-records, the advantages are slowly becoming evident. Any record can be easily and immediately shared with other service providers to improve coordinated care; consumers can access their own records quickly and inexpensively; and e-record services enthusiastically highlight the reduction in human errors made during service provision. None of these seem to be purposely connected to outcomes documentation. However, the advantages are substantial and are being seen across existing and new rehabilitation related outcomes databases.

As a federal agency, NIDRR and its current form as NIDILRR, has advocated for outcomes research tools and studies through the programs of its core funded centers. The Rehabilitation Research and Training Centers and Model Systems each always have paid serious attention to outcomes. For decades, the Model Systems Programs in Spinal Cord Injury (SCI), Traumatic Brain Injury (TBI), and Burns have collected data depicting the nature of the population and general aspects of outcomes. NIDILRR staff publicly report when they present information about the Model Systems that extensive numbers (hundreds) of publications have been generated using the model system data.

The Veterans Administration (VA) system also has initiated key directions that may prove a foundation for outcomes research. As a self-contained health system with its own funding mechanism, the VA has created its own e-medical record system that opens the opportunity for potentially sophisticated outcomes research. However, the VA system has many challenges that restrain outcome implementation for AT devices and services. One challenge is that the VA is a standardized set of services and uses a process for approving AT devices nationwide. As a highly governed system, it has less inherent flexibility and opportunity for personalizing interventions. A second challenge noted in all VA research announcements is that the VA data have restricted access. In general, VA research is available only to VA personnel or researchers. This enables keen access to those close to the system, but is restrictive to quick research engagement by the rehabilitation and therapy research community at large.

Furthermore, across rehabilitation outcomes research, a general insidious and important disconnect has existed between rehabilitation services and AT. While AT and rehabilitation engineering have been seen as key medical rehabilitation interventions, they have been funded, trained, and treated as parallel, not integrated as part of the outcomes of overall rehabilitation interventions. Clear evidence of this perspective of segregated interventions is revealed in the functional outcome assessment instruments themselves. Rust and Smith (2005) examined 100 rehabilitation and health outcomes instruments to determine how AT was integrated into the measurement and interpretation of these tools. They found that AT usually was omitted from the instruments. Moreover, when it was included, it was often treated as a necessary, but not preferred intervention compared to the more curative rehabilitation approaches. Possibly, this perspective evolved due to the added cost of technology, that AT devices and service provision were often funded and provided outside the core rehabilitation services team, or from the constrained definition of independence that did not include assistive devices.

Large numbers of rehabilitation clientele have received and used AT devices temporarily or chronically. These range from small self-care devices, to expensive mobility equipment, to devices that support and monitor basic physiological functions such as respiratory supports, to fundamental prosthetic replacements. Rust and Smith (2003) speculated that it is not only possible, but that outcomes of rehabilitation services are commonly influenced by AT. Thus, investigations that examine rehabilitation outcomes, but neglect to document or report the contributions of AT devices and services as covariates, may draw inaccurate conclusions.

Documenting the use of AT devices and services must be integrated as foundational components of rehabilitation outcomes research and related methodologies.

The Methodological Challenge

An AT system-wide outcomes methodology is a challenge for many reasons. These include the large numbers of devices and combinations of their use, coding AT device use consistently, the provision of devices and services, the distributed application of AT across vocational rehabilitation, education, health services, and personal purchase, the special purchase and mass market availability of devices, and the fact that outcomes variables themselves cross many domains and total hundreds of factors of interest. This challenge has been said to range from daunting to impossible to solve.

Those who have disabilities or work with people disabilities know how unique each case, situation and environment is. This diversity of individual needs challenges all AT team members and stakeholders to select the most appropriate device and service. Consequently, obtaining the outcomes of such a personalized intervention is highly complex. It is critical to understand the full scope of this outcomes assessment challenge, the implications on available outcomes methodologies, and what it demands of a yet-to-be-designed future system.

Smith (1992) described the measurement of functional outcomes in occupational therapy as being particularly problematic. The paper emphasized the science of functional assessment. A key set of variables that was identified was the wide range of disability and impairment types. The enormous number of possible populations for which research outcomes of AT devices and services is needed continues to be a key challenge. In 1996, Smith pointed to the challenges specific to AT, one being the extensive numbers of AT devices and services in use, for which more than 30,000 devices were catalogued by ABLEDATA at that time, with thousands more listed today (New Editions Consulting, n.d).

ABLEDATA uses a thesaurus that structures this U.S. national database. This highlights an important component of outcomes assessment. Intervention and outcome domains must be coded for any outcome study to be generalizable and informative to other like individuals. Indeed several descriptive taxonomies related to AT interventions and outcomes have been promoted. The International Standards Organization (ISO) created a specific taxonomy to code devices. Many hundreds of device codes portray the diversity and extensiveness of the field. Very few outcomes studies, however, have been completed using these device codes (International Standards Organization, 2011). The World Health Organization's International Classification of Functioning (ICF) also has been used as a guideline for highlighting AT areas of outcomes (Bauer, Elsaesser, & Arthanat, 2011). The multidimensionality and extent these categories related to AT devices and services creates a matrix that is compatible, but highlights the size and complexity of coding structures needed for disability and AT outcomes.

Coding consistency is essential for outcomes research, particularly when data are compiled into large databases. Any coding database designs that do not exactly coincide may lose the value of the data forever. Three historical examples make an important point. First, the fundamental listing of types of impairments used by the National Health Information Survey (Disability) in the 1980s was also used by the U.S. Department of Education to code students with disabilities. While the intent for data record compatibility was clear, the two agencies elicited the survey responses differently. One requested the respondent to identify which impairment was primary. The other solicited "check all that apply." The outcome was that neither database could be used with the other for analysis of school and home health related status and outcomes (Moser, 2003).

A second national database with significant AT outcomes potential was the Rehabilitation Services Administration (RSA) 911 longitudinal database of over 600,000 records per year. It listed key outcomes variables, including several levels of back-to-work outcomes. In the 1990s, however, the RSA honed its database fields for efficacy and reduced the five AT and rehabilitation engineering intervention fields to three, losing the intervention granularity for outcomes (Schwanke & Smith, 2005).

Lastly, the NIDRR/NIDILRR national databases from their model systems centers were mentioned previously. These SCI, Burns, and TBI databases are extraordinary, as they contain decades of follow-up national population data. However, they never embedded sufficient codes to delineate rehabilitation interventions, including the delineation of AT and rehabilitation engineering devices and services.

There is a lesson to be learned from this outcomes history. When databases are created, attention must be paid to the details, and they must delineate AT and rehabilitation engineering interventions. This is easier said than done. The ATOMS Project documented the importance and suggested a possible elicitation method (Whyte, 2002) for coding the implementation of specific AT interventions. Of interest, one intervening variable is that users of AT devices may fail to recognize that they are using an AT intervention. The more integrated the device is in the daily activities of an individual, the more the person views the device as a part of themselves and may miss that they are using an AT device. One can understand why a prosthesis might lose its special AT device status when used day in and day out, but large obtrusive devices like wheelchairs also can be omitted inadvertently by users (Fennema-Jansen, Whyte, & Smith, 2006).

An additional challenge for measuring AT outcomes is that AT device use does not reside in any specific service model or funding domain. The ATOMS Project posed that AT devices that a person uses often cross health, community living, vocational, and educational service domains. Thus, any service provider may be able to elicit outcomes in one of the domains, but it becomes more difficult to obtain outcomes data from multiple domains. One possible solution that, to date, has only been suggested, is to increase the role of device automation and intelligent outcomes acquisition. We can embed data collection into devices for more unobtrusive and widespread outcomes data leveraging Internet-based data collection and the cloud. However, this would require funding support or an external mandate since little to no financial incentive currently encourages such an implementation. Another option would be to increase the role of the AT device consumer (and their responsibility) in contributing to the AT outcomes system. The AT device consumer resides as the focal point across domains. Figure 1 depicts this relationship. Of course, this also would require a new model of funding as agencies support the mission and focus of their particular service sector. A new external mandate is needed to operationalize a cross sector outcomes system for AT interventions.

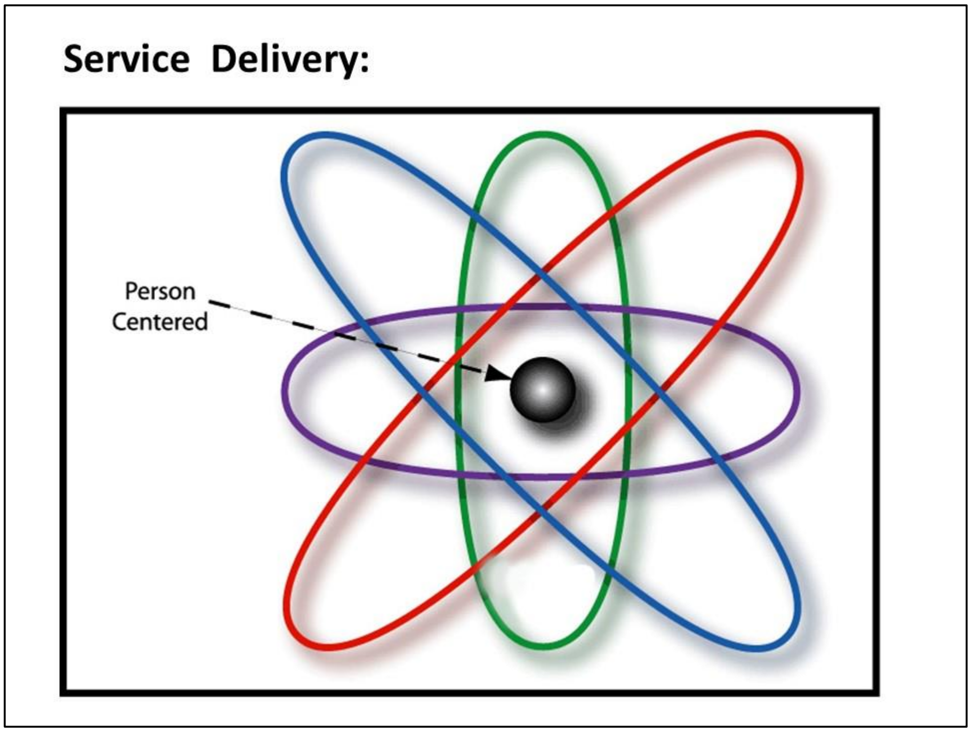

Figure 1. The ATOMS Project logo as it depicts the four service delivery models looping around the AT user in the center (Edyburn, Smith, Schwanke, & Fonner, 2002).

To further aggravate the challenge of knowing what AT interventions are used, the boundaries between AT devices and services and general information technologies are blurring. A prime recent example is the advent of the smart phone. Mobile phones have replaced the need for extensive and expensive TDD/TTY devices with texting that is mobile. Specialty blind accessibility devices have been supplanted with social networking or inexpensive or free apps. For example, today, people who are blind can use the mobile "MoneyReader" app to confidently identify currency/bills in the U.S. and across the world through smart object recognition. This challenges methodologies that measure outcomes that revolve around a pharmaceutical intervention model. Prescribed medications reside in a category of their own due to Food and Drug Administration approval that delineates open versus prescribed access to interventions. AT is not so governed.

While this confounded and complex nature of AT outcomes is clear from the previous discussion, there are still additional complexities that are important to highlight. The fact that AT devices and AT services are concurrent interventions used in parallel with most rehabilitation interventions should not be underestimated in its methodological significance. The interactions of AT device outcomes are embedded in a larger context of the environment and concurrent rehabilitation and educational interventions.

The unique needs of an individual frequently require custom application of AT devices and services that are personalized for the physical and social environments for which they are used, the functional activities they are addressing, and their interaction with a wide range of other rehabilitation interventions. The ATOMS Project found that it needed to place AT devices and AT services in the context of overall human functional performance. The IMPACT2 model portrays this structure and context where AT devices and services reside.

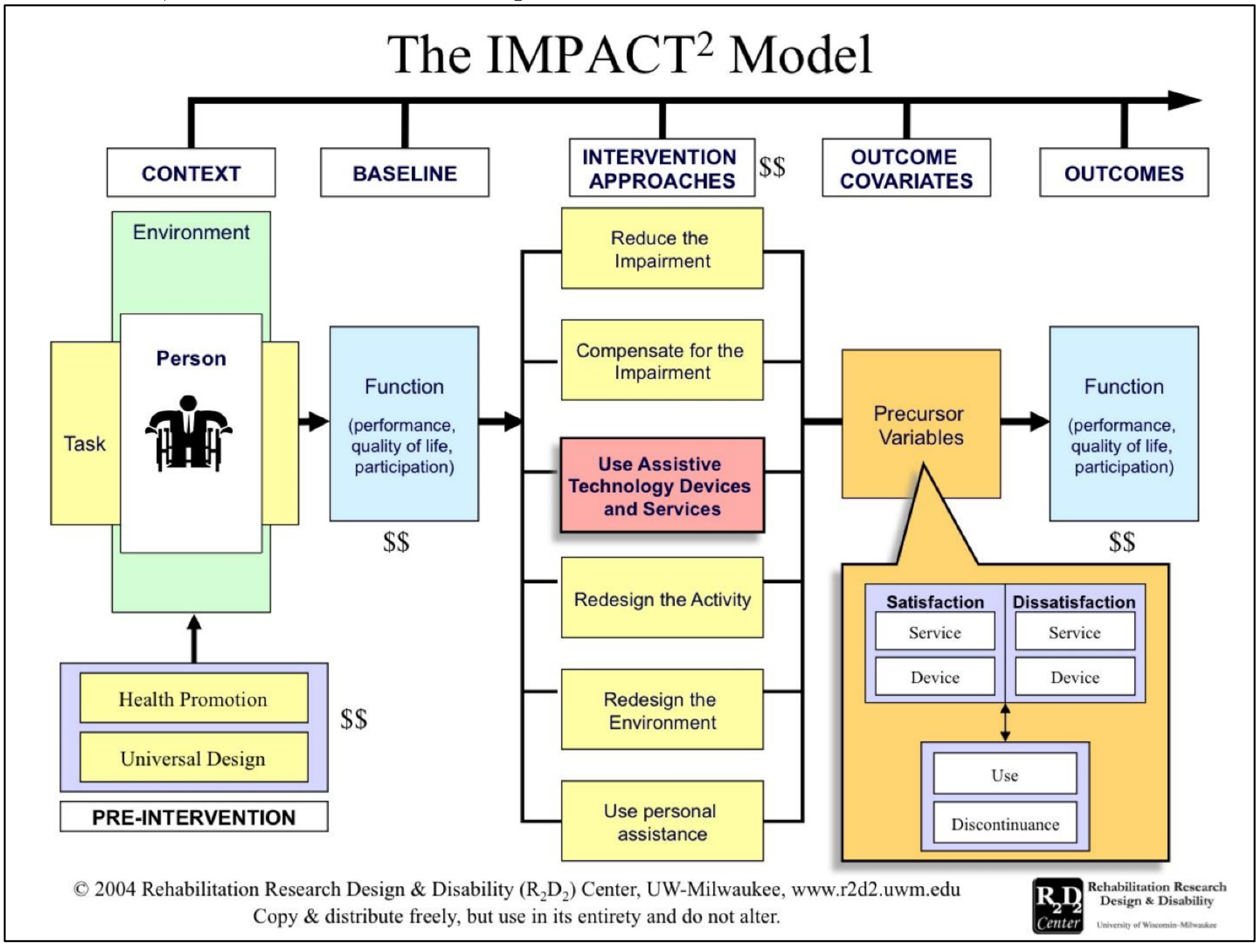

Figure 2. IMPACT² Model depicting the multiplicity of factors related to AT outcomes with particular focus on the concurrent interventions for which AT is one of six. (Smith, 2005)

The IMPACT2 model as depicted in Figure 2 also highlights the relationships between AT and universal design. Universal and accessible design must be considered as AT devices are being examined for their outcomes. For example, a wheelchair will not work well if the environment has stairs and narrow doorways. Both types of intervention must be examined together.

Lastly, the field still needs to determine which variables are most important and efficient to measure in AT outcomes. Personal performance with and without the device, satisfaction of device, quality of life, health-related quality of life, and the source of the data (user, observer, or physiological) are all relevant and serve as complications for measuring AT outcomes (Lenker, Harris, Taugher, & Smith, 2013; Lenker & Paquet, 2003, 2004; Smith, 2000).

Clearly, the quick review of issues related to the valid and reliable measurement of AT outcomes is daunting. The number of potentially relevant AT outcomes variables themselves verge on countless. Substantial research is needed to continue to clarify best measures and measurement tools. Even more problematic is that feasible research methodologies for assessing AT outcomes are elusive. Traditional outcomes research methodologies are expensive and highly time demanding; for which both of these resources are scarce. The small research capacity of the AT field is dwarfed by the needs for research. Thus, new research strategies and methods must be innovatively designed, developed, tested, considered, and adopted by practitioners, researchers, funders, and policymakers.

Lack of Sufficient and Acceptable Methodologies

The RCT (Randomized Controlled Trial)

While the RCT is the gold standard for research, due to the types of factors portrayed above, the RCT is not practical for the AT field. RCTs require large and homogenous samples. RCTs require independent control and intervention groups for which to compare outcomes. Control groups typically require a placebo or alternate interventions and are double blinded so participants and data collectors are not aware of which intervention is being investigated. RCTs are staged with pilot and small rounds, prior to executing a large study. RCTs are costly to run (tens of thousands to millions of dollars each) and extremely time consuming, requiring highly specialized personnel and many hundreds of labor hours. Many dozens of methodology texts and papers guide researchers in this methodology.

Simply, there are not enough time, funding, and qualified research personnel resources to mount a sufficient set of RCT studies for AT outcomes. The large number of interventions used are prescribed individually for what comprises unique and small populations. This makes the large group RCT gold standard that depends heavily on population-based inferential statistics not only challenging, but totally impractical. Looking at the economics of outcomes research alone, even if U.S. research agencies devoted substantial funding to perform RCTs for AT, there is not enough money across all of these agencies to mount and complete the RCTs needed to document the needed effects of all of the numerous AT devices and services. Additionally, this is one area in which the AT field differs dramatically from the larger medical equipment and pharmaceutical industries. The field is primarily supported by small businesses that lack the research and development funding or research capacity to perform the necessary research in addition to their basic day-to-day business expenses.

The Onset of Evidence-Based Practice

The British Medical Journal published a paper that is a "must read" for all practitioners, researchers, developers, educators, students, and policy makers in the AT field (Smith & Pell, 2003). The paper, using a "tongue in cheek" format, reviews published evidence for the use of parachutes, and explains that according to evidence-based practice concepts, parachutes should not be used (or funded). The relevance to AT research and the industry is obvious. Funding policy is driving toward withholding funding unless there is evidence that a device or service works. Since we have a paucity of research capacity, another model must be implemented. Funding agencies need to innovate. For example, a provisional funding model for new device types might be implemented while studies are being implemented. Or, trial device use with documented baseline and follow-up outcomes could be used when sufficient evidence is not available for generic funding decisions.

The Emergency of AT Outcomes in Rehabilitation

Criticality of Now

Earlier in this paper it was noted that more than a decade ago outcomes researchers predicted that funding agencies would begin to restrict funding AT devices and services unless researchers documented evidence that assistive technologies worked. It is no longer a prediction, but a reality. Policymakers are encountering the need to use any apparent acceptable criteria to manage their limited resources in the current funding environment. Even when they acknowledge the limitations of using the lack of evidence to make decisions, at face value it seems like a rational choice when charged with allocating limited funding. In recent years, more and more anecdotal stories are emerging about funding denials. They are often embedded in "fugitive literature" such as funding denial letters. Occasionally, however, a letter or statement rises to public attention. One example is that of the medical director in a Pacific Northwest state who explained that the quantity and quality of evidence needed to adequately defend the funding of a particular seating system was that of an RCT of a sample of over 200 participants. Those who know the field understand how unrealistic to impossible it is to expect research on this level across AT devices and systems that need outcomes studies. Many AT devices are only available in small lots due to small populations of specific need. Furthermore, these small populations may be distributed across large geographical areas and served by a wide variety of independent AT services and programs. And if it is the manufacturers that need to create this evidence, such as in the pharmaceutical industry, we know that small companies in AT do not have the funds or expertise to support such large research studies.

AT also changes quickly. Indeed, measuring AT outcomes is a moving target (Smith, 1996). RCTs are ponderous and take substantial time preparing several phases of research to lead up to clinical trials. Then, rarely is an RCT run quickly. This is a conundrum. Technology can advance so quickly that an RCT has little hope of documenting its effects before it is outdated. The augmentative communication (AAC) industry serves as an example. AAC discovered that the advent of the mobile smart phone and tablets dramatically shifted the entire industry within relatively few months. Traditional research methods simply are not feasible under these rapidly changing conditions when new assistive technologies are emerging daily.

This AAC experience also revealed that no part of the AT industry can be complacent. At one time, practitioners in augmentative communication thought that the evidence-based funding decision-making was focused on seating and mobility, and they were exempt. They discovered that augmentative communication was also on the target list without evidence. Such situations can even necessitate big solutions like an "act of Congress". The AAC challenge resulted in the Steve Gleason Act (2015). One could speculate that no AT device or service has been given a waiver in this new environment. Evidence-based funding provides a seemingly logical mechanism for managing limited funds.

The Mandate and Opportunity for Innovation in Assistive Technology Outcomes

Hope does exist for the future of AT outcomes research in rehabilitation. AT agencies that fund rehabilitation research are aware of the methodological issues and challenges. They have articulated the need to advance methodologies in this area. Plus, many outcomes research methods are beginning to be recognized in various (but disparate) research communities, demonstrating the potential of future outcomes research approaches. Some of the more open thinking about new methods is deliberate, and some are more serendipitous.

An indicator that the field has accepted the need, at least among researchers, is the draft of the Medical Rehabilitation Research Priorities in the National Institutes of Health, which was released for public comment in the fall of 2015. It included the call for future research to tackle the methodological challenges created by the limitations of group RCT methods so that the future includes the development of new robust, yet practical, outcomes research methodologies.

As is also well known to the research community, the RCT and the Cochrane-based systematic reviews have been promoted as the pinnacle of the outcomes research methods. What is lesser known is that esteemed health and medical evidence-based practice methodologists have also acknowledged that the N=1 is a legitimate and powerful outcomes assessment methodology. A prime example of this was published in the Journal of the American Medical Association (JAMA) Evidence-Based Medicine (EBM) series of 25 papers (Guyatt, Rennie, Meade, & Cook, 2015). The authors espoused the importance of sound methods and created an evidence hierarchy (Levine et al., 1994/2015). Over the period of this series, the RCT method was articulated, elevated and then superseded by the strength of systematic review. In the final issue of this EBM series (Guyatt et al., 2000/2015), however, the EBM author team updated their strength of evidence hierarchy. At the top, they placed the N=1 RCT, depicting the importance of individual differences in response to interventions. While this was largely philosophical and not practical for policy decisions (just because an intervention works for one person does not mean it should become policy), the overt placement of the single subject design at the top acknowledges the importance of personalized intervention. This depiction of the individual being the critical focus of research is fully consistent with the person-centered and highly individualized nature of AT service assessment, device selection, and implementation. We only need to more broadly convince traditional RCT researchers and agencies to instill this philosophy into their policy decision-making.

The Single Subject Design (SSD) methods are also being legitimized as an early Phase I clinical trials method for pilot and exploratory discoveries (Johnston & Smith, 2010). The phases of research are being better articulated in the medical field and have promoted some acceptance of the necessity of demonstrating the promise of an intervention using personalized small population methods (U.S. National Library of Medicine, 2008). While these are medical and health oriented, they are representative of many of the research perspectives in the rehabilitation research community. Kratochwill and colleagues have continued to update, articulate, and promote SSD methodologies in the psychology and education literature (Kratochwill & Levin, 2014; Kratochwill, Levin, Horner, & Swoboda, 2014; Kratochwill, Hitchcock, Horner, Levin, Odom, Rindskopf, & Shadish, 2010; 2012). These recent works are enabling an increased acceptance and appreciation of SSD methods in education. Hopefully, we will see a transfer of these to medical, health, and rehabilitation venues soon.

Some of this update revolves around the maturation of SSD methods to include systematic reviews. Statistical and procedural frameworks are developing. In one way of thinking, SSDs are quite random. They represent various populations, timeframes, service provider training, and settings, and most have used some personalization of the interventions. But a constant can be the AT device as the key intervention. So if SSD studies can be aggregated formally, they become a strong meta-analytical method. Of course, to aggregate like studies, the documentation must include more extensive demographic profiling of AT users and a much higher degree of detail describing the interventions than is typical today. Plus, we have little to no standardization in how we document SSD studies for AT outcomes. Important steps need to be completed to mature the aggregation of SSD AT outcomes studies.

So, one can ask how mature SSD meta-analysis methodology has become. This is a young area, but the literature is growing. Currently, no single method has been established for the meta-analysis of N=1 design studies, despite their importance to clinical practice (Gabler, Duan, Vohra, & Kravitz, 2011; Guyatt, Keller, Jaeschke, Rosenbloom, Adachi, & Newhouse, 1990). As far back as the 1970s (Gentile, Roden, & Kelein, 1972), researchers debated the proper use of statistical analysis for single case design studies (Kratochwill & Levin, 2014). A recent volume (2014, volume 52) of the Journal of School Psychology was dedicated to the issue of analysis and meta-analysis statistical methodologies for single-case research studies (Shadish, 2014). Methods include using standard mean differences (d-statistic) (Shadish, Hedges, & Pustejovsky, 2014), generalized additive models (GAMs) (Shadish, Zuur, & Sullivan, 2014), and Bayesian methods (Rindskopf, 2014; Swaminathan, Rogers, & Horner, 2014). Other authors have suggested hierarchical linear modeling (Gage & Lewis, 2012), multilevel meta-analysis of effect sizes (Moeyaert, Ferron, Beretvas, & Van den Noortgate, 2014; Ugille, Moeyaert, Beretvas, Ferron, & Van den Noortgate, 2012), and percent non-overlapping data (PND) methods (Heyvaert, Saenen, Maes, & Onghena, 2015).

Registries are also serving as a new formal outcomes tracking methodology and a robust vehicle for policy decision-making in health care. The Agency for Healthcare Research and Quality (Healthcare 411, 2012) has been publishing extensive descriptors and guidelines for developing, handling, and using registries for effective decision-making. A two-volume, 600-plus page third edition of *Registries for Evaluating Patient Outcomes: A User's Guide* was published in 2014 (Gliklich, Dreyer, & Leavy, 2014). These articulate how massive databases with a priori data can drive appropriate decision-making on clinical and policy levels. Major findings have been revealed from the use of medical registries that have changed the course of technology and clinical interventions (Bates & Bitton, 2010), e.g., hip replacements (Paxton, Inacio, Khatod, Yue, & Namba, 2010) and endarterectomies (Menyhei et al., 2011).

Another example of innovation in research methods that relate to AT Outcomes is the potential of data collection using social media. Research in rehabilitation can leverage community science based on social networking and crowd sourcing. The advent of the smart phone allows AT users to contribute directly to AT outcomes documentation passively and automatically via tracking apps or actively by responding to questions that an app asks. This outcomes data revolution was enabled when "the cloud", the cellular systems, phone providers, and user/societal acceptance of allowing the sharing of helpful personal data began to converge. Today, the many transducers in mobile devices have opened new possibilities to document community mobility (GPS), degree of activity (accelerometers), location of indoor activity (Bluetooth), environments (microphone, camera), motion (camera), and personal perspectives (surveys).

Most of the uses of the mobile and cloud joint networking have yet to be implemented and much of it is not yet conceptualized. These new possibilities may be the methods of choice in the future for AT outcomes where unobtrusive, registry capable, physiological, and deliberate response data become integrated into daily AT practices. In the NIH, an initiative called mHealth has been launched. The NIH has seen the potential of mobile health applications and generated much excitement around their emerging capabilities (Okuboyejo & Eyesan, 2014).

These new rehabilitation AT outcomes opportunities run parallel to new Electronic Health Records (EHR) that are expanding rapidly and building mobile platforms at a rapid rate. EPIC and Cerna health record software apps and Apple Health apps that integrate with health researchers and providers are quickly infiltrating modern society. Recent years have been active with product announcements in the popular press, such as the new array of fitness watches that link to the cloud and research data bases that can be monitored by personal physicians. AT outcomes, however, remains a minor player as an intervention for people with disabilities and, therefore, has not been invited to participate to any degree with these mega EHR operations.

Lastly, major advances in AT outcomes may be seen internationally, especially in the systems and models emerging from Australia or the Scandinavian nations. Australia, for example, has recently embarked on a continent-wide system called the National Disability Insurance Scheme (NDIS). This national funding entity could mandate an AT outcomes methodology that precedes any widespread rollout in more distributed and unstructured systems in the United States or Europe. It will be important to watch international colleagues as they implement AT outcomes systems (NDIS, n.d.).

Target Audience and Relevance: The Challenge to Funding Agencies, Practitioners, and Researchers, and Prospects for the Future

There is potential for a revolution of AT outcomes research on the horizon. However, whether this occurs depends on all AT stakeholders and how well they organize and coordinate. Currently, the field is sufficiently fragmented, hampering substantial progress that will only occur if separate AT communities collaborate on direction and seek common funding to influence the policies of research and service funding agencies. A core vision and the development of systemic initiatives to measure and document AT outcomes across the field are needed.

To enable this, all AT stakeholders have a role. The AT industry needs to help fund outcomes events, collaborate across organizations, and be ready to promote and facilitate standard outcomes data collection processes. Higher education professional training programs need to instruct and create a new generation of researchers comfortable with these new outcomes methodologies. Practitioners need to continue to develop an understanding of what evidence-based funding is, and ready themselves to engage in continual data collection efforts as part of day-to-day operations. People with disabilities must press researchers and policymakers to create, demonstrate, and implement methods that convey the outcomes of devices and services. Grant and journal research reviewers need to expand their understanding of practical and rigorous outcomes methodologies, so RCTs are not considered as the only acceptable approach. Funders and policymakers must support next generation outcomes data and methodologies and adopt new methods of decision-making that include mechanisms for funding devices and services for people with disabilities that change individual lives, but may not have the support of group RCTs with inferential statistical results.

Importantly, this charge cannot be aimed solely at one stakeholder such as policy makers. Each of our respective roles in the field of AT is responsible and has action to take. Practitioners, industry partners, researchers, instructors, and people with disabilities all must personally decide how they can contribute to a new AT outcomes tracking system to elevate it from a wish to a movement. With the right support, maybe planning and creating an AT outcomes tracking system can begin immediately. Perhaps testing and implementing such a system within the decade should be optimistically considered.

Declarations

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Multiple Means of Measurement: Tools for Collecting and Analyzing Evidence of Student Progress

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Abstract

Evidence should be the guiding factor for educational practices before, during, and after the implementation of technology. Evidence about student performance can come from a variety of sources including images, video, audio, work samples, and both formative and summative assessments. Once the raw evidence has been compiled, educators must analyze and synthesize the information into a product that is consumable and comprehensible to everyone involved in the decision-making process.

Affordable, efficient, efficacious, and easy-to-use tools are available to streamline the evidence collection process. Contemporary visualization tools and techniques for effective representation of the evidence show how change has or has not occurred following the implementation of assistive technology. Implementation of these tools can transform the decision-making process into one that consistently and confidently uses reliable evidence to inform instruction when implementing assistive technology.

In considering the use of assistive technology as a tool to improve access to curriculum and support the attainment of proficiency toward educational standards, evidence needs to be collected to determine the efficacy of the tool being used. While evidence may be collected on a student's use of a tool, what actually needs to be measured is the student's demonstration of proficiency toward the standard or learning objective. Evidence needs to be collected to measure growth as a means of evaluating attainment of skills and knowledge. The same tool used to demonstrate the attainment of these skills might be used for a range of students, including those with disabilities, for whom the provision of the tool is documented in an Individual Education Plan (IEP), and those without disabilities, who are simply provided access to the tool as a part of a Universally Designed for Learning classroom.

"Not everything that counts can be counted and not everything that can be counted counts." - Albert Einstein

Keywords: data, assessment, technology

Introduction/Background

The Individuals with Disabilities Education Improvement Act (20 USC §1400 et seq., 2004) requires public schools to monitor and document a student's progress towards mastery of annual goals outlined in the Individual Education Program (IEP) When student work is primarily done via pencil and paper, data collection and teacher feedback to students is also typically limited to pencil and paper. Tests are scored, graded and marked with number of correct items over total number of items (e.g., 20/25) on the top of the paper, while essays are marked with the infamous red pencil. Special education teachers learn creative ways to keep hash marks to track observable behaviors to measure progress. Educators using this methodology make anecdotal notes accompanying the tally marks to complement the quantitative data with qualitative or descriptive information. Student work samples might also be collected and analyzed, depending on the goal. Quarterly, at a minimum, the educator reviews the data and writes a progress note describing the current state of evidence that has been gathered along with how the student is progressing toward the goal. However, with the advent of 21st century schools moving toward paperless classrooms and the expectation for increasing amounts of student work to move from paper to digital formats, data collection has evolved as well. Today's educator has the means to use software programs and other digital tools that collect student responses for analysis by the educational team or through the software capabilities. What has not evolved consistently, however, is educators' and administrators' understanding of the ways that technology can be used to collect and analyze data in order to track student progress with greater efficiency and increased consistency.

This article examines ways that special and general education professionals can track student progress toward the standard as a means of collecting information to make decisions regarding instructional practices and methodologies, including the use of assistive and instructional technology. The student is the source producing endless amounts of data. Multiple means are used to capture and gather those individual elements of data (see Figure 1).

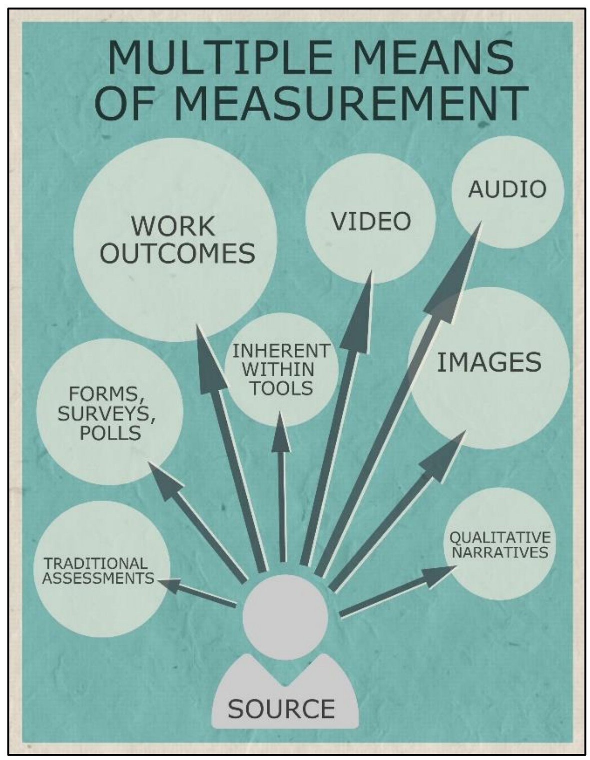


Figure 1. The student is the source producing endless amounts of data

Target Audience

This article is intended to aid educators, including special and general education teachers, therapists, assistive technologists and administrators, in examining methods used currently to collect data, and in reflecting on ways that would improve this process. Educators who value quality of data, as well as being able to collect it in an efficient and effective manner, will find a host of tools and strategies to apply to their individual needs throughout the article.

Why Digital?

For many educators, development and maintenance of an accurate data collection system is a complex, arduous task. In contemporary education, rarely does a single educator work on a single goal with a single student. Typically, educators are working with multiple students who are working on multiple goals which necessitates multiple data sheets. Multiple educators collecting data on the same goals for a student can be problematic as methodologies differ among educators. In some cases, the task of collecting unique data targeted to the goal may prove to be too difficult. In these cases, when the time comes to analyze the evidence, teams find themselves relying on test scores and work samples alone rather than a robust, multimodal, comprehensive conglomeration of data. Using only this small set of inputs makes it difficult to develop accurate decisions about future instructional practices based on real, purposeful evidence. In the absence of robust evidence, there is a possibility of teams making decisions based on intuition and perceptions alone.

Gathering evidence through digital means has multiple benefits (Zimmerman, 2008). Adoption of a digital means of data collection supports a more consistent and streamlined process for the educators working with an individual. When every educator working with a student uses the same tool, such as a form or survey, the information being collected is more uniform from the onset and then can be more easily analyzed. Generation of a digital system also helps the educational team provide an opportunity for more immediate and interspersed analysis of the evidence. Data collected in a central, digital repository accessible to multiple parties allows any member of the educational team an opportunity to examine the breadth of evidence whenever necessary, as opposed to being limited to quarterly reviews. Administrators also can review the evidence collected to make inquiries about the frequency, amount, location, and duration of events related to the collection of data. Finally, digitally collected evidence provides more immediate feedback for students, who can reflect on their own work through the feedback shared by teachers. This increased access to real-time, on-demand data helps to increase the fidelity and transparency of the educational impact of instruction for a student. Digital collection methodologies also make it easier to use data visualization tools and resources to aid in the consumption, analysis, and understanding of the evidence. Quantitative and qualitative forms of digital media can be combined to formulate comprehensive, yet comprehensible, reports which more accurately represent the progress of a student.

Tools and Methods for Digital Evidence Collection

Recording Evidence

Screen Capture

Most electronic devices contain a methodology for capturing an image of the screen. On Windows-based computers, a user presses the PrntScr button to copy whatever is on the screen to the computer's clipboard. The user can then paste that screenshot into a document or file. Student work samples can be taken using screenshots to create an archive of accomplishments. For example, if using an online tool, students might take a screenshot of a final score and save that image in an ongoing journal or portfolio. These screenshots can then be analyzed over time for patterns, trends, discrepancies, and/or improvements. Other static screen capture tools include the Windows Snipping Tool, pressing both the Home and Power buttons on iOS devices, and using the Command + Shift + 4 keyboard shortcut on a Macintosh computer.

Short video samples of a student's onscreen work also can be collected as data. The methodology for creating and collecting videos depends on the tool used by the student to complete the task. If a student uses a computer with Internet capabilities, an online tool such as http://www.screencast-o-matic.com/ can be employed. If a student uses a tablet (e.g., an iPad), apps such as Educreations and Explain Everything allow for the creation and sharing of video recordings. More robust video editing tools are available if larger samples have been collected. Editing video is useful for maintaining the length of a sample to isolate information pertinent to the educational goal. Examples of video editing tools include Windows Movie Maker, iMovie, and Camtasia.

Audio Samples/Sound Recorders

Samples of audio are also useful as data. Moments of oral reading, collected speech and/or language samples, and demonstration of understanding of a learned concept are all examples of methods for using audio recordings as data. Audio samples can be recorded from online tools such as http://recordmp3online.com/ and http://Vocaroo.com, software such as Garageband and Audacity, and applications on mobile technology with voice memo features such as Recordium and Evernote.

Evidence within the Tools

Many of the digital tools used in classrooms today have data collection as an integral feature of the technology. In general, there are two types of data available within digital tools: automated analysis of information input by students or teachers collecting observable data, and data that can be extrapolated and interpreted from student work.

In automated tools, data is collected within the tool and analyzed by the tool. Frequently, the tool generates graphic representations of a student's progress which can be tracked over time or compared to a larger group of students. There are hosts of subscription and retail apps and programs which provide instruction and interventions that track and analyze progress. Teachers also can build their own data collection resources within surveys and other online form generators.

Instructional and Intervention Tools with Built-in Data Collection

Software and app developers are publishing an ever-increasing number of tools that track the results of student work against IEP goals or educational standards. The tools mentioned here are by no means inclusive of all the tools available. Boardmaker Online and the Boardmaker Instructional Solutions line, including Boardmaker Expedition Education and Boardmaker Book Bridge, provide an online repository of standards-based curriculum activities, and also provide tracking of student progress toward curriculum standards and/or IEP goals. The information provides formative data to educators to tailor and adapt instruction to meet individualized learning needs. Conceptua Math at www.conceptuamath.com provides individual and classroom based progress toward mathematics indicators with color coding to indicate who is meeting standard, who is near standard but needs more practice, and who is in need of additional support in order to make progress. Charting of individual student scores and duration of time spent in the software is also available for teachers to view (see Figure 2).

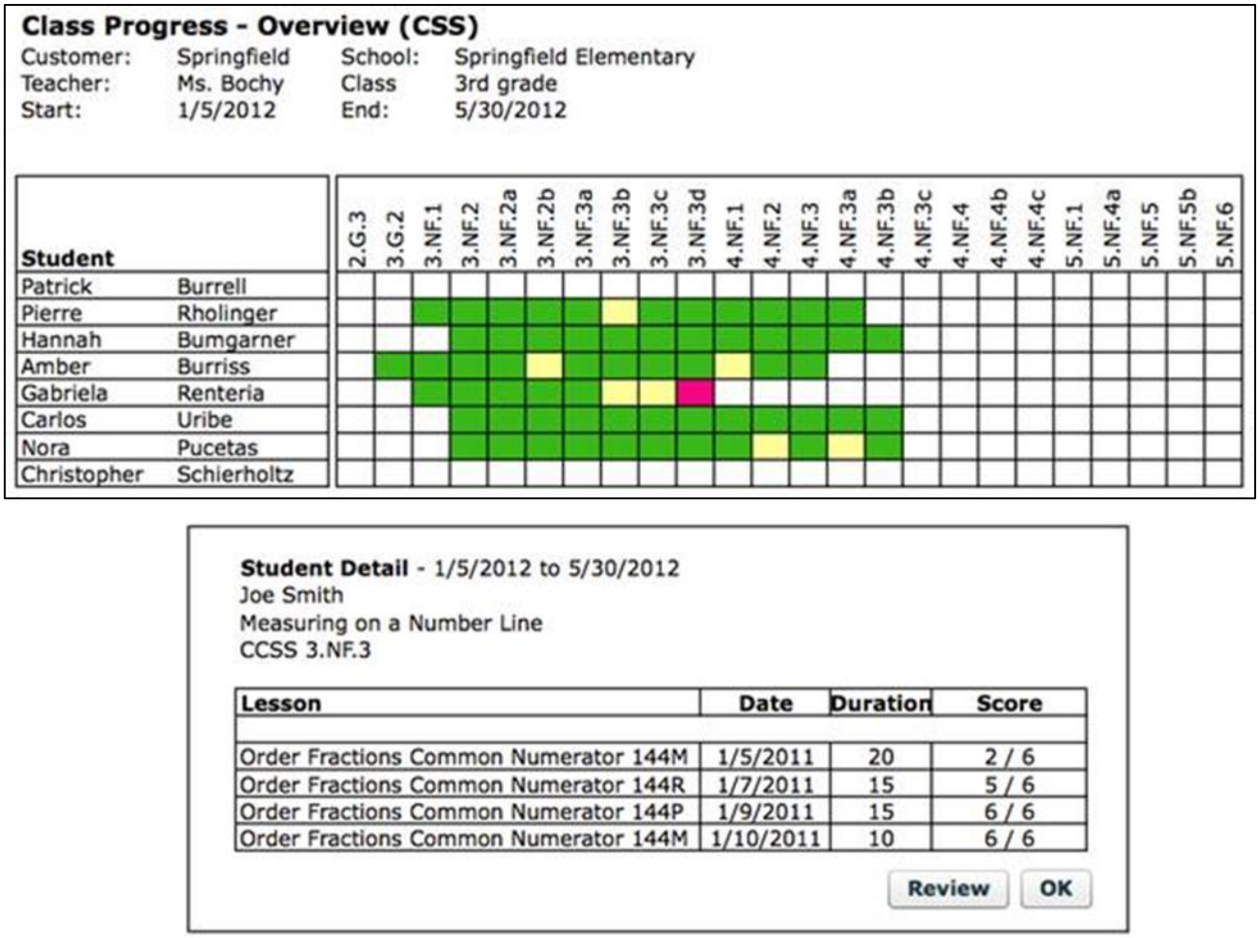


Figure 2. Class and student data generated by Conceptua Math

Lexia Reading Core and Lexia Strategies provide reading interventions with norm-referenced performance data and analysis in the context of an embedded assessment system that allows for real time data at the student, class, school and district level, with data provided on how much time students spend in the program, how frequently students log in, and monthly changes in reading levels to assist educators in monitoring growth.

Snap & Read from Don Johnston Inc., which provides text to speech support, collects data on the readability level of a text, the number of words read, and the time spent reading.

The Language Activity Monitor (LAM) built into augmentative/alternative communication devices, such as the Accent series from Prentke Romich Company, provides practitioners with a means of analyzing the frequency, type, and combination of utterances produced by a user. LAM maintains a running log of every item pressed on the screen of the communication device. Educators, family members, and users themselves can review the collected language samples to find patterns, target areas and times of concern, and chart progress. Uploading the LAM data to http://realizelanguage.com with a subscription allows for the creation of charts, graphs, and other visualization tools helpful in making decisions about instructional practices involving language development. A person's use of language can be very intimate and personal. Access to and analysis of a person's use of language should be accompanied with permission. The privacy of the individual should be respected and honored.

These are just a few examples of the hundreds of technology-based instructional and intervention tools that are available for educators to use to analyze evidence of attainment of proficiency toward a standard or IEP goal from within the tool itself.

Online Forms, Polls, and Surveys

One methodology for establishing a consistent, digital means of data collection is the transference of individual student goals from an IEP to an online form. Google Forms is one example of an online form generator. The central question surrounding a goal can be rewritten and placed in an online form. Writing specific yet comprehensive goals helps in the process of online form generation. Every member of the student's education team can use one specific hyperlink to access the same form, thereby eliminating the need for a paper-based method for collection. Educators then use any Internet-capable device to access the hyperlink and complete the form. Online forms populate a backend database that can be shared among the educational team (including the family), which can be analyzed and visualized, in some cases, nearly instantaneously. For instance, Google Forms maintains the functionality for users to see both individual or a summary of responses. The Summary feature aggregates the data and displays it in comprehensible visualizations such as diagrams and charts (see Figure 3).

Polls and surveys provide another method for collecting information which can be analyzed either by the individual responder or entire group. Educators use polls and surveys formatively to make in the moment decisions to adjust instructional methodologies. Polling or surveying students provides the educator with an opportunity to gather information about what specific information students are understanding, target individual or groups of students when they are not understanding a concept, and alter instructional strategies that have proven ineffective for some students.

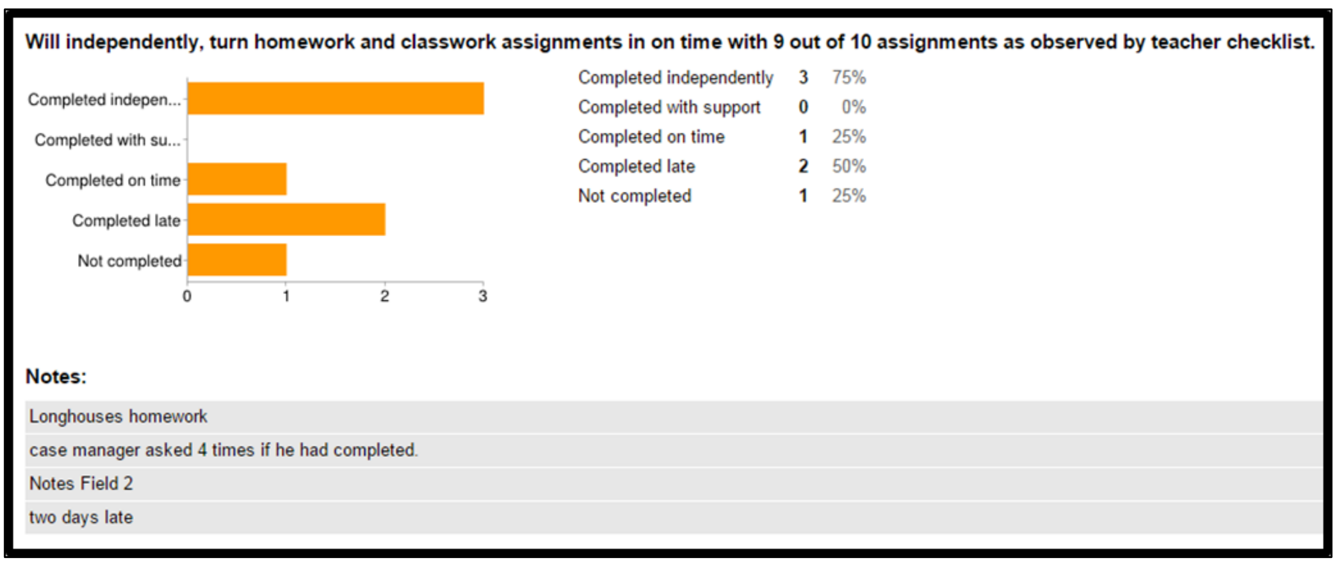


Figure 3. Show Summary of Responses of data collected using a Google Form

Tools useful for creating and disseminating polls and surveys include online tools such as Google Forms, Survey Monkey (http://Surveymonkey.com), Poll Everywhere (http://Polleverywhere.com), and Polldaddy (http://polldaddy.com), as well as mobile applications such as Plickers.

Data via Collected Annotations and Highlights

The reading and writing standards from the Common Core, as well as other non Common Core State Standards (CCSS), emphasize the need for students to be able to annotate text in order to "draw evidence from literary or informational texts to support analysis, reflection, and research" (CCSS.ELA-LITERACY.CCRA.W.9, National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). Viewing a student's text annotations, including highlighted text and notes, allows educators to gather evidence of a student's understanding of the relevance of text in relationship to their analysis, reflection and research. With the emphasis and ever increasing availability of online digital text, more and more student reading and research is accessed online. To complement this, there are a variety of free and for-fee tools that allow students to highlight and annotate text images, and even video, from online sources.

Read&Write for Google Chrome, from TextHelp, is a multifaceted text reader that also collects highlighted text. Working within a collaborative online Google Doc, teachers can see what text a student has highlighted to help determine if the student is finding the main idea and relevant details in text in the document.

Diigo is a free web curation tool that also provides annotation features, such as highlighting and the ability to add notes within any website. Websites can then be shared collaboratively with a teacher, and the highlights and notes as annotations in the webpage can be viewed and collected as data (see Figure 4).

Beyond simply creating highlights and annotations of text, the use of the Sticky Notes feature of Diigo also allows educators to post questions for students to answer within the body of the online text, allowing them to then view the student's response in real time.

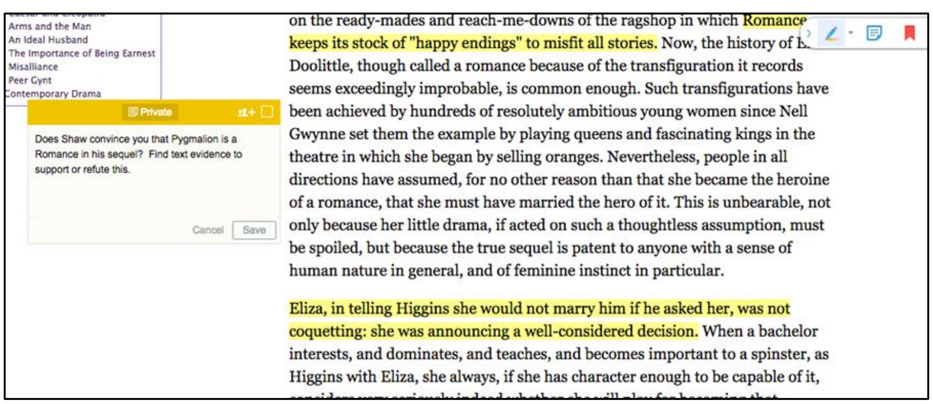
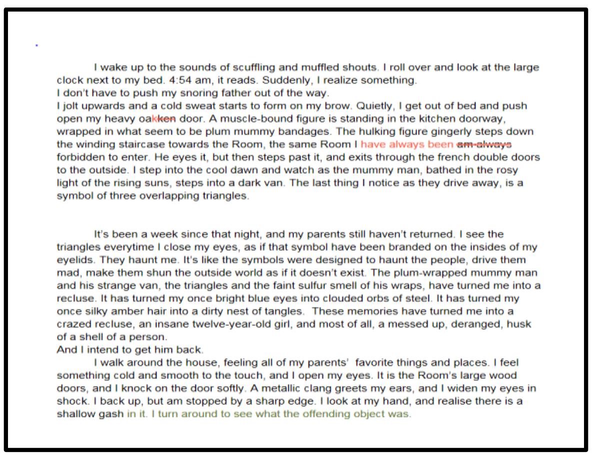


Figure 4. Screenshot from The Sequel to Pygmalion with annotations including highlighting and notes via Diigo. (Shaw, 1916)

Finding Data through Revision History and Track Changes

Typically with pencil and paper writing tasks, students begin with a graphic organizer, create a draft, and then submit a polished, edited writing piece. Their teachers may see each element, but with many different pieces of work and paper to juggle, they may not get a clear picture of the drafting, composing, revising, and editing process, and how the interventions being used to support writing are working for the student. The use of digital tools that provide a means of tracking the changes in a document can bring all of these elements together and allow a clearer picture of the evidence needed to make decisions regarding the efficacy of interventions.

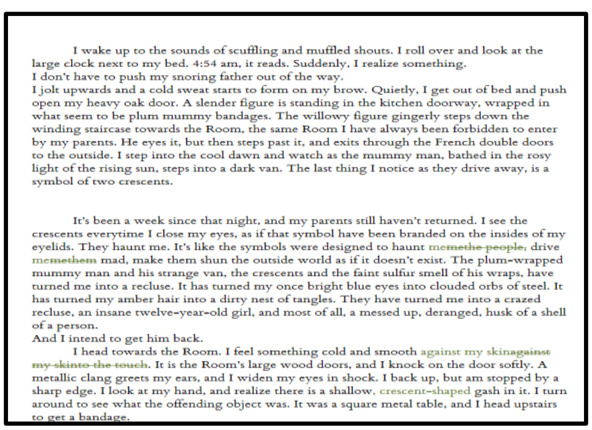
Many online word processors such as Google Docs, along with Google Slides and Google Sheets, allow any collaborator to see the revision history from the file menu. Revision history typically shows every change in a document, with the ability to compare earlier with later versions and see the evolution of the document from beginning to end. Comparing earlier and later versions of the document allows teachers or students to view the changes made, including editing suggestions (see Figures 5 and 6).



I wake up to the sounds of scuffling and muffled shouts. I roll over and look at the large clock next to my bed. 4:54 am, it reads. Suddenly, I realize something.
I don't have to push my snoring father out of the way.
I jolt upwards and a cold sweat starts to form on my brow. Quietly, I get out of bed and push open my heavy oakken door. A muscle-bound figure is standing in the kitchen doorway, wrapped in what seem to be plum mummy bandages. The hulking figure gingerly steps down the winding staircase towards the Room, the same Room I have always been am always forbidden to enter. He eyes it, but then steps past it, and exits through the french double doors to the outside. I step into the cool dawn and watch as the mummy man, bathed in the rosy light of the rising suns, steps into a dark van. The last thing I notice as they drive away, is a symbol of three overlapping triangles.

It's been a week since that night, and my parents still haven't returned. I see the triangles everytime I close my eyes, as if that symbol have been branded on the insides of my eyelids. They haunt me. It's like the symbols were designed to haunt the people, drive them mad, make them shun the outside world as if it doesn't exist. The plum-wrapped mummy man and his strange van, the triangles and the faint sulfur smell of his wraps, have turned me into a recluse. It has turned my once bright blue eyes into clouded orbs of steel. It has turned my once silky amber hair into a dirty nest of tangles. These memories have turned me into a crazed recluse, an insane twelve-year-old girl, and most of all, a messed up, deranged, husk of a shell of a person.
And I intend to get him back.
I walk around the house, feeling all of my parents' favorite things and places. I feel something cold and smooth to the touch, and I open my eyes. It is the Room's large wood doors, and I knock on the door softly. A metallic clang greets my ears, and I widen my eyes in shock. I back up, but am stopped by a sharp edge. I look at my hand, and realise there is a shallow gash in it. I turn around to see what the offending object was.

Figure 5. Draft of document being written in Google Docs



I wake up to the sounds of scuffling and muffled shouts. I roll over and look at the large clock next to my bed. 4:54 am, it reads. Suddenly, I realize something.
I don't have to push my snoring father out of the way.
I jolt upwards and a cold sweat starts to form on my brow. Quietly, I get out of bed and push open my heavy oak door. A slender figure is standing in the kitchen doorway, wrapped in what seem to be plum mummy bandages. The willowy figure gingerly steps down the winding staircase towards the Room, the same Room I have always been forbidden to enter by my parents. He eyes it, but then steps past it, and exits through the French double doors to the outside. I step into the cool dawn and watch as the mummy man, bathed in the rosy light of the rising sun, steps into a dark van. The last thing I notice as they drive away, is a symbol of two crescents.

It's been a week since that night, and my parents still haven't returned. I see the crescents everytime I close my eyes, as if that symbol have been branded on the insides of my eyelids. They haunt me. It's like the symbols were designed to haunt memethe people, drive memethem mad, make them shun the outside world as if it doesn't exist. The plum-wrapped mummy man and his strange van, the crescents and the faint sulfur smell of his wraps, have turned me into a recluse. It has turned my once bright blue eyes into clouded orbs of steel. It has turned my amber hair into a dirty nest of tangles. They have turned me into a crazed recluse, an insane twelve-year-old girl, and most of all, a messed up, deranged, husk of a shell of a person.
And I intend to get him back.
I head towards the Room. I feel something cold and smooth against my skinagainst my skinto the touch. It is the Room's large wood doors, and I knock on the door softly. A metallic clang greets my ears, and I widen my eyes in shock. I back up, but am stopped by a sharp edge. I look at my hand, and realize there is a shallow, crescent-shaped gash in it. I turn around to see what the offending object was. It was a square metal table, and I head upstairs to get a bandage.

Figure 6. Revision of earlier document

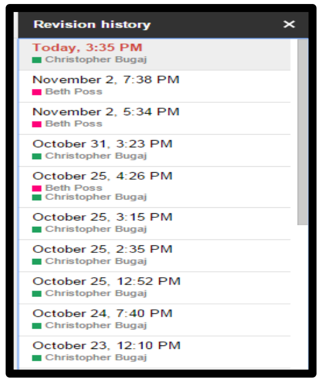


Figure 7. Google Drive Revision History

When used as part of a collaborative project, the Revision History also shows what each student (or teacher) wrote in which parts of a document, presentation, or spreadsheet. Grading collaborative work can be challenging because it is not always clear who has done what in the final project, so this is valuable data that permits an educator to examine individual skills, abilities, and efforts (see Figure 7).

MindMeister, which is available as an app, a Google Chrome extension, and a website (www.mindmeister.com), is a graphic organizer/mind mapping tool that also has a revision history feature and the ability to be worked on by multiple collaborators. In addition to showing the evolution of the mind map, it also provides explicit feedback to teachers by showing exactly who has added what to any mind map.

Microsoft Office, including Word, has Track Changes as a feature that allows a peer or adult editor to make suggestions to a piece of writing. As seen in Figure 8, the Track Changes feature allows the student to see suggestions made as comments and make changes, and then permits the teacher to see how the student acted on those suggestions.

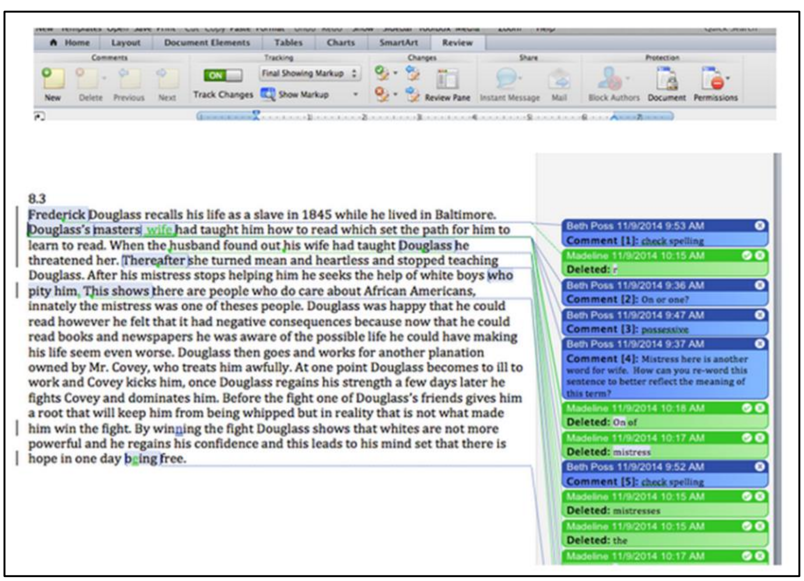


Figure 8. Student work with revisions in Word using Track Changes

Student Self-Reflection

It can be useful to collect information about student self-monitoring and the perceived usefulness of the tools used to accomplish the work. The ability of students to be meta-cognitive in monitoring their own progress has been documented as an effective strategy in increasing significant learning gains (Chappius, 2005). Self-monitoring as a critical part of formative or ongoing assessment allows students to understand how far they have come and how much further they need to go in order to achieve educational goals.

Beyond monitoring their own progress, students' reflections on their own engagement in learning provide data to schools and educators that can provide insight into why a student is or is not making progress. Does the student enjoy the learning experiences? Do they want to use the technology provided? Why or why not? Technology used by educators, such as video or audio, online forms, surveys, and polls can also be utilized by students to provide feedback. Examples of video student testimonials on the use of TextHelp's Read&Write programs can be found at http://bit.ly/rwgstudenttestimonials.

Visualization Tools for Presentation

Maintaining a corpus of evidence is useless without thorough, thoughtful analysis. Sets of numbers, images, sounds, videos, and other media are a collection of observations that paint a picture of what has transpired. These individual pieces of data need to be interpreted to make deductions. Data alone, in its raw form, can be interpreted differently by different people. Synthesis of the evidence into a format that others can understand is necessary to help stakeholders make decisions. Historically, evidence reporting has been in the form of large blocks of text. Although accurate, information presented in this format may be confusing, confounding, frustrating, and even inaccessible to every individual expected to read it. Visualization tools can help every member of the education team comprehend the evidence in order to make informed instructional choices.

Contemporary reports can include charts, graphs, and informational graphics (infographics), and can be created and provided digitally to increase accessibility. Educators have been reported to feel more competent at finding information shown explicitly in a table or graph (United States Department of Education, 2011). Educators need not be constrained to representing information in text-only formats. Examples of tools that can be used to present visualizations of evidence include http://infogr.am, http://venngage.com, http://easel.ly, and http://trackthisfor.me, as can be seen in Figures 9 and 10.

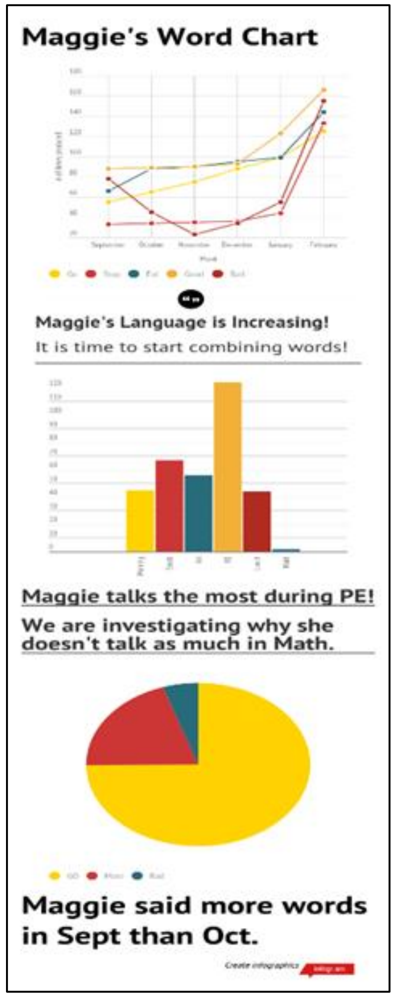


Figure 9. *Example of visualization using* *http://infogr.am*

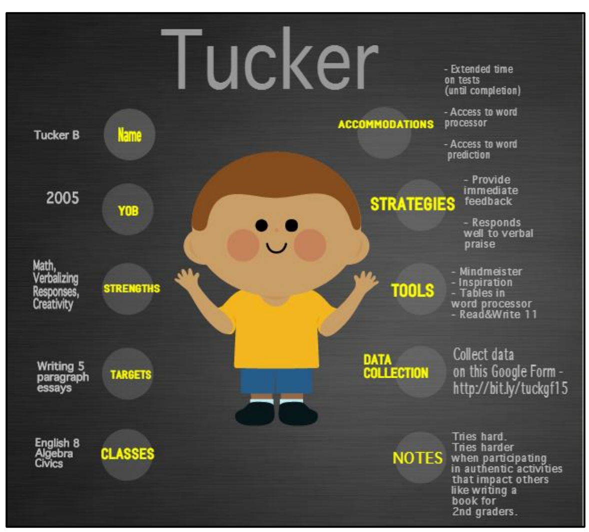


Figure 10. *Sample image embedded in an educational report outlining a student profile created using* *http://easel.ly*

Professional Goals and Teams

Transitioning to a digital collection methodology, either individually or as an entity, is not necessarily an easy adoption. Here are steps to be considered in order to maximize the probability of a positive outcome when attempting to convert a practice from paper-based to digital. Presume there will be challenges and that it will take some time will help to temper the expectations. Consider the development of a professional goal to measure progress. For instance, one strategy is to set up a storage system for digital artifacts. It could be a digital portfolio, such as a folder system using a network or Cloud based system such as Microsoft's OneDrive, Dropbox, or Google Drive. Another goal might be to collect data digitally using an online form for only one student before branching out to include other students or educators.

If attempting to make a systematic change for an entire entity, such as a department or school, consider the development of a Data/Evidence Collection Team that maintains the responsibility of helping others in the transition (Feldman and Tung, 2001). The team might help others create digital storage centers, utilize and demonstrate embedded functions in commonly used technologies, generate online forms, create visualizations, and answer questions that arise pertaining to data collection. The data/evidence collection team provides opportunities to become a professional learning community with meetings centered around data collection methodologies and practices, as well as reflection on the impact that this has on instruction. Establishing a team with shared responsibilities helps the entire organization achieve its targeted goals.

Student Privacy and Digital Data Collection

Of valid concern in the age of digital data collection is the potential impact on student privacy as guaranteed by the federal Family Educational Rights and Privacy Act (FERPA). FERPA is intended to protect student privacy, while still allowing education agencies to collect and use data to improve student achievement. Schools districts are tasked with maintaining confidentiality of student information, including names, addresses and identifiers such as student identification numbers or social security numbers. School districts develop safeguards for maintaining confidential information within their own networks, and educators must ensure that identifying student data is not used outside a protected school network. For school systems that have become Google Apps for Education (GAFE) districts or have adopted district-wide use of Microsoft OneDrive, student privacy is ensured through the use of a school domain for the GAFE or OneDrive account, both of which can be configured to maintain all data within a district's own network. For other digital tools that save data to the Internet, beyond the school network, educators and administrators should consider establishing protocols that minimize unauthorized access to protected information. Possibilities include the use of pseudonyms for students and teacher-created email accounts that are linked to the school or teacher rather than to a student. It is hoped that as more and more digital, web-based tools evolve for educational use, the options for protecting student information will evolve as well.

Outcomes and Benefits

The end result of using digital tools to collect and analyze data is that educators, including teachers, therapists, assistive technology specialists, and administrators, are provided with richer, more consistent evidence to measure progress toward educational standards. When the digital tools used to collect data are inherent in the assistive and instructional technologies being used by the students, or the tools facilitate the synthesis of raw data into meaningful formats that can be analyzed to support students, the data collection also becomes more efficient and efficacious.

Moving from paper and pencil data collection to integrated, technology based digital data collection requires a paradigm shift, in much the same way that infusing technology into instruction requires a shift from traditional instructional practices. It will take training and practice. While over time the process of technology based data collection becomes more efficient, as with any new skill, it may take more time to develop new habits and proficiency with new tools. To aid in the shift from traditional to digital data collection, all of the resources mentioned in this article are available in a Diigo curated list at http://bit.ly/atobdata.

Declarations

The content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. The author Christopher Bugaj disclosed a past financial relationship with Prentke Romich Company in the form of a one time consultation and two presentations. Christopher Bugaj also disclosed a past relationship with Texthelp who has been a legacy sponsor of specific podcast episodes hosted by the author. The author Beth Poss reported no financial or non-financial relationships.

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Supporting Literacy Achievement for Students with Intellectual Disability and Autism through Curricular Programs that Incorporate Assistive Technology

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Abstract

Education professionals are challenged with re-evaluating the learning capacity of students with developmental disabilities (e.g., intellectual disabilities, autism). Assistive technology (AT) provides both the means for delivery of instruction and the measure of outcomes. Students with developmental disabilities are learning to read and develop general education English Language Arts (ELA) skills across the grade span. This article summarizes ten selected research studies that demonstrate gains of students with developmental disabilities, including individuals who use augmentative and alternative communication (AAC), who have made measurable strides in literacy general education ELA skills. This selected research focused on literacy interventions specifically created for students with developmental disabilities which incorporated the use of AT, use systematic instruction and shared stories, and are commercially available. The research studies include a range of literacy instruction from picture books and early literacy skills to adapted contemporary fiction novels grade aligned to general education secondary level ELA. In these research protocols, AT

facilitated both the delivery of instruction and measure of outcomes.

Keywords: literacy, assistive technology, autism, intellectual disability

Introduction

Assistive technology (AT) has long been used to support instruction for students with developmental disabilities, including intellectual disability and/or autism spectrum disorder (Hourcade, Pilotte, West, & Parette, 2004). There is a plethora of research that demonstrates how AT has been used for skill acquisition across a variety of areas, including promoting choice (e.g., Stasolla, Caffo, Picucci, & Bosco, 2013), increasing social skills (e.g., Sigafoos, O'Reilly, Ganz, Lancioni, & Schlosser, 2005; Walton & Ingersoll, 2013), requesting personal needs (Lancioni, Singh, O'Reilly, Sigafoos, Green et al., 2011), and increasing overall communication (Ganz, Hong, & Goodwyn, 2013). The potential for AT to enhance educational experiences and outcomes for students with developmental disabilities has been fostered by the development of new technologies (e.g., communication apps on tablets), federal requirements for academic rigor (Individuals with Disabilities Education Act [IDEA], 2004; No Child Left Behind, 2003), student interest and engagement with technology (Cafiero, 2008), and groundbreaking research on the use of AT to provide meaningful access to the general curriculum (Knight, McKissick, & Saunders, 2013).

Target Audience and Relevance

Five commercially available literacy curricula (*Pathways to Literacy*, *Early Literacy Skills Builder*, *Early Reading Skills Builder*, *Teaching to Standards: English-Language Arts*, and *Access: Language Arts*) combine AT and systematic instruction to provide students with developmental disabilities with the tools necessary for acquiring literacy skills. The purpose of this paper is to describe the integration of AT across these five programs and specify the outcomes and benefits of using programs with AT supports for students with developmental disabilities across a range of ages and grade levels. The audience for this paper includes special educators, related service providers (e.g., Occupational Therapists, Speech and Language Pathologists), and administrators who seek to provide students with developmental disabilities with evidence-based curricula for literacy and ELA across a continuum of ages, grades, and physical abilities.

Assistive Technology Intervention

AT is described as "any item, piece of equipment or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain or improve functional capabilities of children with disabilities" (IDEA, 2004, sec. 602.1.a). The AT commonly used in literacy instruction has included both low and high technology items, such as Voice Output Communication Aids (VOCA) (e.g., Browder, Lee, Mims, 2011), printed response options (e.g., Hudson, Browder, & Wakeman, 2013), adapted text (e.g., Browder, Trela, Jimenez, 2007), graphic organizers (e.g., Mims, Hudson, & Browder, 2012), and iPads (e.g., Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, & Davis, 2015). Additionally, both systematic instruction (e.g., Ahlgrim-Delzell, Mims, Vintinner, 2014) and shared stories (e.g., Hudson & Test, 2013) have been commonly paired with AT to target increases in literacy and overall access to grade aligned English Language Arts (ELA) skills.

VOCAs provide an avenue for students without vocal-verbal ability to respond during literacy lessons (Erickson & Koppenhaver, 1995; Fenlon, McNabb, & Pidlypchak, 2010; Ruppar, 2013; Schlosser & Blischak, 2001).

Many studies have demonstrated the use of VOCAs to promote participation and demonstrate comprehension of targeted content (e.g., Bellon-Harn & Harn, 2008; Skotko, Koppenhaver, & Erickson, 2004; Soto, Yu, & Henneberry, 2007). For example, Browder, Mims, Spooner, Ahlgrim-Delzell, and Lee (2008) conducted a study targeting increases in engagement and comprehension during a shared story for three students with profound multiple disabilities. All three students used a VOCA to read the repeated storyline at the appropriate time and answer prediction and literal recall questions during the read aloud.

Providing response options where students point to an answer is another common form of AT used in literacy research (e.g., Erickson & Koppenhaver, 2005; Hudson, Browder, & Jimenez, 2014; Mims et al. 2012). When students are unable to generate a verbal response, providing response options with a range of distractors and targeted responses assist the student to identify the best response. For example, Hudson and Browder (2015) used a nine-option response board for each type of WH question (i.e., who, what, when, what or why) asked during a peer- delivered read aloud of an adapted novel for three students with moderate intellectual disability.

Adapted text provides an additional means for students with developmental disability to gain access to grade appropriate text. Providing students with significant disabilities access to grade-aligned adapted text reduces barriers to accessing text such as simplifying text complexity by reducing the Lexile level or adding picture or object supports to increase comprehension and overall engagement with text. The use of adapted text in literacy research involving students with developmental disability has become more common as a means to provide meaningful access to the same text as their nondisabled peers (e.g., Browder et al., 2007; Roberts & Leko, 2013). For example, Mucchetti (2013) conducted a study targeting the impact of teacher-led shared reading of adapted stories on the overall engagement and comprehension of four young children with autism. Books were adapted with visual supports, objects, and simplified text.

Graphic organizers can also be used to promote access to literacy and ELA. Graphic organizers have long been used for students with high incidence disabilities, but more recently have been applied to literacy and ELA interventions for students with developmental disabilities. For example, graphic organizers have been used to help students with developmental disabilities sequence story events (Mims et al., 2012), conduct student led research (Mims, Lee, Browder, Zakas, & Flynn, 2012), learn science concepts (Knight, Spooner, Browder, Smith, & Wood, 2013), improve comprehension of text-based recipes (Douglas, Ayres, Langone, & Bramlett, 2011), improve narrative text comprehension (Williamson, Carnahan, Birri, & Swoboda, 2015) and improve writing (Pennington & Delano, 2012). Research in this area is just beginning to scratch the surface regarding the use of graphic organizers for students with developmental disabilities.

Recent advances in technology have led to new applications of high-tech AT. Tablets, such as iPads, have been used as AT in classrooms to provide instructional support to students with disabilities. Kagohara et al. (2013) examined the literature and identified 15 studies in which these devices were used to deliver content or teach students with intellectual disability or autism spectrum disorder to access target stimuli. Additionally, research provides evidence of using supported electronic texts to promote access to academic content for students with disabilities (Clay, Zorfass, Brann, Kotula, & Smolkowski, 2009; Douglas, Ayres, Langone, Bell, & Meade, 2009). Features of supported electronic text, or e-text, that have a research base for supplementing learning include text-to-speech capabilities, visual supports, auditory supports, and graphic organizers (Douglas et al., 2009; Douglas, Ayres, Langone, & Bell, 2011). For example, Coyne, Pisha, Dalton, Zeph, and Smith (2010) and Wood, Browder, and Spooner (2015) conducted studies on the use of supported e-text to promote academic comprehension outcomes for students with developmental disabilities.

In addition to studies using supported electronic text, there are studies that have examined technologies including applications (apps) or Web-based programs for supporting academic outcomes for students with disabilities. For example, Okolo, Englert, Bouck, Heutsche, and Wang (2011) developed a Web-based learning environment (i.e., the Virtual History Museum) and taught students with and without disabilities to access social studies content online. Also, Spooner, Kemp-Inman, Ahlgrim-Delzell, Wood, and Davis (2014) examined the effects of a shared story delivered via the GoTalk NOW app on engagement and literacy responses for students with developmental disabilities. Similarly, Ahlgrim-Delzell et al. (2015) examined the effects of systematic instruction and the GoTalk NOW app on decoding skills for students with developmental disabilities.

A common thread throughout most of the research highlighted above is the use of instructional packages consisting of both AT and systematic instruction. Systematic instruction is a critical component in most research on literacy for students with developmental disabilities (Ahlgrim-Delzell et al., 2014). Systematic instruction is the practice of teaching specific skills and content through individually prescribed prompting, reinforcement, error correction, and fading procedures (Snell, 1983). Examples of systematic instructional techniques include time delay, task analysis, and least intrusive prompting. In a recent review of the literature on teaching academic skills for students with severe disabilities (Spooner, Knight, Browder, & Smith, 2012), two specific systematic instructional practices, time delay and task analytic instruction, were identified as evidence-based practices. Additionally, emerging research supports the use of a system of least prompts procedure for teaching comprehension (e.g., Hudson & Browder, 2014; Mims et al., 2012; Wood, Browder, & Flynn, 2015).

Constant time delay is an evidence-based practice for teaching sight word acquisition and other discrete skills to students with developmental disabilities. In the time delay response prompt system, the instructor selects one prompt (usually a model prompt). In an initial round of instruction, the instructor promotes errorless learning by delivering the directional cue (e.g., "Read this word.") followed immediately by the prompt (e.g., "This word is <u>cat</u>. Your turn<u>.</u>"). The instructor waits for the student to respond and provides verbal praise, even though the response was fully prompted. After several trials or sessions using this 0-second (s) delay procedure, the instructor inserts a brief and consistent pause (e.g., 4 s) between the delivery of the directional cue (e.g., "Read this word.") and the prompt (e.g., "This word is <u>cat</u>"). If the student responds independently before the prompt is delivered, the instructor delivers specific verbal praise. If the student waits for the prompt, the instructor delivers specific verbal praise, but with less intensity. If the student makes an error, the instructor corrects the error by demonstrating the correct response and directs the student to repeat the correct response.

The system of least prompts, or least intrusive prompting, is another response prompt procedure that has been used to teach complex literacy skills, such as answering comprehension questions, to students with developmental disabilities (e.g., Mims et al., 2012). In this procedure, the instructor selects a hierarchy of prompts, from least intrusive to most intrusive, to help students determine the correct answer. For instance, when asked a comprehension question, the instructor first waits for the student to respond independently. If the student does not respond after a predetermined wait time (e.g., 5 s), the instructor delivers the first level of prompt (the least intrusive prompt). For example, "I heard the answer in the text. Listen." Then the instructor rereads a portion (e.g., three sentences) of the text containing the target answer. If the student still cannot answer the question after 5 s, the instructor delivers a more intrusive prompt (e.g., "I heard the answer in the text. Listen." The instructor rereads one sentence with the target answer.) Finally, if the student still cannot answer independently after 5 s, the instructor delivers a controlling prompt (typically a model prompt). For example, "Listen, I heard the answer in the text. Cat. Touch cat." Students can select response options from an array of choices or provide answers without response options.

Critical features of systematic instruction include reinforcement, fading, and error correction. Correct responses should be reinforced immediately with specific feedback. Additionally, all systematic instruction includes a plan for fading supports. To avoid prompt dependency, instructors must select methods that gradually and systematically withdraw the level or frequency of supports. In constant time delay, supports are faded by the insertion of the wait time between the delivery of the directional cue and the controlling prompt. In a system of least prompts, the supports are self-fading; as students become more successful in locating answers in the text, they will not require as many prompts from the hierarchy.

Considering the findings that supported that features of low- and high-tech devices can increase access to literacy when combined with evidence-based systematic instruction, the use of AT is a viable strategy that educators can use for increasing academic skills, including emergent reading and reading skills (Carnahan, Williamson, Hollingshead, & Israel, 2012). When the philosophy of the least dangerous assumption (Donnellan, 1984), which promotes assumed competence, is applied to all students, educators can promote access to meaningful literacy instruction for students with developmental disabilities across a continuum of skills and topic areas. By pairing this access with high quality technology-based systematic instruction, educators can increase opportunities for student success.

Literacy Programs with AT Components

Five commercially available curricular programs (*Pathways to Literacy*, *Early Literacy Skills Builder*, *Early Reading Skills Builder*, *Teaching to Standards: English-Language Arts*, and *Access: Language Arts*, see *Table 1*) address a range of literacy skills through systematic and explicit instruction and AT. Ten research studies demonstrate literacy gains that resulted from the use of these five programs by students with developmental disabilities, as described in *Table 2*. These ten research studies were selected for this paper because they encompass the body of research for the five curricula, with a focus on integrated AT. Other studies were conducted on individual components of these curricula (e.g., Mims, Browder, Baker, Lee, & Spooner, 2009), but the selected studies for this paper were chosen because they were the studies on the comprehensive program versus the iterative studies on components of the programs. Collectively, the programs include instruction for students with developmental disabilities from pre-K to secondary grades. The content spans from pre-reading skills (e.g., text awareness and engagement) to emergent reading skills (e.g., phonological and phonemic awareness) to early reading skills (e.g., decoding and text comprehension). Specifically, foundational literacy instruction is provided by *Pathways to Literacy (Pathways)*, followed by early literacy in *Early Literacy Skills Builder* (*ELSB*), to early reading in *Early Reading Skills Builder* (*ERSB*), to grade-aligned secondary English Language Arts curriculum with the blended product *Teaching to Standards: English/Language Arts* and *Access: Language Arts* (*TTS:ELA/ALA*). See *Table 1* for a summary of each product focus, target population, product description and AT features. Across the programs, students can access materials aligned with their grade level. For example, adapted texts from the *TTS:ELA* program include grade-aligned texts that have been rewritten at an accessible readability level for students with developmental disability who are emergent or early readers (approximately a second grade readability level).

Pathways to Literacy (Pathways)

At the beginning of the literacy continuum is *Pathways to Literacy*. The curriculum is divided into five levels which systematically build students from an early concrete symbolic level to a more abstract symbolic level and is meant for students at a very early understanding of emergent literacy, including those with significant, multiple disabilities who do not consistently use words, pictures, or other symbols to communicate. *Pathways to Literacy* is focused on increasing overall awareness and engagement. *Pathways* builds on the research from Blyden (1988), Browder, Mims, Spooner, Ahlgirm-Delzell, and Lee (2008), and Mims, Browder, Baker, Lee, and Spooner (2009) which have all investigated successful methods to increase engagement, awareness, and comprehension during literacy lessons. The scope and sequence for *Pathways* focuses on a variety of objectives (e.g., attends to reader by reacting to name read in text; locates object on the page when asked to "read" with me; identifies title of story; identifies book from nonbook) while moving from Level 1 to 5. AT is integrated into all levels with alternative response options. Level 1 focuses on the student engaging with a book and Level 2 focuses on students choosing a response. In Level 3 the students use objects to respond and gradually shift to responding with picture symbols paired with objects in Level 4 to only picture symbols in Level 5. All objectives are taught using systematic and direct instructional strategies. For example, task analytic instruction is used along with response prompting strategies such as time delay and System of Least Intrusive Prompts. Lessons are scripted to ensure fidelity of implementation and include procedures for reinforcement and error correction. Additionally, lessons can be individualized so learners with a variety of exceptionalities can participate. For example, a student at the awareness level with a cortical visual impairment may turn her head toward the book to indicate understanding that it is time to open the book. While the focus of the curriculum is to promote early emergent literacy such as concept of print, the potential barriers for engagement, expression, and representation often seen for students with severe, multiple disabilities are minimized as AT supports are added and individualized based on student characteristics.

Research by Browder, Lee, and Mims (2011) used a multiple probe across participants/response modes design to investigate the effects of *Pathways* on engagement and comprehension of three elementary students with multiple, severe disabilities. During the intervention the teachers used scripted task analytic lessons with systematic prompting from the curriculum, but all lessons were individualized based on three types of students including a student who used eye gaze to respond, a student who used a point response, and a student who was visually impaired and used salient objects to represent response options or text from the story (e.g., when reading a story about baseball, the student would be presented with a baseball) to respond. Results indicated all three students showed gains in both comprehension and engagement.

The Early Literacy Skills Builder (ELSB)

The *ELSB* is divided into two sections called *Building with Sounds* and *Building with Stories*. *Building with Sounds* focuses on early literacy skills including concepts of print and four of the five essential components of reading instruction identified by the National Reading Panel (2000) phonemic awareness, phonics, vocabulary, and comprehension. Concepts of print include skills such as text pointing, completing a repeated story line, and selecting a word to complete a sentence. Phonemic awareness skills consist of syllable and phoneme segmentation. Phonics skills include letter-sound correspondence, identification of first and last sounds in words, finding pictures that begin and end with a specific sound, pointing to letters in segmented words, and pointing to pictures that represent segmented words. Vocabulary teaches sight word identification for irregular, non-decodable words and picture vocabulary. Students respond to questions about text that is read to them to answer literal and inferential questions to develop listening comprehension. The *Building with Stories* section reinforces these skills by providing teachers with a task analysis for engaging students in reading grade-level adapted text. AT is integrated with alternate response modes including VOCAs.

ELSB is available in print, software, and app. The software and app include professional narration, prompting, and error correction using systematic instructional strategies and assessment. The *ELSB* provides multiple ways for students to access, engage, and respond to the instruction. Using the print version, teachers provide the systematic instruction with a scripted text. The print version provides special adaptations for those who are nonverbal and use augmentative and alternative communication (AAC) to communicate. Although students are encouraged to verbalize to approximate phonemic sounds, they can point, use adaptive switches connected to AAC devices, or eye gaze to response boards. Materials can be enlarged and printed for students with visual impairments.

The systematic instruction is embedded into the computer software and app versions. Students use the mouse, touch, or an adaptive switch to select their responses. Touching options can include adaptive devices such as a head pointer. An adaptive switch can be used with the scanning option whereby students stop the scan across response options to select their answer. The size and color of the text can be changed as needed for students with visual impairment. The pace of the lessons and volume can be changed providing longer response times for students with processing difficulties or hearing impairment. Response options are randomly placed on the screen so they appear in a different order to avoid memorizing the placement of correct answers.

The *ELSB* was created and evaluated after one year and three years using a randomized control design with elementary school age students with moderate-to-severe intellectual disability, including some students with autism and some who were nonverbal (Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers, 2008; Browder, Ahlgrim-Delzell, Flowers, & Baker, 2012). Both studies found statistically significant interaction effects between treatment/control groups and pre-posttest. The treatment group outperformed control group in convention of reading, phonemic awareness, and decoding at both one year and three years of instruction. In addition to using statistical significance to evaluate the effect of the *ELSB* curriculum, the magnitude of the effect as measured by Cohen's *d*, also provided such evidence. Cohen's *d* is a standardized measure of the amount of the effect in standard deviation units and can be compared across studies. There were large effects for conventions of reading for both groups after one year of instruction as both groups received this intervention (d = 1.57 treatment, d = 1.24 for control). There was a large effect for phonics skills (including phonemic awareness and decoding skills) for the treatment group receiving the *ELSB* (d = 1.35) and a moderate effect for phonics skills for the control group (d = .51) indicating a larger effect for the *ELSB* after one year of instruction. After three years of instruction, the magnitude of the difference between the treatment and control groups was moderate for both conventions of reading (d = .49) and phonics (d = .44). Both statistical significance and effect size estimates indicate that the *ELSB* is an effective intervention to teach early literacy skills, including conventions of reading and phonics, for students with intellectual disability and autism.

The Early Reading Skills Builder (ERSB)

The next product in the continuum of literacy, covering the scope and sequence of beginning reading, is *ERSB*. The *ERSB* scope and sequence includes phonics instruction for English language reading up to the second grade level and reading comprehension. *ERSB* is a blended (i.e., technology integrated) curriculum available as an iPad app, or computer software format fully integrated into the curriculum protocol. The integrated AT uniquely provides the opportunity for students who are unable or reluctant to sound out the phonemic elements of the English language to have the technology sound out, blend, and segment phonemes into real words. At the end of each lesson, students read connected text using non-decodable sight words and decodable words using the phonemic elements that they have been taught. The multi-year reading instruction curriculum spans 26 levels where students learn to identify individual phonemes and phoneme blends, blend and segment words, decode words to identify pictures, read connected text, and answer literal comprehension questions about the text. The technology also provides for randomization of answers and distractor options, and the same adaptive interfaces as described for *ELSB*. Students are moved to the next level once competence is gained on the current level as a result of automatically tracking student progress. Systematic instructional elements integrated into the *ERSB* technology include constant time delay, stimulus prompting, least intrusive prompting, reinforcement, error correction, and fading.

A functional relation was established between the intervention and the percentage of correct responses on phoneme identification, blending and decoding across participants in the single-case, multiple-baseline research study (Ahlgrim-Delzell, Browder, & Wood, 2014). In the second *ERSB* research study (Ahlgrim-Delzell, Browder, Wood, Stanger, Preston, & Kemp-Inman, in press), a randomized control research protocol, statistically significant interaction effects were found between treatment/control groups. The treatment group outperformed the control group in phoneme identification, decoding and total score. No significant interaction effect was found for blending. The lack of a statistically significant difference for the blending skill may reflect learning that occurred in the control group while students participated in shared stories activities. HLM analysis found the time + intervention interaction model to be the best fit. Inclusion of teacher and student level characteristics did not improve model fit.

Teaching to Standards: English Language Arts (TTS: ELA) and Access Language Arts (ALA)

English Language Arts aligned to middle school content is made accessible to students with developmental disabilities through the products *TTS:ELA* and *ALA*. AT is integrated with *TTS: ELA* in a variety of ways. First *TTS: ELA* is applicable to learners who are using photographs, picture symbols, or beginning to use words, and it provides response options in each of these formats for students to use to answer grade aligned skills such as comprehension, vocabulary, poetry skills, play terminology, writing, and student led research. The curriculum includes four Theme-based Units that use fictional novels (e.g., *The Outsiders*), nonfiction text (e.g., *Sadako and the Thousand Paper Cranes*), informational text (on topics such as Ghandi), poems (e.g., *Still I Rise* by Maya Angelou), and plays (e.g., *The Diary of Anne Frank*) all aligned to the theme of the unit (e.g., Social Justice). Each unit contains eight scripted lessons that teach the grade aligned ELA skills using systematic and direct instructional strategies such as constant time delay, system of least prompts, model lead test (MLT), error correction, and reinforcement strategies. In addition to these materials, *Access: Language Arts* (*ALA*) was developed both as an app and software as a supplement to the paper curriculum, *TS: ELA*. *ALA* incorporates the systematic instructional strategies into the program and includes other features such as automatic data collection. The app is divided into both a vocabulary and comprehension component as well as an opinion writing component. Students are provided access to the same adapted grade-appropriate texts seen in the paper curriculum. These texts are read aloud and include interactive features such as underlined vocabulary words within the text that can be selected with the definition provided. To teach vocabulary, constant time delay is incorporated for both identification and definition and includes two rounds of 0-s. delay and one round of 5-s. delay. To promote comprehension, the system of least prompts has been programmed into the software and app to provide a hierarchy of prompts similar to those described in the introduction of this paper. The opinion writing component (under development as *ALA II*) is broken down into instruction on the format of the paragraph (i.e., introduction sentence, opinion sentence, two reason sentences, and a conclusion sentence) and an opportunity for students to write their own opinion paragraph based on the text read (e.g., "I think it was good/bad that Ponyboy was a Greaser."). The system of least prompts and MLT are used with this technology to promote grade-aligned skills in writing.

Several studies have been conducted on both the *TTS: ELA* and *ALA*. First, a study by Mims, Lee, Browder, Zakas, and Flynn (2012) was conducted with 15 middle school students with mild to severe developmental disabilities using *TTS:ELA*. Using a single group, pre-, post-test design, students received instruction using the theme-based scripted lessons from *TTS: ELA*. Students participated in a curriculum based pre- and post-test both before instruction and after eight weeks of instruction (one week per lesson). Differences in scores from pre- to post-test were calculated with a nonparametric, related samples test (i.e., The Wilcoxon Signed Rank Test). The ESs for significant differences were determined with Cohen's d. Results indicated significant gains for vocabulary (d = 1.31, p = .005), and comprehension of familiar text (d = .93, p = .017). Although not statistically significant, moderate gains were made for comprehension of unfamiliar text (d = .52), poetry (d = .48), research (d = .40), and writing (d = .45).

In a second study on *TTS:ELA*, the researchers added a control group as well as a generalization measure, which was an assessment testing the same skills taught, but using texts the students had never been exposed to (Lee, Mims, Browder, Ahlgrim-Delzell, in preparation). A non-equivalent group research design with a pre-posttest was used to examine the effects of instruction on Unit Four of the curriculum with 30 middle grade students with developmental disabilities. Two repeated measures of ANOVA were used to examine the group interaction effects on the total score of the direct (familiar) and the indirect (unfamiliar) items. Results showed statistically significant interaction effects for vocabulary identification and definition, comprehension, story grammar, figurative language, writing skills, and research skills in both the direct Curriculum Based Measure as well as the generalization measure (indirect assessment). In both cases, the treatment group outperformed the control group.

In addition to research on *TTS:ELA*, a few studies have been conducted on *ALA*. First, a study by Mims and Stanger (in submission) used a multiple probe design across participants to investigate the effects of the app focused on teaching vocabulary identification, definition, and comprehension across Bloom's taxonomy using grade- appropriate adapted nonfiction text with three students with moderate to severe developmental disabilities. Results indicated a functional relationship between the app and targeted vocabulary and comprehension.

A second study (Mims, Stanger, Sears, & White, in preparation) replicated the Mims and Stanger study, but this study focused on a fictional novel (i.e., *The Outsiders*) delivered via the app, *ALA*. A functional relationship was established between the intervention and the percentage of unprompted correct responses to vocabulary identification, definition, and comprehension questions (e.g., application, literal recall, inferential, analysis, sequence, main character, etc.) for all four students with developmental disabilities.

Finally, a third study investigated the effects of the writing component of the *ALA* app (Mims, Stanger, Pennington, White, Sears, and Strickler, (in preparation). Using multiple probe design across participants, three students with developmental disabilities were provided instruction via the app on components of writing an opinion paragraph and constructing their own opinion paragraph after reading a grade-appropriate adapted text. Results indicated a functional relationship was established between the intervention and the dependent variable, which included the percentage of unprompted correct steps of writing process.

AT Outcomes and Benefits

While none of the research studies that examined the effects of the five programs specifically measured the differential effects of AT outcomes, all studies demonstrated positive effects of the literacy interventions with AT supports for students with developmental disabilities. The following section will describe potential outcomes and benefits of the AT embedded in the programs, specific evidence of these benefits, and a description of how AT may have supported student outcomes.

Potential outcomes and benefits. The five programs included AT supports that have the potential to support literacy skill acquisition for students with developmental disabilities. Specifically, AT potentially increased student engagement, student understanding of the skills and content, and increased access to communicating responses across skills. With an increase in engagement with the curricula, students acquired access to the grade-aligned content. With an increase in the response modes, students were able to demonstrate their knowledge. In this way, AT facilitated student learning and an increase in knowledge gained across the curricular area was measured.

Evidence of outcomes and benefits. In the ten research summaries, there were a total of 208 participants from ages six to 14, or grades K to middle school (see Table 2 for the citation, age or grade of participants, and student description). While all of the research participants had a diagnosis under the broad term 'developmental disabilities' and most were identified as having an IQ of 55 or below, the IQ range across all of the studies was 31 to 86. Some participants had an additional diagnosis of Rett syndrome, Down syndrome, autism, physical, or sensory disability. More than a third of the participating students were also described as being non-verbal. The non-verbal participants included nonsymbolic communicators, including those whose modes of communication included gestures, sounds, facial expressions, and vocalizations (*Pathways*) and symbolic communicators who used pointing or eye gazing to pictures to respond to instruction (*ELSB* and *ERSB*). At the opposite end of the literacy continuum with the *Access: Language Arts* research studies, middle school age participants were measured to be reading at the Pre-K/K level and used an iPad.

How AT supported outcomes and benefits. Access to the curricular content was possible through the AT integrated into the curricula. In each case, AT provided for multiple means of representation, multiple means of engagement, and multiple means of expression. Across the five curricular products, AT features included alternate response modes including pointing, eye gaze, single and double switches, VOCAs, adapted text, and graphic organizers, which were incorporated in both print form and tablet format (e.g., iPads).Technology products added professional narration with highlighting, integrated vocabulary instruction with error correction, automatic randomization of selections, and automated student assessment including automated advancement where the instructing adult sets the advancement criterion. See Table 1 for specific AT features per product. VOCAs were used across products for making selections and participating in re-telling of a repeated story line. The AT features in each product provided for multiple means of engagement and multiple means of response modes which allowed for students to access the curriculum and demonstrate knowledge in literacy.

AT Outcomes - Literacy Outcomes

Across the variety of research designs and analyses as listed in Table 2, there are consistent findings of positive student outcomes in achieving gains in literacy made possible through the integrated AT. The studies accessed a variety of grade level literature formats ranging from picture books to grade-aligned fiction novels, non-fiction, poetry, and writing opinion paragraphs. Across the studies, the literacy outcomes that were measured and shown to improve include: listening comprehension, engagement, conventions of reading, phonemic awareness, phonics (decoding), reading comprehension, vocabulary, research skills, and writing. Please see Table 2 for details.

Discussion

Within this paper we have demonstrated how AT, when integrated within an instructional protocol as a part of a literacy curriculum, provides measurable gains for students with developmental disabilities in literacy and ELA. Measurable gains were the result of the multiple ways that a student was provided access to the curriculum through AT, and the multiple ways in which a student was able to demonstrate his/her knowledge, through AT. As demonstrated through these examples, all students can achieve measurable increases in literacy and ELA when provided with access and instructional strategies. Special educators, including teachers, specialists, Occupational Therapists, Speech and Language Pathologists and administrators, can replicate success in the classroom by seeking literacy curricula with a scope and sequence tied to standards in literacy where AT is integrated into the curricular protocol. AT provides a means for students with developmental disabilities to make independent selections, receive best practice instruction across modalities, and demonstrate measureable competence. As a result, students with developmental disabilities have increased opportunities to develop lifelong skills associated with higher levels of literacy or reading ability, and an appreciation for both literature and literacy. A major finding from this body of research is that students, across all of the curricula, made measurable gains in literacy achievement. Gains occurred across ages, grades, ethnicity, and disability. Students improved on measures of conventions of reading (e.g., orientation of reading material, turning pages, text pointing) phonological awareness, phonics, listening and reading comprehension, writing, research skills, and engagement. Students made gains in comprehension and engagement measures of shared stories (*Pathways*); knowledge of conventions of reading, phonemic awareness, and beginning decoding skills (*ELSB*), and measures of phoneme identification and decoding for picture-word matching (*ERSB*). Additionally, students made gains for vocabulary and text comprehension (e.g., questions related to story elements, prediction, figurative language, and main idea), and writing skills (*TTS: ELA*, *ALA*). Every curriculum integrated AT which provided student instruction, allowed for student generated responses, and measured assessment outcomes.

Listening comprehension skills were not limited to literal comprehension. Students who participated in the *TTS: ELA* and *ALA* programs answered questions about familiar and unfamiliar text across levels of Bloom's Taxonomy (Bloom et al., 1956). For example, students responded to higher-order thinking questions about figurative language, author's purpose, and main idea. Text types spanned fiction, nonfiction, and poetry, and students applied ELA skills to research activities. Finally, students completed writing assignments, including writing about an opinion. AT was integral for student production and assessment.

An important benefit of these programs is increased access to standards-based literacy instruction and progress in literacy achievement for students with developmental disabilities, including students who use AAC (i.e., VOCA or response options). Students from kindergarten to 8th grade improved in their development of understanding text they heard or read independently. Comprehension measures and strategies were varied across several formats to promote generalization of skills to untrained texts (e.g., varying the pictures used to represent objects in comprehension texts in *ELSB* and *ERSB*; varying words used in programs to discourage memorization). Accessing texts, of all varieties, and understanding the content are vital lifelong skills that have the potential to improve the quality of life for all students. Particularly for students with developmental disabilities, increased opportunities for grade-aligned literacy instruction can increase access to the general curriculum, provide more opportunities for students to interact with peers without disabilities, and promote the development of a life-long appreciation of both literature and literacy (Browder et al., 2009; Jackson, Ryndak, & Wehmeyer, 2008-2009). Through carefully designed curricular programs that combine elements of both AT and systematic instruction, research indicates students with disabilities can gain important ELA skills.

Implications for Practice

The programs (*Pathways, ELSB, ERSB, TTS: ELA*, and *ALA*) examined by the body of literature reviewed in this paper all made use of many of the same specific strategies. That is, all programs were scripted, explicit, and systematic. Four of the programs (*ELSB*, *ERSB*, *TTS: ELA*, and *ALA*) incorporated constant time delay procedures to teach discrete foundational literacy skills, such as letter or word identification, phoneme identification, blending sounds, or matching vocabulary from the literature with definitions. An implication for teachers is to first model pointing to or saying the target response, then repeat the trial with a 4 or 5 s delay embedded between delivery of the instructional cue (e.g., "Show me the letter that makes the /m/ sound") and the delivery of the controlling prompt (e.g., the teacher points to the letter "m"). *ELSB* software and app, *ERSB* and *ALA* all provide systematic instruction integrated within the technology platform of delivery, serving as a model for teaching instruction and best practice delivery with automated error correction.

There is also evidence from all five of the programs that supports the use of a least intrusive prompting method to teach complex literacy skills, including literal or inferential text comprehension, knowledge of story elements, sequencing, main idea, and poetry. Teachers can use a traditional verbal-model, physical prompting hierarchy to teach the steps of a chained sequenced (such as ordering events in a story) or a modified hierarchy that gradually reduces the amount of target text to guide students to locate answers to comprehension questions independently. Additionally, findings from all of the studies support the use of consistent error correction procedures (e.g., "No, ___ is the answer. Show me ___.") and reinforcement, typically in the form of specific verbal praise (e.g., "Yes! ___ is the answer! Great job reading ___."). Within the software and app programs (e.g., *ALA*), reinforcement with specific verbal praise is automatically delivered in response to student input and selection.

In all of the studies reviewed, either low- or high-tech AT was incorporated into the program components. An implication for teachers, therapists and specialists is to provide students with low- or high-tech response options to promote participation in literacy instruction. Students can point to letters, words, or picture symbols with words to indicate an answer to literacy questions (e.g., *Pathways, ELSB*, *TTS: ELA*). Alternatively, software or tablets can be used to provide response options that include audio (e.g., *ELSB*, *ERSB*, *ALA*). Students can use software or an app on an iPad to select buttons that will voice individual phoneme sounds (e.g., *ERSB*). Using this capability, students who also have communication support needs can blend sounds and segment words using an iPad. Students can also access texts via an iPad, which can include supportive text features, including highlighted text and professional narration (e.g., *ERSB*, *ALA*).

Conclusion

The evidence from the ten research studies discussed and reviewed in this paper suggests students with developmental disabilities can learn a wide range of literacy skills, including reading connected text and higher-order comprehension. More research is needed as replication by other researchers to help to corroborate these findings. When we approach reading as a science, and incorporate systematic instruction (instructional practices with a strong evidence-base for teaching a range of skills to this population), then teaching literacy skills to students with developmental disabilities becomes a successful and exciting endeavor. The addition of AT, both as a low- and high-tech mechanism for supporting learning, increases student voice by providing students with a means to communicate literacy knowledge. Overall, no matter where students are in their academic achievements in literacy, there is a curriculum and an approach that will yield measurable results.

Declarations

The content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. The authors disclosed financial relationships with Attainment and no non-financial relationships.

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**** Asterisks denote research studies that provided the foundation for this manuscript. These publications are described in Table 2: Summary of Research Studies.***

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Table 1: Comparison of Five Literacy Products

Product Name - **Curriculum Focus**	**Target Population**	**Product Description**	**AT Features**
Pathways to Literacy Literacy for Early Communicators	Students with significant developmental disabilities combined with physical or sensory disability, including those who are nonverbal, who do not consistently use words, pictures, or other symbols to communicate	Scripted lessons for five levels with three story books provide strategies to increase awareness and engagement in story reading while systematically building comprehension for early communicators participating in emergent literacy skills such as phonological awareness and print principals engaging in activities that include viewing pictures and objects in a book, retelling stories, and building vocabulary.	Response options include real objects, pictures of real objects, pictures representing real objects and instructions for programming a VOCA to read a repeated story line and answer prediction and literal recall questions during a read aloud.
Early Literacy Skills Builder (ELSB) Early Literacy	Elementary age students with developmental disabilities including those who are nonverbal who use words, pictures, or other symbols to communicate.	Multi-year scripted curriculum with 7 levels. The scope and sequence includes 14 literacy skills and an assessment protocol at each level.	Curriculum is available as print, computer software, or app. Systematic instruction is embedded into software. Response options accommodate pointing, eye gazing, and switches to select pictures, letter, and words and VOCAs. Materials can be enlarged. Text color, volume, and pace of the lessons can be changed in the software. Response options are randomized.
Early Reading Skills Builder (ERSB)	Students with disabilities who are (a) nonverbal or require communication	Multi-year reading curriculum that spans 26 levels where students learn to identify individual phonemes and	This is a blended curriculum (i.e., technology is integrated). Students can access lessons via

Early Reading	supports, (b) have acquired basic literacy skills such as concepts of print and phonemic awareness, and (c) are ready to learn to read.	phoneme blends, blend and segment words, decode words to identify pictures, read connected text, and answer literal comprehension questions about the text. Constant time delay procedures, error correction procedures, reinforcement, are built into the program to teach letter-sound identification, blending, decoding, and sight word identification. A system of least prompts procedure is used to teach segmenting and text comprehension. Scope and sequence includes phonics instruction for English language reading up to the second grade level with reading comprehension.	an iPad app or cross-platform software. These formats provide students who are unable or reluctant to sound out the phonemic elements of the English language to use the technology to produce letter sounds. Students can (with the support of technology) produce individual sounds or blend sounds to form words. The technology interface provides professionally narrated systematic instruction with error correction, integrated randomization of answer selections, automated student assessment, and advancement to the next level after achieving competency (i.e., the program will advance students to the next level only after the student achieves the predetermined criteria for mastery).
Teaching to Standards: English Language Arts Grade Aligned English Language Arts for Middle School	Secondary students (Middle School or High School), with developmental disabilities and/or autism who have a range of literacy skills from communicating with pictures to reading.	32 progressive scripted lessons incorporate evidence-based teaching procedures and are organized into four theme-based units: Change, Values and Decision Making, Social Justice, and Global Awareness. Provides literacy instruction across Bloom's Taxonomy	Adapted text for grade-appropriate novels, picture cards used as response options, and graphic organizers. The curriculum provides materials at three literacy levels: object/photo, concrete symbols, and text.

		(Bloom et al., 1956) aligned with upper elementary to secondary standards in English Language Arts including story grammar, comprehension, vocabulary, and writing.	
Access: Language Arts Comprehension, and writing with Middle School aligned English Language Arts	Secondary students with developmental disabilities and/or autism in Middle School or High School who have access to an iPad or computer who have a range of reading levels from pre-K to second grade.	App and software with adapted non-fiction and fiction (under development) stories from TTS:ELA across all four Units. The adapted text in ALA complements the scripted plays included in TTS:ELA. Comprehension questions in ALA offer greater depth than those included in the TTS:ELA curriculum.	Professionally narrated read alouds with highlighting the adapted text (grade-aligned books), vocabulary instruction, prompting, integrated systematic instruction with error correction, randomization of answer selections, and automated student assessment. Alternative access includes built in scanning with single or double switch access.

Table 2: Summary of Research Studies

Curriculum Focus - *Product Name*			
Citation	**Participants** **# in study** **Age or grade** **Disability**	**Research Design**	**Outcomes/Results**
Literacy for Early Communicators – *Pathways*			
Browder, Lee, & Mims (2011)	3 students Age 6/8/9 MD/NV	Single-case multiple probe across participants	A functional relationship was established between the intervention and number of correct responses on comprehension and engagement across response modes (i.e., eye gaze, object selection, touch).
Early Literacy – *ELSB*			
Browder, Ahlgrim-Delzell, Courtade, Gibbs, & Flowers (2008)	23 students Grade-K-4 Mod./Severe ID &/or ASD (6), NV(12)	Pre-test, post-test randomized control blocked by teacher	Both *ELSB* studies found statistically significant interaction effects between treatment/control groups and pre- and post-test. The treatment group outperformed control group in convention of reading, phonemic awareness, and phonics skills after one year and three years. Effect size estimates after three years found a moderate effect in favor of the treatment group.
Browder, Ahlgrim-Delzell, Flowers, & Baker (2012)	93 students Grade-K-5 Mod./severe ID; ASD (35), NV (42)	Pre-test, post-test randomized control blocked by teacher across 3 years	
Early Reading –*ERSB*			
Ahlgrim-Delzell, Browder, & Wood (2014)	3 students Age 7/8/10 IQ 54/31/44, DS, ASD	Single-case multiple-baseline across participants	A functional relationship was established between the intervention and percentage of correct responses on phoneme identification, blending and decoding.

Ahlgrim-Delzell, Browder, Wood, Stanger, Preston, & Kemp-Inman (in press)	31 students Grade K-8 ID or DD, IQ range 40-86, ASD (13)	Pre-test, post-test randomized control blocked by teacher	Statistically significant interaction effects between treatment/control groups and pre-/post-test. The treatment group outperformed the control group in phoneme identification, decoding and total score. No significant interaction effect for blending. HLM analysis found the time + intervention interaction model the best fit. Inclusion of teacher and student level characteristics did not improve model fit.
Secondary - *ELA TS:ELA*			
Mims, Lee, Browder, Zakas, & Flynn (2012)	15 students Middle School Mild/Mod./Severe ID or DD ASD (9)	Single-group, pre-, post-test	Statistically significant gains with large effects for vocabulary and comprehension of familiar text. Although not statistically significant, moderate effects were made for comprehension of unfamiliar text, poetry, research, and writing.
Lee, Mims, Browder, Ahlgrim-Delzell (in preparation)	30 students Middle School Mod/Severe ID or DD	Pre-test, post-test non-equivalent groups	Statistically significant interaction effects for vocabulary identification and definition, comprehension, story grammar, figurative language, writing skills, and research skills. The treatment group outperformed the control group.
Secondary ELA - *Access: Language Arts*			
Mims & Stanger (in submission)	3 students Age 10/13/14 IQ 50/40/59, ASD, MD	Single-case multiple probe across participants	Functional relationship was established between the intervention and the percentage of unprompted correct questions answered to nonfiction text read aloud.
Mims, Stanger, Sears, & White (in preparation) Mims, Stanger, Pennington, White, Sears,	4 students Age 9/12 IQ <40/50, Rett Syndrome (1) & ASD (1)	Single-case multiple probe across participants	Functional relationship was established between the intervention and the percentage of unprompted correct questions answered to a fictional novel read aloud.

& Strickler (in preparation)	3 students Age 9/12, IQ 50/<50/<40	Single-case multiple probe across participants	Functional relationship was established between the intervention and the percentage of unprompted correct opinion writing responses.

*ASD- Autism Spectrum Disorder; MD- Multiple Disabilities; NV- Nonverbal; DS-Down Syndrome; ID Intellectual Disability; DD- Developmental Disability

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The Realize Language System: An Online SGD Data Log Analysis Tool

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Abstract

Automated data logging is a feature of some speech generating devices (SGDs). Such data can provide clinicians with information on how a client uses a device. Clinicians can then use these data to help improve the client's skills and opportunities. Logged data could also help answer questions such as: What medical and demographic characteristics are most often associated with usage and vocabulary? What are the characteristics of consumers who end up using their devices the least? How many consumers use their devices with the telephone and other devices? Using example data from an online data analysis tool, the authors will outline some of the positive ways in which data logging can be used to ask, and ultimately answer, many questions about how individuals interact with their SGD technology.

Keywords: automated data logging (ADL), speech generating devices (SGDs), graphical representation, vocabulary analysis, Realize Language system

Introduction

"Would you tell me, please, which way I ought to go from here?"
"That depends a good deal on where you want to get to," said the Cat.
"I don't much care where – " said Alice.
"Then it doesn't matter which way you go," said the Cat.
"-- so long as I get somewhere," Alice added as an explanation.
"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

(Alice's Adventures in Wonderland: Lewis Carroll).

In all fields of endeavor, the ability to measure change is critical. This is as applicable to the field of augmentative and alternative communication (AAC) as it is to any other. To make a statement about change in the absence of some kind of metric is *speculation* and not evidence, and it is important that *evidence* drive educational and clinical practice (Byiers, Reichle, & Symons, 2012; Dollaghan, 2007; Lof, 2011; Schlosser, Koul, & Costello, 2007). Fundamentally, the challenge is to decide (a) what should I measure, and (b) how do I measure it? For professional researchers, there is much more to it than these two questions, but for clinicians and educators in the field, taking just a few minutes to consider them before implementing a new technique or strategy is more scientific than "I'll try X and see what happens." Apel (2009) recommends applying a scientific approach to clinical practices to enable clinicians to provide the best evidence-based practices for clients.

The inability to collect and analyze client data over time was pointed out by Lesher, Moulton, Rinkus, and Higginbotham (2000). They noted at the outset that:

> Over the past few years, technical and technological advances in augmentative communication have outstripped our ability to assess the impact of these advances on the actual act of communication. This is due in part to the lack of a consistent and reliable method to measure long-term communicative efficacy. It has been extremely difficult for researchers, clinicians, and manufacturers to perform the kind of quantitative empirical studies that are an essential counterpart to theoretical advances and qualitative evaluations. Without a disciplined quantitative analysis, it is hard to identify and correct problems in a communication interface. (p.1)

Specific analyses of data gathered from logging have been reported in the literature. Romich, Hill, and Spaeth (2001) used logging to demonstrate selection rate for aided communicators; Lesher and Rinkus (2002) used logging to measure improvements in character prediction; Lesher, Moulton, Higginbotham, and Alsoform (2002) analyzed different scanning arrays via logging; and Hill (2004) reported using logs to break down data in different types as found in Prentke Romich devices. All of these illustrate how automated data logging (ADL) can be used to provide information that would not be easy to get manually.

Without the facility to log over extended periods of time, vocabulary samples collected manually from individuals using speech generating devices (SGDs) could be so small as to be of limited value in terms of being representative. Heilmann, Nockerts, and Miller (2010) reviewed a number of studies that recommend the minimum sample size necessary for allowing a reliable analysis and theses run from 50 to 175 complete utterances. Yet for clients who use AAC systems and who have significant physical and/or cognitive challenges, collecting such a sample during one-on-one sessions could take weeks. ADL is an ideal tool for helping to collect much larger samples over shorter periods of time. In a recent article by Hill, Kovacs, and Shin (2015), the authors argue that in "the ICF [International Classification of Functioning, Disability and Health] framework the most representative samples would be obtained from language generated during participation in activities of daily living" and "Capturing these data is not possible without automated data logging" (p. S10). This ability to capture very large samples is enhanced by the use of ADL as a feature of SGD technology.

Obtaining demographic information on each subject allows for additional data analysis. We can answer a series of questions that can impact usage. Demographic information can be supplemented by medical information (such as hearing, vision, cognitive and dexterity deficiency) related to device use. The more demographic, medical, and education data available, the better we can explain the quantity of usage with multivariate statistical tools.

Demographic data can help to explain variation in the amount of usage associated with age, gender, race, education of user or family, family income, and the availability of contact with other users. Responses to demographic questions may vary depending on whether they are provided by the user or a family member, a caretaker, or a speech-language pathologist. Usage can vary by degree of speech disability because people with minimal ability to be understood will need to use their device more. Usage will increase when the device is also used to keyboard a computer.

Collecting data, therefore, is an essential part of what it means to be a professional in any field. And, it is analysis of the data that can inform future practice. So, it is critical to decide what data is to be collected and how that relates to what is being measured.

In AAC, what we choose to measure is often determined by the goals we are seeking to achieve at any particular point in time (Hill, 2009). A goal such as "will be more communicative" is hard to measure because it is too global. To be more accurate, and more effective, it is usually necessary to have small, explicit targets that can be counted easily. A goal such as "will increase use of prepositions from 3 to 6 over a period of 4 weeks" is much more focused and identifies specific data points that can be scored.

Collecting data is only part of the process that can lead to benefits for an individual using an AAC system. Presenting that data in a format that can be shared among all involved with a client is also important. Whalley (2007) recommends that staff and parents dialogue to develop a shared conceptual framework and common terminology. Shared language facilitates discussion of the ways to improve a child's learning and effective intervention to support and extend a child's learning. Graphical representations can help to provide a "common terminology" by transforming complex log files into easily understood formats.

Privacy Concerns

Collecting data is a feature of the clinical process that has existed within professions prior to the use of computer-based technology. Long before having the option to store data on mobile devices or web-based servers, clinicians would write down evaluations and test results and then lock them away in physical filing cabinets, sharing the information only with professional colleagues on a "need-to-know" basis, or perhaps mail them securely using registered mail. Clinician-client confidentiality has always been part of the therapeutic process that has adapted as the ways of collecting and storing information have changed. Device-based data logging is not "new" in the sense that it is another way of recording data, but there are processes and procedures that need to be in place to maintain the clinician-client privacy.

One critical first step in the privacy arena is simply to make sure that data logging is a process that is optional and requires client permission before it can be used. This means that if data logging is a feature of a device or app, it should be *off* by default and accessible to the client – or the client's legal representative – so that it can be turned back off at any time. The Prentke Romich Company (PRC) and Saltillo devices have password-protected access to the logging so that clients can lock unauthorized others out of the system. Another way to add extra security is to encrypt the log data at the level of the device and/or at the level of the server to which log files are uploaded.

The Realize Language system includes password-protected access to the website so that only legitimate account holders can access the client data. Furthermore, the server owners cannot access those passwords, which is a security measure included to prevent even individuals within the Realize Language support and development team from seeing individual data collections.

Automated Data Logging

ADL is a feature of some SGDs. Such data can tell clinicians how well a client uses a device, and more importantly, how effective the client communicates. There are limitations to the data, which include:

- absence of input from communication partners;
- absence of any multi-modal elements;
- absence of social/geographical context; and,
- lack of information about teaching interventions that may be present, e.g. on-device modeling.

Even with these limitations the resulting information can be useful. For example, one simple measure of AAC use is to count words used, which can give an idea of an individual's knowledge of the lexicon available to them in their AAC system. Another measure is the time period between linguistic events to estimate communication rate. A third is to look at the types of words being used to determine the spread of different parts of speech.

One challenge with machine-logged data is that, in its raw form, it can be difficult to interpret. It is possible to use manual and semi-automated systems such as SALT: The Systematic Analysis of Language Transcripts (Miller & Chapman, 1983), AQUA: Augmented Communication Quantitative Analysis (Lesher et al., 2000), PERT: Performance Reporting Tool (Romich, Hill, Seagull, Ahmad, Strecker, & Gotla, 2003), and QUAD: Quick AAC Developmental Profile (Cross, 2010) to convert such raw data into more user-friendly formats. SALT is a manually intensive system in regard to data collection. Language samples have to be recorded, transcribed, and then entered into the SALT software. Once there, the system uses a number of different comparison databases against which the client's sample can be matched. AQUA and PERT also require some degree of manual parsing, but they are much better for data collection because they both use ADL. The file formats differ (see Figure 1 and Table 1), so each requires a different piece of software to help with the final analysis. The QUAD is basically a series of checklists and, as its name suggests, it is designed to provide a quick profile and does not have any software associated with it.

In a previous presentation, Cross (2013) demonstrated a web-based automated data analysis software that had been in beta testing for nine months. The system allowed for the uploading of a log file to a secure server, where it was parsed in a number of ways in order to present summary data in the form of a visual dashboard. Since then, the development team has made significant changes to the user interface and modified the underlying database to make it more accurate. The online tool is now called the Realize Language system and the server on which it is housed is referred to as the Realize Language server. The current version allows for data to be analyzed in terms of word frequency, parts of speech, performance against target vocabulary, and daily/weekly/monthly device use. It is also possible to search for specific instances of words and to see them in context.

The system includes the capability to match the words used by the client against a default target list of 300 high frequency words created from a number of AAC vocabulary studies, or to import any other vocabulary list as a target set.

Automated Data Log Format

Lesher et al. (2000) specified a set of fundamental events that could be tracked using ADL:

- Time: A timestamp can mark the exact time at which an event took place.
- Output: This primarily refers to any text generated by the person using an AAC device.
- Action: As well as seeing textual output, non-text events such as key presses, mouse clicks, and page changes can be tracked.
- Input: A marker to show the input method a client may be using to generate text and actions.
- Type: A marker to indicate whether the action was a character, numeral, shift key, control key, etc.
- Context: Information that immediately *precedes* an entry and which therefore enhances or refines the current meaning.
- Page: The name of the page on which an action was taken or word generated.

Figure 1 illustrates logged data from IMPACT software that was available on Enkidu products.

```
TIME              Absolute time
OUTPUT            Text output
TYPE              Type of selected element
ACTION            Selection action
CONTEXT           Local context
Time: 12:10:39 09/29/1999

$$$ End Header (and begin Body)

12:10:41.0  ""      Shift      key_shift  ""
12:10:42.7  "The "  List       key_f1     ""
12:10:43.8  "b"     Character  key_b      "The "
12:10:45.4  "est "  List       key_f3     "The b"
12:10:46.5  "t"     Character  key_t      "The best "
12:10:47.8  "h"     Character  key_h      "The best t"
12:10:49.2  "i"     Character  key_i      "The best th"
12:10:50.9  "ng "   List       key_f2     "The best thi"

$$$ End Body (and begin Analysis)

Time: 12:10:53 09/29/1999
Output: "The best thing "
Characters: 15
Words: 3
Characters/word: 5.00 (4.00)
Keystrokes/character: 0.47
```

Figure 1. Example log file from Enkidu IMPACT software. Source: Lesher, G. W., Moulton, B. J., Rinkus, G., & Higginbotham, D. J. (2000). *A Universal Logging Format for Augmentative Communication*, p.4. Paper presented at the 2000 CSUN Conference, Los Angeles.

Subsequent AAC devices have included data logging capabilities, although there are variations in the exact formatting because of the need to track features and functions that might be specific to certain technologies. For example, in devices created by PRC, logged data is stored as a LAM file. LAM stands for "language activity monitor" but this is really just a proprietary label for the more generic label of ADL – automated data log. In a PRC device, word strings can be generated using *sequences* of icons rather than specific pages, so there is a need to track that a sequence is being used as opposed to, say, a word on a page or a spelled word. Thus, in a PRC log file, one of the 'Type' markers is the 3-letter code SEM to mark that a word was generated using a sequence. The SEM code is for "Semantic Compaction" and means that the item was stored using a sequence of keys rather than just a single key on a page; the code SPE represents "SPElling" and means the item is a letter key; and, WPR stands for "Word Prediction," meaning the item was chosen from a list of words generated by spelling in the first few letters of the words. Table 1 is an example of how a PRC data log file looks:

Table 1: *Example of Prentke Romich Company data log format.*

Time	Type	Output
17:41:42	SEM	"she "
17:42:17	SEM	"talk "
17:42:28	SEM	"s "
17:43:06	SEM	"to "
17:43:22	SEM	"me "
17:43:31	SEM	"like "
17:44:10	SEM	"a "
17:44:15	SPE	"g"
17:44:17	SPE	"r"
17:44:19	SPE	"o"
17:44:25	WPR	"grown "
17:44:37	SEM	"up"

The Realize Language system was designed primarily to work with the Prentke Romich Company format but in such a way as potentially to allow it to work with data log files created by other devices. The Realize Language system focuses on three aspects of a log file -- time, output, and type. So, if a log file from other sources includes such data, it is theoretically possible to "filter" any file and recreate it in a format that the Realize Language server can analyze. It is now possible to upload and analyze log files not only from PRC products, but also from Saltillo NovaChat devices, and the *TouchChat* and *Words For Life* apps for the Apple iPad. Each of these has different types of information being logged but the RealizeLanguage server can extract time, output, and type data to perform analyses.

The Realize Language Database

To provide a large corpus against which client-generated utterance could be matched, the Corpus of Contemporary America English (Davies, 2008) was used. This was chosen not only because it provides a very large database – far larger than any currently available in the field of AAC – but, also because it includes frequency data and grammatical tagging based on the Constituent Likelihood Automatic Word-tagging System (CLAWS) (Garside, 1987). Both word frequency and syntax (mainly in the area of morphology) are important pieces of information when monitoring the performance of an aided communicator (Binger, 2008; Binger & Light, 2008). Furthermore, such information can help in the development of educational and clinical intervention programs (Cross, 2013).

Lemmatization means that words such as *eating* and *ate* are not just tagged as two separate strings but also as variations of the underlying root verb, <EAT>. This can provide a level of analysis that has implications for the teaching of vocabulary as *word sets* rather than individual lexical items. For example, if a client demonstrates the use of *jump*, *jumps*, *jumped*, *walks*, and *walking*, teaching *jumping* and *walked* to "complete the set" would make linguistic sense. At present, the Realize Language system does not make any significant use of this information, except for using it in conjunction with frequency data to create something called a "smart part of speech (SmartPOS)." This is used to assign a single part of speech to a word that can exist in multiple parts of speech. For example, if a client-generated data log contains the word *blue*, the word itself has many different meanings and could be an adjective, noun, adverb, or verb. For human interpreters, context is what determines the meaning and part of speech, but the Realize Language system is currently not sophisticated enough to do this, so it uses frequency data based on lemmas to assign such multi-meaning words to the most frequent category. See Table 2.

Table 2. *Database representation of the word* blue

Word String	Lemma	Part-of-Speech	Frequency	SmartPOS
blue	blue	ADJECTIVE	54736	ADJECTIVE
blue	blue	NOUN	4006	ADJECTIVE
blue	blue	VERB	41	ADJECTIVE

In the case of *blue*, it is treated as an adjective. In the future, being able to make use of adjacent strings to help determine part of speech is certainly algorithmically possible but such a feature will take some time to develop.

Another major purpose of the database is to provide a reference for determining whether strings generated in a data-log file are "real" words. So the strings *polysemous*, *stipends*, and *unlikelihood* would all be recognized as words by the Realize Language system but strings such a **ploysemus*, **stiipend*, and **unliklyhood* would be flagged as "unknown." This ability to draw a distinction between known and unknown words can be leveraged by the Realize Language system to provide useful data. This will be discussed in more detail in the section headed "List Widget."

A final point about the database is that it can be replaced by any other non-English database to make the Realize Language system available across languages. An earlier beta version was designed to work in German as well as English, and work already is underway to deploy databases that will allow for the analysis of data logs in German and Spanish.

Graphical Representations and Analytical Widgets

A design goal of the Realize Language system was to take text-based data logs and turn them into more easily comprehended graphical representations collected as "widgets" on themed "pages." See Table 3 below for a list of the different widgets available and the function of each. These representations could then be used as a starting point for more detailed discussions among stakeholders. During beta testing of the system, parents who were using the Realize site found that seeing the data graphically as opposed to a native TXT data log file made it possible to talk with therapists and teachers about what their child was doing and ask more questions. As mentioned earlier, there are inherent limitations with using ADL such that simply looking at the data on its own can be counterproductive, but the purpose of the Realize Language approach is not to provide stakeholders with all the answers but to help them ask better questions.

Table 3: *Pages, Widgets, and Functions of the Realize Graphical Interfaces*

Page	***Widget***	***Function***
Overview	Words	A Word Cloud of the words used during the current week from Sunday to Saturday, and links to Words page.
	Use	A vertical Bar Chart of how much the AAC device has been used during the current week, and links to the Use page.
	Analysis	A horizontal Bar Chart showing the frequency of use of words by Part-of-Speech during the current week, and links to Analysis page.
	Log	A Calendar showing every 15-minute period in which the device was used during the current week, and links to Log page.
Use	Daily	A vertical Bar Chart summing every 15-minute period in which the device was used on any day chosen using the Date Range selector.
	Weekly	A vertical Bar Chart summing every 15-minute period in which the device was used for any week chosen using the Date Range selector.
	Monthly	A vertical Bar Chart summing every 15-minute period in which the device was used during any month chosen using the Date Range selector.
Words	Cloud	A Word Cloud showing the most frequently used words during any time period set by the Date Range selector.
	Top 10	A horizontal Bar Chart of the 10 most frequently used words used during any time period set by the Date Range selector.
	A-Z	An alphabetized list of all the different words used during any time period set by the Date Range selector.
	List	A frequency-order listing of known (words in the database) and non-words, as well as words generated as pre-stored items versus those spelled out letter by letter.
Log	Week	A Calendar showing 15-minute periods where the device is used during any week set by the Date Range selector.
	Month	A Calendar showing 15-minute periods where the device is used during any week set by the Date Range selector.

Page	***Widget***	***Function***
Analysis	Parts of Speech	A horizontal Bar Chart showing Parts of Speech by frequency for ant time period set by the Date Range selector.
	Word Groups	An alphabetized display of words used by the client from a Target List of words set using the Manage Goals widget.
	Manage Goals	An alphabetized list of targeted words set by choosing a Goal List from a drop-down menu, or by creating a customized list based on Individualized Educational Program (IEP) vocabulary goals.
Reports		A list of all reports and graphics generated using the Generate Reports tool.

Examples of Graphical Representations on the Realize Language Server

When analyzing data on the Realize Language server, the person performing the analysis can set the time period using a function called "Date Range." This allows the user to set a start date and an end date, and then all the subsequent analyses will focus on that period. In the examples that follow, the date range was set to May 3 to May 9, 2015, and the graphics were generated using a feature called "Generate Report," which enables users to click on a button to create a PNG file of the graphical representation that is currently on screen. Not all the widgets available are included, just a selection of some of the more popular ones.

Word Cloud Widget

Being able to see the words a client has used during a specific time period as a cloud is popular among parents who use the Realize Language system. What it does is show the most frequently used words, with the font size enlarged to indicate increased frequency of word use. In Figure 2, the word *I* appears as the largest with the words *to*, *now*, and *it* coming close behind, demonstrating that the word *I* is the most frequently used word.

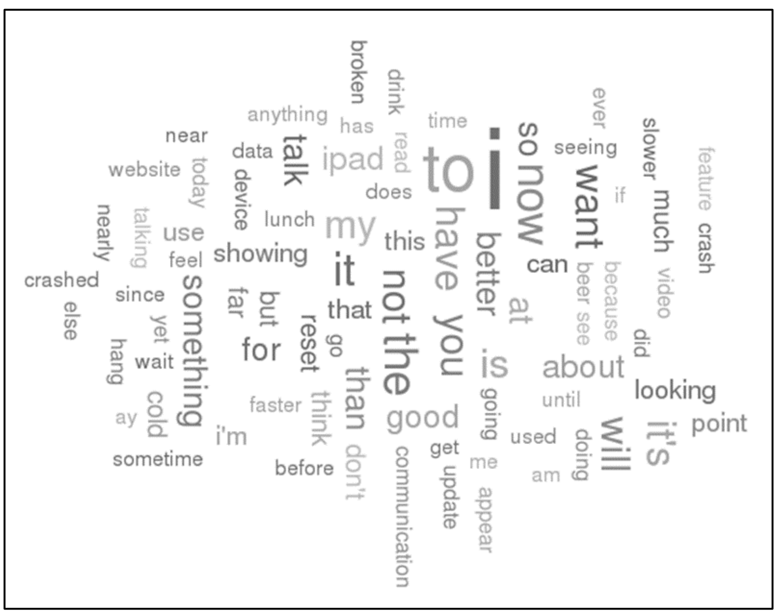

Figure 2. Word Cloud for May 3-9, 2015.

A secondary value of the cloud representation is that it can be used as a physical reinforcement tool with younger clients. Having a simple piece of paper that can be handled, shared, and referenced provides motivation and a sense of achievement. Parents using the Realize Language server have used the cloud graphic as a discussion starter with other people involved in their child's teaching. It can function as a simple way to represent the vocabulary a client is using as well as how frequently words are being used.

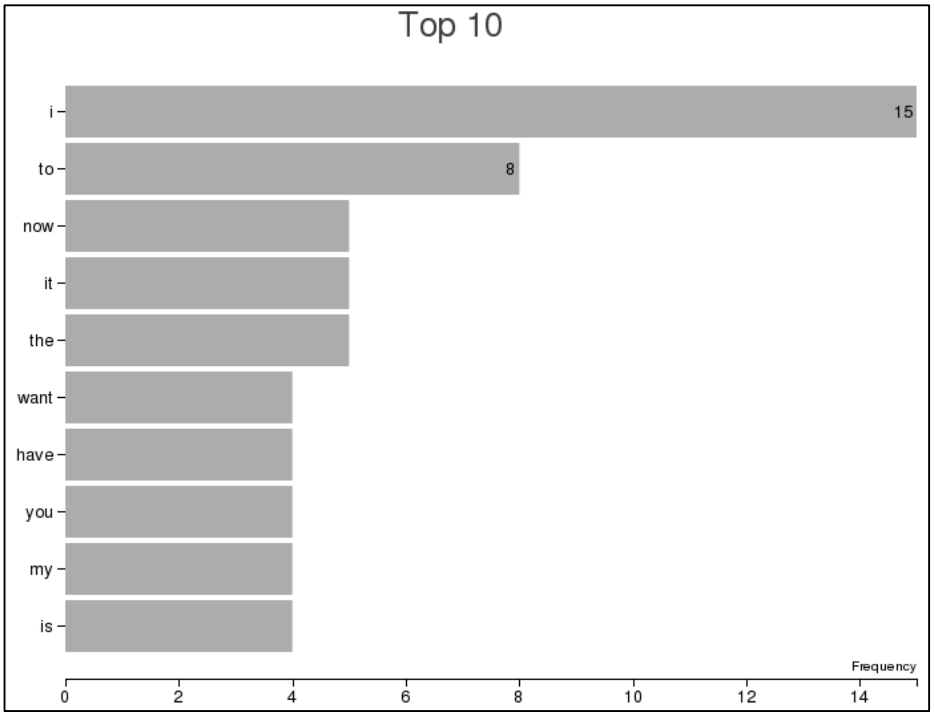

Figure 3: The 10 most frequently used words for May 3-9, 2015.

Top 10 Widget

The Top 10 takes the Word Cloud data to the next level by quantifying the 10 most frequently used words. See Figure 3

The distribution of the words by frequency in this Top 10 approximates what one would expect to find with many AAC vocabulary lists (e.g., Boenisch & Soto, 2015; Clendon, Sturm, & Cali, 2013; Trembath, Balandin, & Togher, 2007) and non-AAC lists (e.g., Brezina & Gablasova, 2013; Lo Bianco, Scull, & Ives, 2008). However, if there had been an unexpected word in the list, this would have been an opportunity to go back to the log data and look at the context in which it appeared and to investigate when and where the exchange took place to see why the word had such a high frequency. For example, during the beta test period for the Realize Language system, one client had a Top 10 list with the word *yogurt*, a word that is not found often in AAC word lists and that scores very low in any large frequency lists. By looking in more detail at when *yogurt* was used, it was apparent that the SGD was only being used at mealtimes and that this was a favorite food. On the basis of this, the need to make the device more accessible outside of mealtimes was identified.

A-Z Widget

Increasing an individual's vocabulary size and use thereof is a common goal in AAC intervention. Being able to track changes in vocabulary use is therefore a vital measure.

The A-Z widget on the Realize Language server can be used to show a sample of current vocabulary use, which can then be used to compare against a later sample. Figure 4 shows all the different words used during the May 3-9 time period.

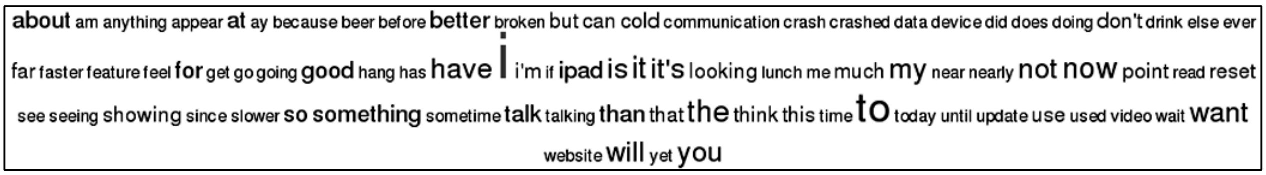

Figure 4: Total different words used for May 3-9, 2015.

List Widget

For clients who are literate, or developing literacy, the List widget provides the facility to see which words have been generated by spelling versus those generated as whole strings that have been pre-stored. Figure 5 illustrates how setting parameters of "Known" and "Spelled" will produce a list of all the words that it recognizes as being real words (i.e., words that are in the system's database) and that have been spelled out.

Notice that the list also includes the frequency with which words have been spelled. At present, one limitation with the system is that words generated by using a Word Prediction feature are counted simply as "pre-stored" words. In a future revision of the analytical software, the aim is to be able to count such predicted words as a separate category along with "Pre-stored" and "Spelled."

Figure 5. Words that were spelled out letter-by-letter during May 3-9, 2015.

Manage Goals and Word Groups Widgets

When working with individuals to help develop their use of vocabulary, it is not uncommon for clinicians and educators to set up specific goals and to develop a set of vocabulary targets as a word list. Text-based word lists can be uploaded to the Realize Language system and used to track when and how often these occur in a client's data log. The Manage Goals widget is where you can input a list and then monitor a client's performance against this list using the Word Groups widget. For example, in Figure 6 there is a customized list of 100 target words.

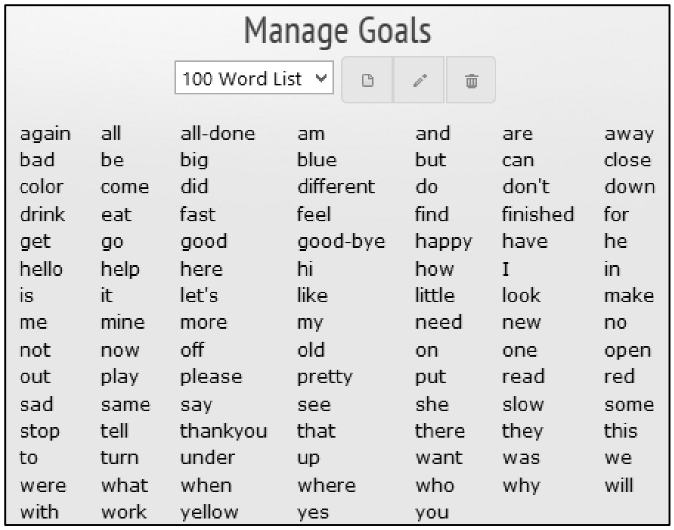

Figure 6. Goal list of 100 words

The box marked "100 Word List" is actually a drop down selection and multiple lists can be stored in the system. The key point is that at any one time the user can have a single goal list that works in conjunction with the Word Groups widget. Once the user has selected a Manage Goals list, he/she can switch to Word Groups to see how closely a client is following that list. See Figure 7.

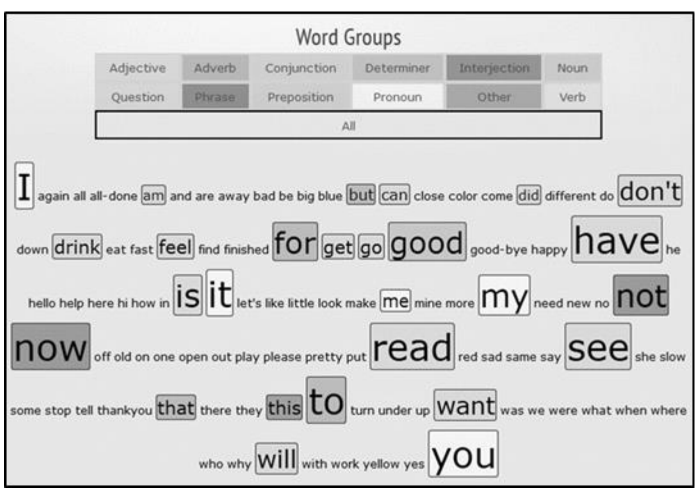

Figure 7. Client use of target words as set in the Manage Goals widget.

In Figure 7, any word that has been outlined in a box has been used in the data log file, and the size of the box relates to relative frequency of use. So the words *now*, *read*, and *have* appear to have been used most frequently. The words are also color-coded by part of speech and clicking on any of the buttons at the top will isolate those words, e.g. clicking on the ADJECTIVE button will show only instances of adjectives.

Example Case Study: Tom

For the purpose of illustrating how the Realize Language tools can be used for specific clients, consider the case of Tom, an ambulant 7-year-old boy with cerebral palsy who has moderate to severe learning problems. He had been using a Prentke Romich Vantage device for three months and was still in the early stages of using the device when beta testing the system. Data logging was enabled for a one-month period between October and November 2014. What follows are observations and comments based on that sample period, split into four weekly periods for the purpose of illustrating changes over time. See Table 4. Specifically, the focus will be on the behavior of four words: *circle*, *I*, *that*, and *want*.

Period	Date
Week 1	10/19 – 10/25
Week 2	10/26 – 11/02
Week 3	11/03 – 11/10
Week 4	11/11 – 11/18

Table 4: *Sample periods for data log analyses*

A-Z Analysis

The A-Z Widget not only lists all the different word types used during a sample period, but also presents the most frequently used one in a larger font. "Type" refers to a distinct string of letters that makes up a word, which contrasts with "token" that is used to indicate the number of times a type is used. For example, in the sentence "I think that I should have finished that paper earlier" there are eight types and 10 tokens, with the types 'I' and 'that' being used twice. The A-Z widget shows the number of different words types used each week. See Figure 8.

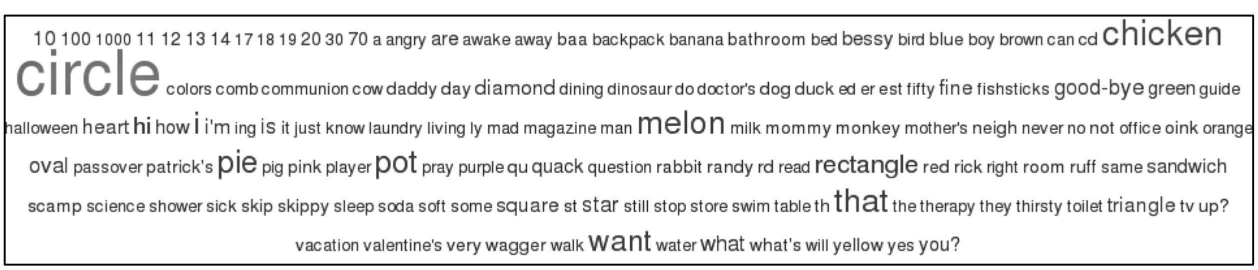

Figure 8. A-Z for Week 1

Period	Date	Word Types
Week 1	10/19 – 10/25	128
Week 2	10/26 – 11/02	164
Week 3	11/03 – 11/10	231
Week 4	11/11 – 11/18	179

Table 5: *Word types by week*

The results for the four-week period are summarized in Table 5.

During the logging period, all of Tom's team was aware that his device use was being tracked and so efforts were made by all to encourage communication activity. From Week 1 to Week 3 there was an increase in the number of different word types being used with a drop in Week 4. One of the possible reasons for this was that Tom's device was not used on 11/18 and so there was a day without logging.

Word type measures can give an indication of how broad a client's lexicon might be but knowing more about the frequency of use of these words is much more useful. So to look in more detail at this, the List widget can be used.

List Analysis

The List widget (see Figure 9) supplies frequency data for the word types and thus provides more information about vocabulary use.

151 circle	10 sandwich	2 cd	1 boy	1 soft
59 chicken	9 how	2 daddy	1 they	1 question
51 melon	8 green	2 yellow	1 a	1 soda
51 that	6 blue	1 guide	1 swim	1 fishsticks
47 pot	5 it	1 milk	1 stop	1 sleep
47 pie	5 skip	1 awake	1 never	1 backpack
44 i	5 mommy	1 shower	1 away	1 brown
43 want	4 randy	1 dinosaur	1 just	1 banana
26 rectangle	4 day	1 cow	1 still	1 purple
21 hi	4 scamp	1 pig	1 right	1 science
19 good-bye	3 neigh	1 walk	1 can	1 man
18 star	3 what's	1 bird	1 fifty	1 the
17 oval	3 red	1 bed	1 know	1 water
16 is	3 pink	1 halloween	1 vacation	1 magazine
15 what	2 tv	1 same	1 some	1 comb
14 i'm	2 bathroom	1 office	1 thirsty	1 no
14 fine	2 duck	1 toilet	1 passover	1 do
14 square	2 monkey	1 living	1 orange	1 table
13 triangle	2 rabbit	1 dining	1 colors	1 will
12 diamond	2 dog	1 store	1 player	1 pray
11 heart	2 room	1 laundry	1 mad	1 communion
10 are	2 very	1 read	1 sick	1 yes
10 quack	2 not	1 therapy	1 angry	

Figure 9: List of words used during Week 1

The most frequently used word is *circle* followed by *chicken* and *melon*. The high frequency words *that*, *I*, *want*, *is*, and *what* come further down the list. Notice that *pot* and *pie* have the same frequency and that suggests they are actually used as the compound *pot pie*. It is possible to check this using the "Find Words" feature of the Log page.

By using the List widget to see the data for Weeks 2 through 4, it becomes apparent that the word *circle* is the highest frequency word used throughout all weeks. In general, *circle* is a low frequency word and therefore it is unusual to see it being used so often. The Log page provides more information about how and where it is being used.

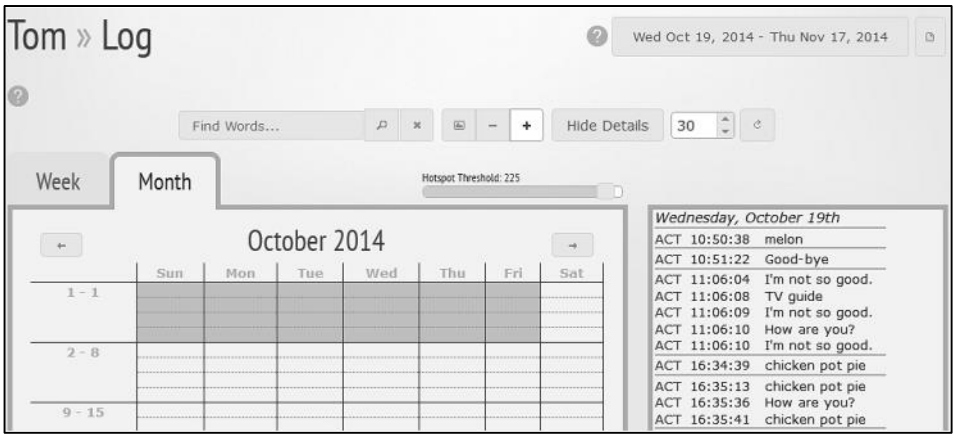

Figure 10: The Log Page

Log Page Analysis

The Log page is a multi-functional tool that can be used to see when a device is being used and what is being said within a context. It is also includes a "Find word" feature so you can see where specific words and phrases occur. Figure 10 indicates that the "Month" tab has been selected to display device use during a single month. The "Week" tab allows the user to switch to a more detailed breakdown of use in 15-minute intervals. On the top right the time range that is currently being analyzed (in this case, the entire sample from 10/19 to 11/17) is displayed, and it can be changed to analyze shorter periods.

The column on the right shows each language event along with a time stamp. This example shows how *pot* and *pie* are yoked as part of the compound phrase "chicken pot pie" and this confirms the earlier suspicions of how they were being used.

The other word about which we were curious was *circle*, and by typing the word into the box marked "Find Words" the system will mark each time period during which it was used with a small black dot. See Figure 11.

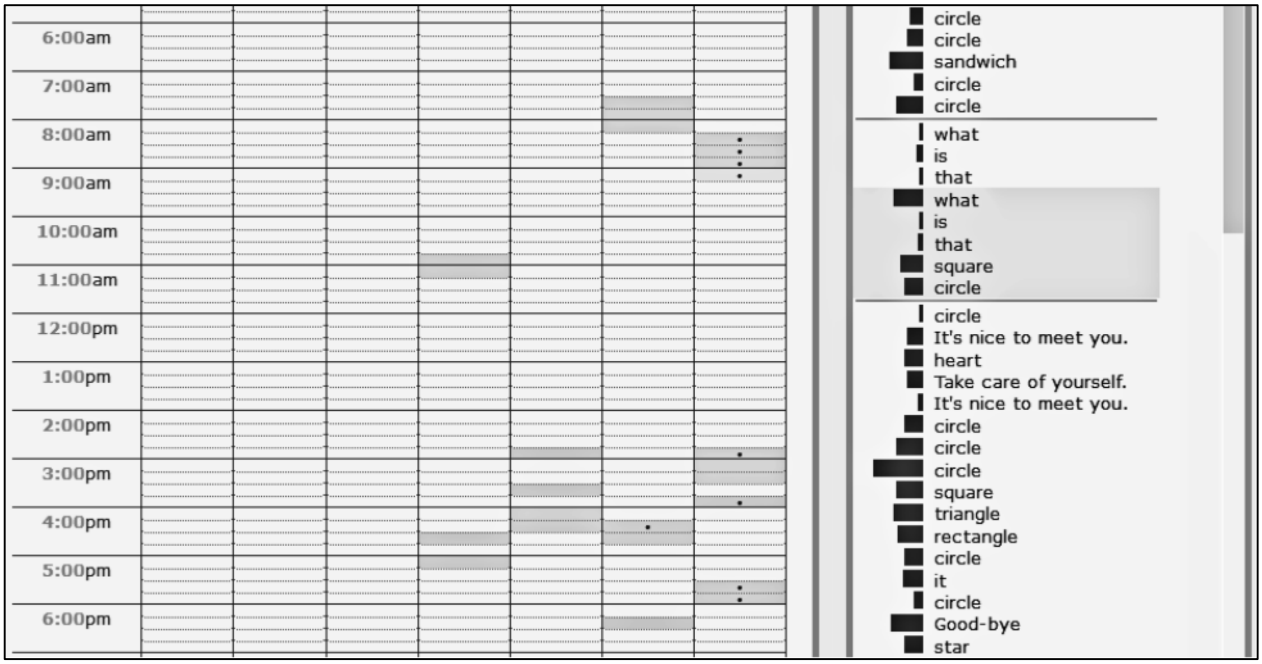

Figure 11: Occurrences of *circle* during Week 1

The word *circle* appears to have been used predominantly on Saturday and repetitively, as the log in the column on the right shows. Its appearance in the Top Ten was seen as being unusual when compared with the low frequency of *circle* in any vocabulary lists used in AAC, or even outside of AAC. Looking through all the instances of when *circle* was used, it seemed to be a perseverative behavior not based on any specific communication need.

Based on the overuse of the word *circle*, one of the behavioral targets Tom's team decided to focus on was to reduce the overall frequency of its use by promoting more use of the words *I*, *want*, and *that*. One simple way to track this was by using the Top Ten.

Top Ten Analysis

Comparing the Top Ten widget week by week, it is possible to see how promoting the three target words affects the positioning of these relative to others. See Figure 12.

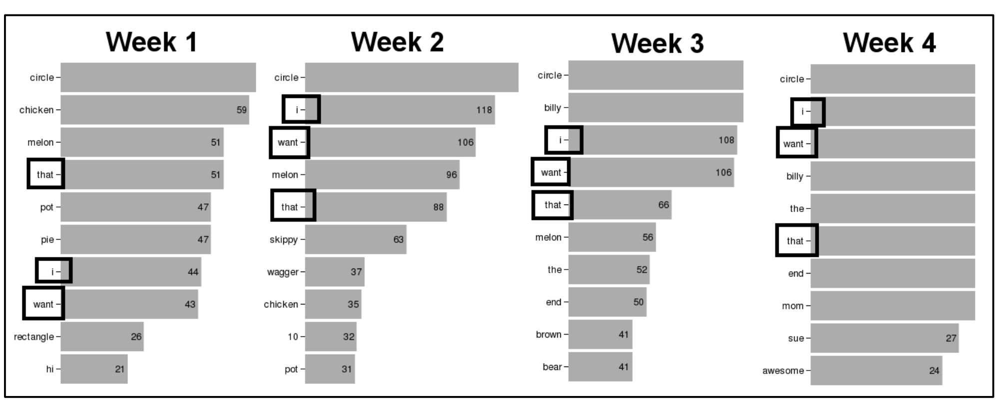

Figure 12: Relative frequencies of target words over four weeks

Note that the word *circle* is still at the top of the list but the aim is to reduce its frequency over time. If the frequency of the words *circle*, *I*, *want*, and *that* are plotted as percentages of the top ten words, a trend emerges over the month. See Figure 13.

This graphing capability is *not* a feature of the Realize Language system but it is relatively simple to extract the data from the Top Ten widget and create the chart in Figure 13.

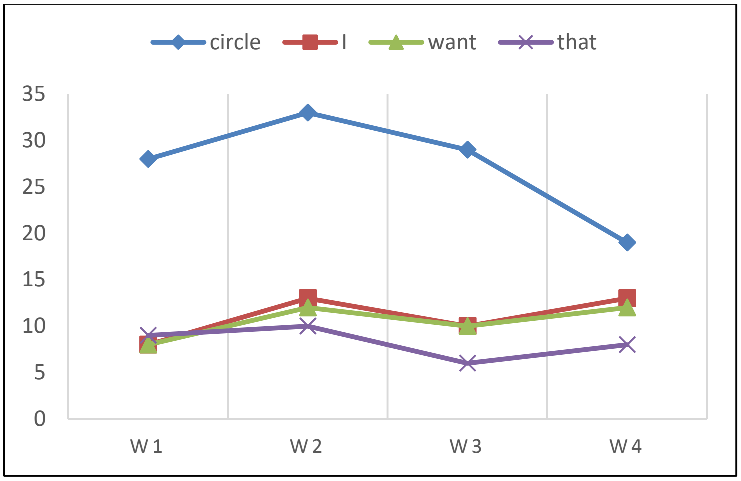

Figure 13: Target words as percentages of the top ten words

Case Study: Summary

This example has focused very specifically on just four words, and the decision to choose these words came from the first week of data logging when the team could see how Tom was using words. Furthermore, there is no "right way" to use the Realize Language analytical tools because each client will produce very different patterns of vocabulary production. In Tom's case, as he is non-literate, there was no need to use the List widget to investigate spelling; all the words he used were already pre-programmed into his device. This includes the names of friends, family, and pets. Nor did this analysis make use of the "Manage Goals" and "Word Groups" widgets to track performance against a target vocabulary list because the team had identified a measurable goal (decrease in the use of *circle* with a concomitant increase in the use of *I*, *that*, and *want*) that could be tracked using just the Top Ten widget.

Change over a four-week period is likely to be very small with clients who have significant learning challenges, but for clients such as Tom, the value of the Realize Language tool is that all the data collected during this sampling period will always be available and in the months to come can provide the team with a reference point for future measurement. And, as Tom continues to use his device, all the data logged is added to create a large cumulative sample that can map his progress for years.

General Discussion

The Realize Language system is the first step in a journey to create visual tools for data analysis. In this first iteration, the focus has been primarily on the development of a database and a framework for the creation of special tools. With this in place, new tools can be added based on specific requests and needs. For example, there are currently two significant tools that have been requested. The first is for one that allows for the calculation of mean length of utterance (MLU) scores, a measure that is often used by researchers and speech pathologists. The challenge in doing this is that an automated MLU analysis is very difficult because MLU calculation requires knowing when a sentence starts and when a sentence ends – a task that humans can do much more easily than computer code. Current language analysis software that provides MLU scores still requires someone to manually mark sentences before a calculation can be made. The second request is for a tool to filter out any data that may have been modeled by a third-party helper. Often in a therapy session a clinician may model a specific vocabulary item, phrase, or sentence, then wait for the individual using the device to imitate. This is certainly a legitimate teaching strategy, but the AAC device has no way of knowing who is making selections. Currently the simplest solution that practitioners have used is to turn the data logging feature OFF during teaching sessions, but they then must remember to turn it back ON or risk losing new data. Ideally, there should be ways for the log to be able to be tagged when modeling is taking place, coupled with a filtering function at the Realize Language server that can then ignore these when performing any analyses using the widgets. Both the tool for calculating MLU and filtering modeling are good examples of how the system as a whole could be improved.

There are certainly challenges in both modifying the data log parameters and then modifying the server software to interpret these. But all systems are constantly in a state of change and the process of improving and expanding the features of the Realize Language system is part of the normal challenge of creating a sustainable product, for without sustainability, any service will simply become moribund and unusable. Nevertheless, despite these – and other – recognized limitations, there are still sound benefits that can come from using the system as it is.

Outcomes and Benefits

The successful development of a robust vocabulary for an individual using a SGD can be enhanced by the measurement of actual device use. Such data also may be employed to look at the patterns of use, for example, when a device is used for speech communication versus its use as an alternative keyboard for text generation, such as in writing emails, sending text messages, or creating articles. Automated data logging allows for large data samples to be collected over long periods, which can in turn help to show change or lack of change. The Realize Language system provides people who use AAC devices and their support teams with a highly visual way of representing logged data that lends itself to providing a springboard for discussions about client performance.

Another benefit is that the use of graphical representations makes it easier to share information among support staff who are not language or AT professionals. Even teachers tasked with supporting children with AAC needs may have had no training in how to do this or be unfamiliar with assistive technology (Alper & Raharinirina, 2006; Van Laarhoven, Munk, Lynch, Bosma, & Rouse, 2007). The graphics are an attempt to create a common language that all involved can understand.

Finally, it is worth noting that a non-technological benefit of using simpler graphical representations is that it encourages more dialogue among shareholders about the nature and interpretation of the data. During the beta-testing period, it was noted that parents who took an active role in tracking data felt much more empowered to discuss what they were seeing with other members of their child's support team. They felt they did not have to rely on a "specialist" to provide all the answers, but could take a more equal part in determining future goals for their child.

As one of beta testers said, "What an incredible help Realize has been for my child. I can't wait to share the program with his IEP Team at his school." And as a result of this enthusiasm, she was able to attend her child's IEP meeting along with printouts from the Realize Language data and work with the team to develop some "next steps."

Declarations

The content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. The author Russell Thomas Cross disclosed a financial relationship as an empoloyee with Prentke Romich Company and no non-financial relationships. The author Dr. Bob Segalman disclosed no financial and no non-financial relationships.

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Measuring Assistive Technology Outcomes: A User Centered Approach

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Abstract

Individuals with disabilities may require mounting systems that provide access to devices they want to use (e.g., a communication device) within reach while they engage in their daily routine. The Mount'n Mover is such a system and was developed with the assistance of users. The purpose of this paper is to demonstrate the benefit of involving users throughout the design and use of an assistive technology (AT) device when evaluating AT outcomes. User involvement in the design process is described and then a retrospective study investigating outcomes is presented, and suggestions for a more rigorous research methodology are provided. This holistic approach to outcomes study suggests that involving users in the entire process can help to ensure that product features relevant to users' functional needs are designed into AT solutions.

Keywords: assistive technology, outcomes, user centered design

Introduction

Assistive technology (AT) professionals are familiar with the challenges of providing evidence to support the efficacy of AT interventions that are available for people with disabilities. Emphasis on documenting outcomes using randomized control studies (considered the gold standard for documenting evidence in a medical model arena), lack of a unified theory guiding systematic research in the field of AT, and inconsistent involvement of all stakeholders are cited as some of the barriers to providing the evidence that is increasingly required by funders in a fiscally constrained environment (Clayback et al., 2014). Consistent with the focus of this journal, and in particular this special edition of the journal focused on "Meeting the Evidence Challenge," this paper describes a collaboration between BlueSky Designs, the developers of the Mount'n Mover and independent researchers at Ithaca College. The first part of the article provides specific details of the user-informed design process which led to the development of the Mount'n Mover. The second part of the paper provides useful product feedback from a small sample of users who responded to reliable and valid outcomes measures and provides suggestions for more empirically sound methods of measuring the impact of consumer involvement in the design process. The paper concludes with a section describing what can be learned regarding the benefits of user input during the design process by using outcomes assessment.

BlueSky Designs Perspective

This section of the paper addresses one company's approach to the development of a new mounting system which attaches various devices such as speech devices, laptops, tablets trays and phones to wheelchairs, beds and tables. Prior to this development project, the founder of BlueSky Designs had worked as a rehabilitation engineer, developing custom solutions for individuals with disabilities. Her approach to product development reflects a rehabilitation engineer's approach to identifying a solution for an individual. First, clearly identify a person's needs and goals. Next, consider whether commercial products address those needs. If it is determined that available technology falls short or does not exist, work with the person to determine the ideal solution. As the design progresses, test it with the person and revise it until you are both satisfied. This approach of involving users is consistent with approaches that are increasingly emphasized by many who engage in product design (ideo.org, n.d.; usability.org, n.d.).

The product development process is similar, but it broadens the scope of audience for the product, and how it will be used. The designer is not only designing for a broad range of end users, but also for family members, attendants, therapists, and AT professionals, and therefore needs their input as well. The design process is iterative and must consider how it will be manufactured, what the cost will be, and how it is distributed and installed. Review sessions by various stakeholders are built into the development plan, in which prototypes are presented to test the form and function. The process continues until users of all types test functional prototypes and are clearly satisfied.

Identifying the Need for a Movable Mount (Pre-R&D effort)

The identification of the diverse needs and the idea for a customizable movable mount came from working as a rehabilitation engineer who was developing custom mounting and positioning solutions for speech devices to meet job accommodations. Existing mounts did not meet the needs of many clients, especially those for whom independence was critical, such as college students or people who worked. Custom solutions often involved movable mounts for tables, wheelchairs, or recliners or beds, such as: a table-mounted phone stand which could easily swing between work areas; rotating turntables to bring different objects within reach; stands with adjustable angles for books, devices or papers; retractable keyboard and laptop trays; a stand attached to an ergonomic chair for a court reporter; and a downward-facing book support that hovered above a person in bed.

Shortcomings of existing mounts (at the time of development):

- Only one operating position:
    - What if the user needs to move the speech device to eat or work, but still needs it within reach, in a usable position?
- Cannot be moved out of the way for independent transfers:
    - A person has to choose between communicating or independent toileting.
- Must be removed for transfers, toileting or pulling up to a table:
    - The person is dependent on others.
    - In restrooms, the user must choose between placing the device and mount in the sink or on the floor.
    - The user is then unable to speak during meals or at work.
- Once removed, most rigid mounts are cumbersome and hard to handle.
- If existing swing-away mounts are swung out of the way:
    - They are not usable (the screen does not face the person)
    - They present a tipping hazard if it is a manual chair (Lange, 1999)
- Armrest-attached trays (another alternative) are confining and carry a stigma.

Client goals <u>unmet</u> by other mounts or trays:

- Use more than one thing concurrently (i.e., book/laptop; tablet/phone)
- Easily and independently reposition a device
- Use it from more than one position (in front, to the side)
- Change devices easily
- Adjust tilt angle for glare, or visual access (for driving, watching television)
- Move it (safely) for transfers
- Repeatable positioning: Move it easily but return to the same secure position

Predecessors to the Mount'n Mover

The case studies below describe clients whose needs and goals were addressed by a movable mount. Their need for a device to be mounted had been met with existing mounts, but the mounts restricted them from achieving other critical goals.

Case 1: LB's school team and her vocational counselor wanted to remove barriers to her education and employment beyond high school. Her vocational goals required that she use a computer workstation. However, her speech device mount kept her from pulling up to the table. If the device was removed, she couldn't communicate. A standard swing-away mount was too difficult for her to operate and it positioned the device such that she could not use it. The idea that she could move her speech device to the side, in a usable position was identified as the optimal solution. A custom, movable mount with two arms and a joint that rotated under the device was designed and supplied. She was able to move it and access it from two positions. No other mounts offered that functionality.

Case 2: An 8-year-old girl with cerebral palsy and her mother wanted her to be able to get out of her chair independently. Then, she could get down on the floor to play, and she could use the toilet herself. At the time, she needed someone to remove her speech device to do this. Even though she had a swing-away mount, when it was swung out in a position from which she could get out of her chair, the weight of the extended device tipped her manual wheelchair. With the custom dual arm system, the device remained closer to the wheelbase and did not present a tipping hazard.

In both cases, the goal of supporting the device (the mount) was important, but there were other equally important goals. The solution, a mount that moved, allowed the two girls to participate more fully in other essential activities. Very importantly, they were no longer reliant on others and could do it when they wanted. The girls' experiences validated the need for and benefits of a movable mount.

The results in the two case studies above motivated the principals at BlueSky Designs to pursue Small Business Innovation Research (SBIR) funding through the National Institute on Disability and Rehabilitation Research and the National Institutes of Health. With SBIR support, BlueSky was able to launch a user-centric research and development effort.

Mount'n Mover Development: User Input in the Development and Testing Process

At various stages of the development process, different types of input were solicited. Sessions were held every 6-9 months, to present new prototypes to testers.

Pre-Focus Group Survey

A pre-focus group survey was used to identify and prioritize consumer priorities and preferences. Questions included which devices they presently mount to their chairs, problems or shortcomings with their existing technology, and the importance of different product attributes. Eleven consumers completed pre-surveys. The consumers were drawn from two organizations, the MS Achievement Center, and Express Yourself Minnesota, a support group for adults who use communication devices.

Of those who completed the survey, the most common devices mounted to the wheelchairs were bags or backpacks (100%), cup holders (91%), trays (45%), and communication devices (45%). Everyone expressed *the need to access multiple devices* from their wheelchair. Individuals rated the importance of twenty factors to consider in a wheelchair mounting system. The top factors, listed in order of importance were durability, proper positioning, wheelchair compatibility, *ability to do other tasks with device in operable position*, device safety, *difficulty moving the device for transfers*, device compatibility, ease of removing the device and mount from the chair, and the effect on the width of the chair. The factors receiving the lowest priority ratings were cost, appearance, and vendor.

In response to questions regarding problems experienced with their existing mounts, 64% reported their mount needed to have frequent adjustment to keep the device in its proper place. Many reported difficulty moving the device out of the way (45%) or back into position (36%). Others reported that devices were not positioned properly to begin with (36%). Only 36% of respondents could move their device out of the way for transfers, yet 64% wanted to be able to do so. Devices were removed from wheelchairs for transfers in 73% of the cases.

Information gathered was incorporated into the design goals and specifications.

Fig 1. Force-testing jig

Phase 1 Focus Groups

In Phase 1, three focus groups were held with different stakeholders, including people who use augmentative and alternative communication systems, people with multiple sclerosis (MS), and professionals who address mounting needs. Early stage prototypes were demonstrated, as were existing mounts.

A simple force-adjustable jig was developed to determine force preferences for actuating the lever and moving the mount (Fig. 1). It could be positioned for downward, lateral or upward activation to determine preferences. It was also useful in observing movement patterns required to access and depress a lever. Observation of individuals using and moving mounts was instructive in determining the ease of use, range of motion, strength and dexterity required for our system and others.

Development of Design Criteria Based on User Input

Consumers and professionals answered questions relating to force and actuation requirements to move, lock, and unlock a device mount; lever operating specifications (up, down, or lateral activation); locking characteristics (preset locking positions, ability to customize, and latching in unlocked position); placement of device in use and storage; ability to lock, unlock, tilt, and move a device; and comparison to existing mounts.

Fig.2. Consumers test prototype mounts

The following design preferences and parameters were derived from input from the focus groups and guided prototype development:

- Dual arm configuration preferred because of flexibility in positioning
- Ability to lock into a specific position very important
- Multiple locking positions for operating, secondary, and storage positions
- Able to mount and access more than one device (i.e. book/laptop)
- Ability to customize locking position
- Release should be with a depression, or a lift; choice would be nice
- Tilt should be a lateral release
- One-handed operation
- Able to depress lever and then push the lever to reposition the mount
- Ability to attach and remove devices without tools (quick release)
- Release force and moving force preferred a pound or less
- Some friction desirable so it doesn't move too easily, or too fast
- Able to have either a single or dual arm configuration
- Able to independently adjust tilt
- Changes or additional requirements identified after trial with prototypes included:
- Option to have a non-locking, friction-only version of the joint positioning mechanism
- Latched unlock option to keep it from locking out in inaccessible position
- Post-located lock release option (so release stays in place when mount moves)
- Lock release levers co-located at the device end

User preferences for the arm length, arm shape, actuation method, and shape of the user interfaces were also determined through developing and testing different options.

Fig. 3. Access multiple devices

Technical development and validation

Technical development involves many different methods and processes, ranging from sketches to 3D computer drawings; from hand-fabricated models for the arms and levers to test concepts, sizes and shapes to 3D computer design models; and then to 3D printed models. Only when the design direction was firmly established and proven with the input of consumers and professionals, was a metal machined prototype created. The investment of time and money increased with each step towards locking down the design. User input guided and validated design decisions and provided the confidence needed to further invest in specific directions. One drawback of the research and development project was that sturdy, load-worthy prototypes were not available for extended user testing. Today's prototyping technologies have made this more affordable and this will be possible in future development projects.

Fig. 4. Iterative design: Operating levers

Usability testing of the lock-setter design

Certain design features do not relate to the end user as much as to the individual setting up a mount, so some usability tests focused on the AT professional or family member. The lock-setting procedure is relatively easy once demonstrated, but it is not immediately apparent. A study was conducted for professionals to assess the usability of the mount and to compare the ease of use of two different lock-setting prototypes. Of lock-setting prototypes, subjects reported the Tab Lock was the preferred mount across all three ranking questions (Ease of Operation, Ease of Setting, and Overall Satisfaction), almost unanimously. It was also the fastest to set, based on the timed task. Subjects liked that a tool was not required to set the lock, that a finger or fingernail could be used. They liked the tactile feedback and that it was visually obvious whether it was set to lock. The tab lock was familiar, similar to a dip switch.

Fig. 5. Twistlet Lock

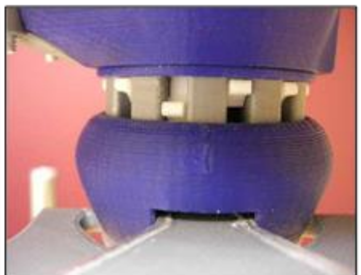

Fig. 6 Tab Lock

Fig 7. Lock setting usability test

Testing of the final prototype

Over 40 individuals, including 25 consumers with disabilities and their family members, and 16 professionals, tested the final metal prototypes. Until this time, the prototypes had not been robust enough to withstand the forces some consumers would exert on it. The results were exceptionally positive, as seen below, especially when satisfaction with their existing mounts was compared with reactions to the Mount'n Mover.

Product testers with disabilities attempted tasks such as moving the arm, rotating the platform, and tilting the device. Many end users, even those with significant disabilities, were able to unlock and move it. A few were unable to, as is to be expected.

It was observed that a number of people who could move the arm had difficulty accessing the tilt handle to unlock it. Once unlocked, many more could change the tilt. Some turned the device to improve the biomechanics, and could then unlock and change it. The tilt handle received the poorest control ratings, so it was modified prior to production.

Results of testing validated the design. 17 consumers, 8 family members and 16 professionals were asked to rate both current mounting systems and the movable mount prototype. When rating the **Positioning Features** of their current systems, they gave negative ratings in 45% of the cases and positive in 45%. No one ranked the movable mount prototype negatively, and 95% gave it positive ratings. Rating results for **Ease of Use** of their current systems resulted in 50% negative and 30% positive. 88% gave the movable mount positive ratings, and 10% gave a neutral rating. The movable prototype received overwhelmingly positive ratings (90%) for **Feeling of Independence**.

Insights based on observation

Through observation, interaction, and surveys, the collective feedback indicated the people testing the mount saw the potential to positively impact a person's independence and abilities.

- Parents were excited about the flexibility of the trays. They saw that they could be used for different things because of the ability to reposition them, for example, for eating and holding books.
- One feature particularly loved is the ability to change angles.
- A young woman in her twenties could not get over being able to change the tilt herself, and to use a phone independently. She was absolutely giddy.
- One product tester who uses a speech device said, "I can eat and talk at the same time!" because he could move his speech device to the side and pull up to a table. He has been using a Mount'n Mover seven years.

Fig. 8. Extended testing

Extended testing with users has the potential to provide critical insights. Unfortunately, the complex design did not permit the production of Mount'n Mover prototypes that were robust enough for extended testing. One prototype was modified for a woman with amyotropic lateral sclerosis (ALS) whose occupational therapist convinced the design team that she needed the product immediately. The client had refused to have a speech device attached to her wheelchair, because she could still transfer to use the toilet herself. She spent much of the day at home alone and made the choice to maintain her ability to transfer. Once she tried the Mount'n Mover prototype and saw that she could transfer, she embraced having her speech device attached and available at all times. She received the very first production unit and is still using it, 10 years after she began her extended use testing.

The Big Leap: Manufacturing and Commercialization

Throughout the development, the design team considered the implications for manufacturing. The choice of production methods greatly affects not only the look, feel and durability of the product, but the tolerances, cost, minimum order quantities, and the up-front tooling investment. Given that the team did not produce any products at the time, this was a very involved process. The design team met with vendors and obtained bids from at least two or three different vendors for each part. Production drawings had to be completed for each part, specifying tolerances and finishing. The team also had to source, order, and stock a wide range of fasteners.

More than 70 custom parts now are made from the following manufacturing processes: magnesium die casting, plastic injection-molding, metal-formed or stamped parts, plastic sheet-formed parts, custom labels, and aluminum extrusions.

The investment in tooling and inventory was significant. Without the investment in the user research to prove effectiveness and the impact of the products, the project might not have gone forward.

During development, discussions were held with the speech device manufacturers to ask that they add the new mount to their line. Infrastructure was developed for manufacturing, production, assembly, and finally, marketing. When prospective users contacted the company to order a Mount'n Mover and asked if it processed insurance, they had to be turned away. The company is too small to process insurance, but it resolved this obstacle by having clients talk to their speech device company or wheelchair vendor to submit funding requests for insurance reimbursement for the purchase of the mount. Our strategy was to develop a network of resellers who could process insurance.

Implications of Outcome and Impact Research Results

A significant barrier to the adoption of new products is reimbursement. To support therapists in their letters of medical necessity, the team decided that it would be valuable to have impartial research demonstrating the impact of the Mount'n Mover on its users. Occupational Therapy (OT) programs who had graduate students were invited to conduct outcomes research.

Another barrier is getting professionals to consider a device other than those they commonly use. The natural inclination of an AT professional in choosing and recommending a mount is to focus on the "device mount", with an emphasis on *device*. If they securely mount the device, they have done their job well. However, they have not necessarily considered the potentially beneficial (or detrimental) overall impact of the mount's characteristics on the person. They often choose "the familiar", a mount they have used for years, and do not consider the more holistic picture and benefits of a movable mount.

The next section, analyzing the impact of using the Mount'n Mover, identifies compelling reasons for a variety of stakeholders to consider options that promote a person's abilities to do more than access a device, but to consider the whole picture. Is it assistive? Is it restrictive? How will each of the available mounts impact their client's ability to do other things?

Outcome Study by Independent Researchers

Integrating user input into the design process as BlueSky Designs did when developing the Mount'n Mover can greatly enhance outcomes of device use. Developers of assistive devices, more specifically non-disabled developers, must use knowledge of a functional deficit that is grounded in the user's lived experience when addressing user need with a particular device. As stated above, therapists and developers may not understand a user's lived experience, thus creating a gap between actual need of the person that the device is intended to assist and the developer's/therapists perception of that experience (Choi & Sprigle, 2011). To insure that the device adequately addresses the user's lived experience, it is vital that outcomes based on the user's perspective are collected. This will insure that the device is serving its stated purpose and will inform further change in design to fulfill that purpose.

Researchers have documented the outcomes of AT devices and services in various ways (Hersch, 2010; Jutai, Fuhrer, Demers, Scherer, & DeRuyter, 2005). Lenker, Scherer, Fuhrer, Jutai, and DeRuyter (2005) described outcome domains commonly found in AT literature. These are device usability, user satisfaction, quality of life, social role performance, functional level, and cost.

Device usability is comprised of factors that include: effort and comfort associated with device use, frequency of device use, and benefits of use. Usability is said to be emerging from interactions between the user, device, and environment during task performance. Common indicators include device usage, safety, and benefits of use. User satisfaction is described as the user's evaluation in response to the AT device and its impacts. Quality of life is often considered to encompass all outcome variables, but it is most often used to describe the user's subjective well-being. Social role performance is often considered a domain of quality of life, and concerns the performance in activities shaped by the roles that the user fulfills (e.g., student or worker) (Lenker et al., 2005). Functional level involves the degree of independence of the user and their functional capacity. Costs may be expressed in monetary value or time expended on behalf of the caregiver or user during AT device use or service (Lenker et al., 2005). While these outcomes vary in scope and purpose, virtually all require the perspective of the end-user.

A member from BlueSky Designs contacted an independent research team in an effort to evaluate the experience of Mount'n Mover end-users. This study aimed to gain that perspective in order to affirm the benefits of integrating user input into the design of assistive devices and to further inform both the users and developer of the functional and psychosocial impact of device use.

Methods

Quantitative assessment of a retrospective case series design was used to investigate the impact that using the Mount'n Mover had on clients who had already been using the device. A convenience sample was recruited by sending an email with a link to an online survey to those who had purchased a Mount'n Mover. The survey was created using the online survey platform Qualtrics (Qualtrics, 2014). The Ithaca College Human Subjects Review Committee approved the study. To gain objective measure of the impact the device had on each client's functional and psychosocial factors, the Psychosocial Impact of Assistive Devices Scale (PIADS) (Day & Jutai, 2003) was selected as one outcome measure.

The PIADS is a 26-item, self-report questionnaire designed to assess the effects of an assistive device on functional independence, well-being, and quality of life. It measures factors intrinsic to the individual, as well as environmental factors, which impact the psychosocial functioning of the person using the device. Participants are asked to rate how the device impacted these intrinsic and extrinsic factors on a scale of -3 (decrease) to 3 (increase) (Jutai & Day, 2002).

The items create three subscales that measure the domains of competence, adaptability, and self-esteem. In the context of this tool, competence is a subscale consisting of items that represent the user's perception of their own performance and productivity; adaptability is a subscale consisting of items that represent the user's willingness to try novel tasks and take risks; and self-esteem is a subscale consisting of items that represent the user's emotional health and happiness. The PIADS has documented reliability, validity, and clinical utility (Jutai & Day, 2002). For this investigation, clients were asked to retrospectively provide information regarding the impact that the device had on their performance following the provision of the device. The user or a caregiver on behalf of the user could fill out the online survey.

Following the completion of the online survey, participants were asked to provide contact information if they were willing to participate in a semi-structured interview. While the PIADS was meant to provide an objective sense of the functional and psychosocial impact of the device, the interview was intended to thoroughly investigate the users' perspective of how the device impacted their performance of activities they consider most important, as well as their satisfaction with that performance. The Canadian Occupational Performance Measure (COPM) was used to structure the interview. The COPM is an individualized and standardized instrument that researchers have used in several studies investigating outcomes of AT (Petty, McArthur, & Treviranus, 2005; Gitlow, Meserve, & Michie, 2006a; Gitlow, Meserve, & Michie, 2006b), and is a reliable and valid measurement tool (Carswell et al., 2004). The instrument asks participants to list the daily occupations they consider most important to them. The participants then describe their performance of and satisfaction with each of these occupations by assigning to each a number from 1 to 10 (one being the least level of satisfaction or performance through 10 being the highest level or satisfaction or performance). Participants were asked to retrospectively complete this interview regarding their performance and satisfaction with the device before and after intervention, which allows an opportunity to capture the perceived impact that the intervention had on a participant's ability to perform occupations most meaningful to them. A change in score of two or more points indicates a clinically significant finding. Due to geographic barriers, the interviews were conducted by telephone, video chat or messaging services.

Finally, users were asked questions that allowed collection of demographic information and information that increased understanding of device use (e.g., "Why do you use the Mount'n Mover?").

Results

Ten respondents completed the online survey (3 females and 7 males) and 4 of them consented to participate in the interviews (1 female and 3 males). Six of the ten online surveys were completed by the client themselves; and three of the four semi-structured interviews were completed by the client. Results revealed that the mount was used to access a wide variety of devices including communication devices, phones, laptops, eating trays, and cameras. The variety of devices used was consistent with information available through the company regarding the diversity of devices accessed using this system (Mount'n Mover by BlueSky Designs, n.d.). When asked the question, "Why do you use the Mount'n Mover?", 90% of respondents indicated that it provided them with better positioning for their device, and 70% indicated that it was easily moved when users needed to approach surfaces.

As one user failed to respond to items needed to calculate the PIADS subscales used to measure the domains of competence, adaptability, and self-esteem, results were calculated for nine of the 10 participants. Table 1 below summarizes the mean change and standard deviation value of each subscale among all nine participants. Values represent the extent to which the device changed users' perception of each domain on a scale of -3 (decreased) to 3 (increased). While the small sample size limits the generalizability of any conclusions drawn, the values suggest that following device use, the users surveyed perceived an increase in factors that contribute to each domain.

Table 1

Descriptive Statistics for PIADS Subscales

Subscale	N	Mean	*SD*
Competence	9	2.12	1.049
Adaptability	9	2.15	1.046
Self-Esteem	9	2.00	1.16

Results of the four COPM interviews provided an in-depth understanding of how the participants used the device, and how the device impacted their performance of activities they consider most important. The participants mentioned 18 total activities that the device had impacted their performance of. These activities varied widely, and included an equal number (*n*=9) of activities directly related to the device they mounted using the mounting system (e.g., using a tablet, photography, or feeding) and activities not directly related to what they mounted (*n*=9) (e.g., playing adaptive baseball, transferring, and shopping).

The rating the participants assigned to their performance of each activity before using the Mount'n Mover was subtracted from that same rating after using the Mount'n Mover to calculate a change in performance score. That same process was used to determine the change in satisfaction score. Table 2 summarizes the average change in performance and average change in satisfaction score along with associated standard deviation values. These values are calculated for all of the activities listed, but are also divided into categories representing activities directly related to what the user mounted (e.g., using a computer) and activities unrelated to what the user mounted (e.g., performing a transfer).

The average change in performance and satisfaction for all activities mentioned represents an increase in those constructs that was well beyond the clinically significant level of greater than 2. While this change was greater in activities directly related to what was mounted to the device, a clinically significant change in performance and satisfaction was found in activities both directly related and unrelated to what the users attached to the device. Again, the small sample size limits the generalizability of any conclusions drawn, but the results suggest that use of the Mount'n Mover resulted in a significant increase in performance and satisfaction with the performance of a wide variety of activities.

Table 2

Descriptive Statistics for COPM Results of Four (4) Participants

Type of Activity	N	Average Change in Performance (SD)	Average Change in Satisfaction (SD)
All Activities	18	6.14 (2.57)	6.22 (2.6)
Related to Device Attached to Mounting System	9	7.39 (2.52)	6.89 (2.67)
Unrelated to Device Attached to Mounting System	9	4.89 (2.03)	5.56 (2.51)

Discussion

The results of this study found that, for the participants, integrating the Mount'n Mover into their daily lives yielded an improved sense of competence, adaptability, and self-esteem. This suggests that, overall, users became more independent in daily tasks, were more willing to seek out new tasks and experiences to engage in, and gained an increased sense of emotional well-being. While these results are encouraging and are useful in determining a general sense of what benefit the device provided, it fails to provide a detailed sense of what the lived experience behind these enhanced outcomes was. The results of the COPM provided increased insight into this mechanism.

The results of the COPM indicated that users experienced a clinically significant (a change greater than 2) change in their ability to perform meaningful activity and a significant change in their satisfaction with their performance. This reveals that the device allowed users to complete activities that were most important to them with increased independence and resulted in an increased sense of satisfaction when completing these activities. Furthermore, the results allowed the researchers to identify how users were using the device. When asked the question, "Why do you use the Mount'n Mover?", the majority of respondents indicated that it provided them with better positioning for their device and it was easily moved when users needed to approach surfaces. This suggests that the device's ability to change positions easily was a feature that users valued because it allowed users to access what they attached to the mount with greater ease and the users could easily move the mount out of the way when not accessing what they attached. The information provided during the semi-structured interview affirmed this suggestion.

The activities mentioned by participants to be most impacted by device use were not limited to activities directly related to what device the mounting system allowed access to. While these activities were mentioned, the users often mentioned activities that were unrelated to what they attached to the mounting system. Examples included transferring, answering technical calls, socializing, feeding, engaging in community service, participating in adaptive baseball, and shopping. Out of the 18 activities mentioned, 50% of them were unrelated to what they attached to the mounting system. During the course of the interviews, many users mentioned the ease with which the mount's position is changed made these seemingly unrelated tasks easier to perform.

The results indicated the importance of considering the user's experience with an assistive device in the context of the performance in all the user's daily activities in a variety of environments, and not just the functional deficit that it is meant to address. Without gaining the user's perspective during the design process and while assessing the impact of the device, the holistic benefits of the features of this device would not be realized. Furthermore, for clinicians who recommend mounts based on the devices to be mounted, rather than user activity and performance, this result was extremely informative.

While these results provided valuable information to the developers and potential users alike, there are limitations that must be discussed. First, the size and nature of the sample prevent generalizations of these results to all potential users. Only 10 participated in the PIADS survey, and only 4 of those participants engaged in the interview. Furthermore, only existing users were involved in the study. This creates a biased sample of those who continue to use the device and may again prevent the results from generalizing to all potential users. The retrospective nature of the study makes assessing the true impact of the device difficult. Some users may have been using the device for an extended period of time, and it may be difficult to recall their functional and psychosocial capacity prior to using the Mount'n Mover.

Time and resource constraints limited the options for methodology for this particular study, and therefore this study should be regarded as a case study from which the developer received confirmation of the utility of the product that was developed by integrating user feedback. For future research, companies may consider developing a similar partnership with academic collaborators but with more comprehensive aims. While the results of this study have important implications for the developer of this particular product, they suggest much wider implications by providing a foundation on which more empirically sound studies can build to measure the impact of involving consumers in the development of assistive devices.

An experimental design that compares the functional outcomes of an experimental group consisting of users of devices that integrated consumer feedback in the design process to outcomes of a device that did not share that design process would allow the impact of consumer involvement in the design process to be measured. While the benefit of consumer involvement in the design of products may seem self-evident to those within the field, it is important to quantify this benefit to provide a deeper understanding on behalf of all relevant stakeholders.

Outcomes and Benefits

These results highlight the importance of user input in the design of an assistive device. User input facilitated a holistic approach to the design of the device, one that took into account the daily routine and activities of the user in addition to the activities that are facilitated by the main purpose of the device (allowing functional access to additional devices). For example, in one of the aforementioned case studies a user was unable to access a computer station to complete vocational goals as a result of the rigidity of her mounting solution for accessing her communication device. By taking into account this user's particular needs while designing the product, it assisted in the development of a custom mount that was easily moved to two accessible positions. This principle can be applied to various assistive devices that target a wide variety of functional needs. Only by gaining the perspective of the user can developers create a product that transcends its primary purpose and becomes a product that impacts the users in a variety of functional and environmental contexts. A product that achieves this use in a variety of functional and environmental contexts will lead to increased functional capacity and increased sense of well-being in the user, which will lead to decreased abandonment of the device.

These functional and psychosocial outcomes are useful in both assessing the impact of a finished product and in assessing the progress of the initial design process. In this case, the outcomes demonstrated the success of integrating user input into the design process by indicating increased functional and psychosocial capacity as a result of device use. Furthermore, it demonstrated the value users attached to using the device in diverse functional and environmental contexts. These outcomes could be equally as important during the design process. Consumer-centered outcomes similar to those used in this study could either affirm the benefits of various device features based on improved functional and psychosocial capacity of the user, or provide valuable information to developers regarding the need to change the design based on underwhelming outcomes.

Integrating user input in the design process and collecting outcomes of device use based on the user's perspective not only benefits the developer, but also the end user. As mentioned previously, using these principles in the design and evaluation of a product will lead to enhanced functional and psychosocial capacity of the user. This will reduce the rate of abandonment for the device and lead to an increased sense of independence and overall well-being of the user.

Target Audience and Relevance

- Developers of assistive devices: Using the principles of integrating user input into the design process and using outcomes to inform the refinement of the design will lead to a product with greater functional implications (and, presumably as a result, greater commercial success).
- Providers of AT devices and end-users: The results of this study demonstrate the benefits of integrating consumer feedback during the design process. In this case, consumer feedback seemed to result in a device that transcended its main purpose and allowed improved independence in a wide variety of functional and environmental contexts for end-users. This information is critical for both providers and end-users during the collaborative process of selecting an AT device.

Declarations

The content is solely the responsibility of the authors and does not necessarily represent the official views of ATIA. The authors obtained Institutional Review Board (IRB) approval for the work described in this article. The author Dianne Goodwin disclosed a financial relationship as an equipment patent owner and company owner and no non-finanical relationship. The authors Adam Kinney and Lynn Gitlow disclosed no financial and no non-financial relationships.

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