Assistive Technology
Outcomes and Benefits

A joint publication of the Assistive Technology Industry Association (ATIA) and the Special Education Assistive Technology (SEAT) Center

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Assistive Technology Outcomes and Benefits

Assistive Technology Outcomes and Benefits is a collaborative publication of the Assistive Technology Industry Association (ATIA) and the Special Education Assistive Technology (SEAT) Center at Illinois State University. This publication is provided at no-cost to readers. It is a peer-reviewed, cross-disability, transdisciplinary journal that publishes articles related to the *benefits* and *outcomes* of assistive technology (AT) across the lifespan. The journal's purposes are to (a) foster communication among vendors, AT Specialists, AT Consultants and other professionals that work in the field of AT, family members, and consumers with disabilities; (b) facilitate dialogue regarding effective AT practices; and (c) help practitioners, consumers, and family members advocate for effective AT practices.

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Assistive Technology Industry Association

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Assistive Technology Outcomes and Benefits

Editorial Policy

Assistive Technology Outcomes and Benefits is a peer-reviewed, cross-disability, transdisciplinary journal that publishes articles related to the *benefits* and *outcomes* of assistive technology (AT) across the lifespan. The journal's purposes are to (a) foster communication among vendors, AT Specialists, AT Consultants and other professionals that work in the field of AT, family members, and consumers with disabilities; (b) facilitate dialogue regarding effective AT practices; and (c) help practitioners, consumers, and family members advocate for effective AT practices.

Assistive Technology Outcomes and Benefits invites submission of manuscripts of original work for publication consideration. Only original papers that address *outcomes and benefits* related to AT devices and services will be accepted. These may include (a) findings of original scientific research, including group studies and single subject designs; (b) marketing research conducted relevant to specific devices having broad interest across disciplines and disabilities; (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; and (e) project/program descriptions in which AT outcomes and benefits have been documented.

ATOB will include a broad spectrum of papers on topics specifically dealing with AT outcomes and benefits issues, in (but NOT limited to) the following areas:

- Transitions
- Employment
- Outcomes Research
- Innovative Program Descriptions
- Government Policy
- Research and Development
- Low Incidence Populations

Submission Categories

Articles may be submitted under two categories—*Voices from the Field* and *Voices from the Industry*.

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.

Voices from the Industry

Articles submitted under this category should come from professionals involved in developing and marketing specific AT devices and services.

Within each of these two categories, authors have a range of options for the type of manuscript submitted. Regardless of the type of article submitted, primary consideration will be given by the journal to work that has *quantifiable results*.

Types of articles that are appropriate include:

> **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. Publication is justified if the results are potentially significant and have broad appeal to a cross-disciplinary audience.
>
> **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.
>
> **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.

In all categories, 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.

For specific manuscript preparation guidelines, contributors should refer to the *Guidelines for Authors* at http://atia.org/

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Outcomes and Benefits in Assistive Technology Service Delivery

Phil Parette
Editor

David Dikter
Associate Editor

We acknowledge that substantive advancements in the knowledge base of the field of assistive technology (AT) this past year, though our understanding of the complex nature of AT outcomes and benefits has yet to come fully into fruition. However, progress is reflected through a number of important scholarly works, including (a) *The Handbook of Special Education Technology Research and Practice* (Edyburn, Higgins, & Boone, 2005); (b) the posting of evidence-based findings and AT matches to support instruction of academic skills for students with disabilities (Hasselbring, Lott, & Zidney, n.d.; Peterson-Karlan, Wojcik, & Parette, 2006; Silver-Pacuilla, Reudel, & Mistreet, 2004; see http://www.techmatrix.org/); (c) various research reports of projects participating in the National Center for Technology Innovation (NCTI, 2005) 'Technology in the Works' competition; and (d) research reports of our two national AT outcomes projects (Assistive Technology Outcomes Measurement System [ATOMS], 2006; Consortium for Assistive Technology Outcomes Research [CATOR], n.d.; F. DeRuyter, personal September 25, 2006). Finally, use of specific research methodologies designed to demonstrate AT effectiveness, such as concurrent time series designs (Peterson-Karlan, Wojcik, & Parette, 2006; Smith, 2000) and alternating treatment designs (Chan, 2006; Langone, Levine, Clees, Malone, & Koorland, 1996; MacArthur, 1999; Van Hull & Hux, 2006) also hold great promise. Such encouraging activities should continue to guide the research, development, and implementation efforts of our readers who are invited to disseminate their findings in *ATOB*.

In this issue of *ATOB*, a plethora of AT issues is addressed, calling attention to the need for concerted and focused efforts for quality research and evidence-based practices. Our lead article, "The State of Assistive Technology: Themes from an Outcomes Summit," focuses on a national AT outcomes summit held last December in Chicago (see http://www.nationaltechcenter.org/partnership/seatcenter.asp). Hosted by the Special Education Assistive Technology (SEAT) Center at Illinois State University, the Department of Special Education at the University of Kansas, and the National Center on Technology Innovation, and with sponsorship by Ablenet, Inc., Don Johnston, Inc., Freedom Scientific, Kurzweil Learning Systems, and TextHelp Systems, Inc., summit participants addressed a cadre of issues related to the outcomes and benefits of AT. In this article by Phil Parette, George Peterson-Karlan, Sean Smith, Tracy Gray, and Heidi Silver-Pacuilla, key questions presented to Summit participants included: (a) *What are the current challenges with the use of technology and AT in assessment of educational outcomes?* (b) *How do these challenges affect the assessment of writing, reading, math, and other content areas?* and (c) *What is needed to measure the impact of AT on educational progress?* Themes that emerged and which are discussed include (a) assessment, (b) evidence-based research in AT effectiveness, (c) professional preparation, and (d) technology generalization. Special future issues of *ATOB* are under development focusing on key issue areas identified at this Summit, with the next AT Outcomes Summit tentatively being planned in conjunction with the ATIA 2007 Conference.

In the second article, "Perspectives of Outcome Data from Assistive Technology Developers," data from vendors regarding outcomes in AT service delivery are presented by Kathy Rust and Roger Smith. The investigators queried both research-based federally funded projects and commercial AT product developers. Developers noted the usefulness of outcomes data, particularly in the development process if outcomes information was available. Interestingly, commercial manufacturers reported cost as being different from other outcome dimensions and rated this factor as having lower importance. The investigators also found formal research methods being employed by both groups more frequently than anticipated.

In the third article titled, "A Case Study Model for Augmentative and Alternative Communication Outcomes," Katya Hill describes a basic case study format for documenting augmentative and alternative communication (AAC) intervention. Designed to ensure reliable and valid measurement of performance and outcomes for evidence-based practice (EBP), the approach is applied in a case study of an adult with cerebral palsy who relies on AAC. Of great interest to this journal is the presentation of *diverse* perspectives related to AT outcomes and benefits, particularly from consumers.

In the fourth article, "AAC, Employment, and Independent Living: A Success Story," a consumer perspective is presented by Carol Isakson, Sheryl Burghstaler, and Anthony Arnold. The third author describes his experiences growing up in North Dakota and the challenges presented by having both a physical disability and relying on a variety of AT devices that supported both his education and development of communication skills. Positive outcomes in employment and independent living are described in this poignant account, resulting from a combination of external factors and the consumer's internal strengths.

In the fifth article, "An Action Research Study of Computer-Assisted Instruction Within the First-Grade Classroom," Tara Jeffs, Anna Evmenova, and Sandra Hopfengardner Warren describe an investigation using *WordMaker* with 18 first-grade students having varying levels of reading ability. Over a 10-week intervention period in a co-teaching classroom, a significant difference was found in pre- to posttest performance in the areas of decoding and spelling skills. The authors discuss the potential of *WordMaker* to support other classroom curriculum activities (e.g., spelling and decoding) *for all students*.

In the sixth article, "Comparison of Semantic versus Syntactic Message Formulation: A Pilot Study," co-authored by Rupal Patel, Katherine Schooley, and Rajiv Radhakrishnan, a description is provided of the implementation of two prototype voice output communication aids (i.e., that used syntactical ordering of icons and semantic frames approaches) to compare the respective methods of graphic symbol message formulation of eight typically developing children (7-10 years of age). Performance of the children using the prototypes was compared with regard to accuracy, speed, complexity, and preference. Interestingly, the researchers found that all participants created equally complex and grammatically accurate sentences using both prototypes suggesting the potential of semantic frame-based message formulation as a viable alternative to conventional AAC methods based on syntax. Although typical children were used in the study, the researchers noted the need for future research extending these findings to children with disabilities.

In the seventh article, "Seeing Chemistry Through Sound: A Submersible Audible Light Sensor for Observing Chemical Reactions for Students Who Are Blind or Visually Impaired," Aaron Musser, Josh Han, Erika Briody, Chip McArtor, Kyle Gregory, Cary Supalo, and Thomas E. Mallouk describe development of a hand-held device designed to output light intensity as an audible tone. Through creation of an audio signal, a submersible audible light sensor (SALS) allows students who are blind and visually impaired to 'observe' chemical reactions in a solution in real time, thus enabling them to independently perform a wide range of experiments. The authors purport that the SALS device may be refined further to provide vibratory and visual outputs for students with learning or physical disabilities.

We hope that this issue of *ATOB* provides insights to our various stakeholders regarding approaches for documenting AT outcomes and benefits. We also note that complementing this issue of the journal is a wide array of presentations scheduled at the ATIA 2007 Conference on January 24-27, 2007, in Orlando (see http://atia.org/ for Conference information). This meeting has become one of the foremost AT consumer and professional venues, with a wide array of important program offerings available to participants.

Many readers may be unaware that *ATOB* is provided at no cost to the public, and hence, sponsorships are increasingly important to support this publishing effort. We would like to express appreciation to those sponsors of the journal recognized herein, and encourage the many vendors of AT devices to support the commitment of ATIA and the SEAT Center in producing this publication. We also express appreciation to our diligent Editorial Board members who consistently make it possible to provide quality feedback to authors who submit manuscripts for publication consideration. In an effort to expand the Editorial Board, we will be announcing a Call for Reviewers at the ATIA 2007 Conference, requesting participation from vendors, institutions of higher learning, government, not-for-profits, and consultants in the field. Information regarding the application process will be posted at the ATIA website in January. Additionally, information will be posted regarding the availability of hard copies of the journal for those individuals and institutions who are interested.

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The State of Assistive Technology: Themes From an Outcomes Summit

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Abstract: This article presents findings from a December, 2005, national assistive technology (AT) Outcomes Summit attended by AT experts representing vendors, higher education, government, and public schools. Discussions conducted centered around three questions: (a) What are the current challenges with the use of technology and AT in assessment of educational outcomes? (b) How do these challenges affect the assessment of writing, reading, math, and other content areas? and (c) What is needed to measure the impact of AT on educational progress? Four overriding themes emerging from these discussions were identified, including (a) assessment, (b) evidence-based research in AT effectiveness, (c) professional preparation, and (d) technology generalization. Specific issues within each of these broad themes are discussed and supported by comments from participants. Outcomes and benefits are presented in the context of 'next steps' for the AT discipline.

Key Words: Assistive technology outcomes, Assistive technology issues, Statewide assessments, Differentiated assessment

This article is based on proceedings of a meeting held December 15-16, 2005, in Chicago, IL, and which was co-sponsored through funding received from U.S. Department of Education Grant #H324EO50016, and through support funding provided by the National Center for Technology Innovation, University of Kansas, Don Johnston, Inc., Freedom Scientific, Inc., Kurzweil Learning Systems, Texthelp, Ablenet, Inc., and the Illinois State University Office of Research and Sponsored Programs and University Marketing and Communications. The opinions expressed herein do not necessarily reflect the position or policy of the U.S. Department of Education and no official endorsement by the Department should be inferred.

The State of Assistive Technology: Themes From an Outcomes Summit

The potential of AT to improve the lives of school-age children with disabilities has been widely acknowledged in the U.S. (Ashton, 2005; Edyburn, Higgins, & Boone, 2005; Peterson-Karlan & Parette, in press; Smith & Smith, 2004), and a broad array of AT devices and services is currently implemented in classrooms nationwide (Parette, 2006; Peterson-Karlan, Parette, & Wojcik, 2006).

Unfortunately, the field of AT is still in an infant state of development with regard to documenting the outcomes of AT service delivery (see e.g., Edyburn, 2005; Edyburn & Smith, 2004). Legislative mandates (i.e., The No Child Left Behind Act of 2002 [NCLB] and Individuals with Disabilities Education Improvement Act of 2004 [IDEIA 2004]) have placed emphasis on the participation of children with disabilities in the general education curriculum. NCLB, in particular, has resulted in tremendous pressure on public schools nationwide to ensure that all children progress and demonstrate achievement in the curriculum. Two nationally funded projects were initiated to develop outcomes monitoring strategies (Assistive Technology Outcomes Measurement System, 2005; Consortium for Assistive Technology Outcomes Research, n.d.), though, to date, little direction is available to education professionals regarding the documentation of AT outcomes (Parette, 2006). Numerous individuals have published reports regarding the role of AT in large scale assessments (cf. Clapper, Morse, Lazarus, Thompson, & Thurlow, 2003; Fletcher et al., 2006; Thurlow, Minnema, & Treat, 2004; Tyndal & Haladyna, 2002) yet guidelines are infrequently available to assist schools in creating systems and strategies for collecting data related to the effects of AT interventions on student progress (SEAT Center, National Center for Technology Innovation, and University of Kansas, 2005). Paralleling these events, researchers in the area of curriculum-based measurement have attempted to provide teachers with means for assessing continuous student progress in the classroom (Fuchs, Fuchs, & Hamlett, 2005). Given these simultaneous events, a current issue is how education professionals can determine the

Table 1
Themes Emerging from Summit Discussions

Theme	Issue
Assessment	Allowable technology on high-stakes assessment may be driving decision to implement tech in classroom – disallowed technologies are being disregarded even in the classroom
	Technology-supported performance is still viewed with suspicion as an academic assessment
	Technology-supported and differentiated assessment (universal design for assessment) should be a model
Evidenced-Based Research in AT Effectiveness	Need a research base demonstrating effectiveness of AT for student learning
	Need to identify common outcome measures related to achievement so that data sets can be aggregated
	Need to make better connections between R&D and research-to-practice
Professional Preparation	Trainings are often focused on technology operations, not on effective implementation
	New teachers may be "tech ready" but curricular materials, classrooms, and standards are not
Technology Generalization	Preparing students for the information technology world requires new thinking
	New technology tools require new skills for implementation
	AT is crossing into general education as instructional technology

role and effectiveness of AT; and perhaps more centrally is the question, "What is the model for determining the effect of AT on educational outcomes for students with high incidence disabilities?" (SEAT Center et al., 2005).

A Collaborative Summit Event to Examine Current Issues

In light of the plethora of AT issues currently impacting public education (Edyburn et al., 2005; Parette, Peterson-Karlan, & Wojcik, 2005; Wojcik et al., 2004), personnel of the Special Education Assistive Technology (SEAT) Center at Illinois State University, in partnership with the National Center for Technology Innovation and the Department of Special Education at the University of Kansas, and with sponsorship support from Ablenet, Inc., Don Johnston, Inc., Freedom Scientific Learning Systems Group, Illinois State University, Kurzweil Educational Systems, Inc., and Texthelp Systems, Inc., hosted an Assistive Technology Outcomes Summit in Chicago, Illinois, on December 15-16, 2005. Nationally recognized individuals representing vendors, research institutions, state projects, government, and school district practitioners were invited to participate. Conceptually, the Summit was designed to bring together a cadre of experts from both general and special education to clarify the inherent issues related to the effects of AT on educational outcomes. Targeted outcomes were to examine participant responses to a series of questions with the identification of strategies and recommendations that would serve as a framework for subsequent research, policy development, curricula, and professional development activities. Key questions presented to the Summit participants included the following: (a) What are the current challenges with the use of technology and AT in assessment of educational outcomes? (b) How do these challenges affect the assessment of writing, reading, math, and other content areas? and (c) What is needed to measure the impact of AT on educational progress? In addition to videotaped large group discussions, small group sessions were conducted by facilitators using flip charts, allowing for capture of key thoughts by participants. Transcriptions were made of both large group proceedings of the small group discussions and analyzed using traditional qualitative methodologies (Bogdan & Biklen, 1998; Leedy & Ormrod, 2001; McMillan & Wergin, 2002). Four main themes that emerged included: (a) assessment, (b) evidence-based research in AT effectiveness, (c) professional preparation, and (d) technology generalization (See Table 1). Analyses of themes emerging from each of these areas of discussion are presented in the following sections.

Assessment

Allowable technology may be driving decisions to implement technology in classrooms. Considerable discussion focused on the issue of high stakes assessment practices across states and the role of AT in those practices. Special emphasis was placed on technology as an accommodation issue. Participants observed that current statewide assessment practices, especially accommodations allowed for testing, drives consideration of research on technology use in content areas. Since limitations are placed on the use of AT in testing practices, students have a diminished ability to demonstrate their proficiency in content areas.

As noted by Martha Thurlow, Director of the National Center for Education Outcomes, there are many issues embedded in the practice of providing accommodations that "have policy associated with them which means they are considered okay or not okay." With the associated costs of providing accommodations, and the statewide assessments themselves, resource constraints are being realized by schools. Denise DeCoste, Technology Consultant with the Montgomery Public Schools, observed:

> It is interesting that because of No Child Left Behind and the emphasis on standardized testing, our districts actually have fewer computers per classroom now because all of those computers are going to labs in order to do the high-stakes testing.

This position was supported by Dave Edyburn, Co-Director of the Assistive Technology Outcomes Measurement System (ATOMS) Project, who commented, "When you put all of the dollars into the assessment, there are no dollars for intervention." However, until there is credible evidence regarding the relationship between AT use and enhanced classroom performance, statewide assessment practices will be driving decisions to use AT in classrooms. This prompted a response by George Peterson-Karlan, Illinois State University:

> Are we waiting for the technology to be allowable on the tests before we make a big push to put that technology in the classroom?...are we waiting for that or should we be thinking about increasing the technology tools in the classroom and having a way to figure out whether the students are doing better. Then if they don't do better on the tests as the tests are now constructed--given a good body of data about their performance in the classroom--then we point to more of a discrepancy with the testing.

Technology-supported performance viewed with suspicion. Of particular concern to participants was the observation that many education professionals continue to view technology as a support for students to participate and make progress in the curriculum. Current standards in the content areas are technologically insufficient. These standards must be met and exceeded by 21st century skills and National Education Technology Standards (NETS; International Society for Technology in Education NETS Project, 2000-2005) which will require an expansion of standards to embrace 21st century skills (Peterson-Karlan & Parette, in press) and NETS. It is important that standards be expanded to 'free' the tool to meet the standard and that all education professionals recognize that new tools are not "cheating."

Equity issues related to statewide testing and AT surfaced repeatedly during discussions. A poignant point was made by Dave Edyburn who commented:

> We are in a situation right now where we have conflicting laws that we have to provide assistive technology. So if there is an academic performance problem, that is by definition the need for assistive technology and yet what we are doing is we are setting this up in the traditional amount of education that it only counts if it's here and we're not looking at the interaction between the person and a tool because that's cheating, that's less performance…When they re-roof your house, they are all using nail guns and yet in school they call it cheating [*if AT is used*, emphasis added].

Unfortunately, biases and misconceptions of teachers regarding the fairness of using AT have a profound impact on whether students learn to advocate for their own technology needed. As Cindy Okolo, of Michigan State University, noted:

> …teachers are a bit paranoid about assistive technology and perhaps the unfair advantage it gives kids and that makes kids kind of paranoid. So, my

> daughter is not going to be a strong advocate for the use of technology in her classroom because her teachers, you know, are not sure about this and they are not sure if it is fair to let her have this sort of advantage as a seventh grader.

Technology supported and differentiated assessment (universal design for assessment) should be a model. The nuances of current statewide assessment practices have resulted in insensitivity to individualization. More specifically, the notion that 'everyone must pass' inherent in NCLB seems to be driving non-individualized implementation of assessment approaches in the states. This problem was clearly summarized by Dave Edyburn:

> Because failing is not an option…we've used a metaphor--the assembly line. We want to control the input. Let me control the curriculum, let me control that processing, that highly qualified teacher, and then my outcome measure is no defects. Everybody is ready to run. So you see here is I think one of the issues we are struggling with--the lack of tolerance for individualization. The assembly line model does not represent what learning is about. When you apply that, what you've got is a one-size-fits-all to meet no one's needs.

Passage of the IDEIA 2004 has resulted in changes in our ideas around learning and cognitive disabilities and the concept of a pre-identification strategy known as 'response to intervention' (RTI; Fuchs, Mock, Morgan, & Young, 2003; Gresham, 2002). The emphasis of RTI focuses on the delivery of more effective instruction by encouraging earlier intervention for students experiencing reading and related learning difficulties. Identification of students as having learning and cognitive disabilities then would be minimized since intervention is provided as academic concerns emerge. Since AT can increase the participation of students with disabilities in the general education curriculum (Edyburn, 2005; Peterson-Karlan & Parette, in press), and minimize the performance deficits resulting from disability (Cook & Hussey, 2002), the RTI model holds promise for the AT field.

Support for developing and implementing technology-differentiated statewide assessment practices was repeatedly expressed by participants. Such strategies would be complemented by *dynamic norming* (Edyburn & Smith, 2004) which involves the extraction of data in a real-time database to make comparative norm groups. Thus, in essence, technology-supported assessment could be equated with universal design for assessment (Dolan, 2000; Ketterlin-Geller, 2005).

Evidenced-Based Research in AT Effectiveness

Need for research base demonstrating effectiveness of AT for student learning. Echoing previous findings of national need (SEAT Center, 2004), discussants found that there is a persistent need for a national database of AT outcomes. Participants identified a need for a research base demonstrating the effect of AT on student learning. As noted by Jane Lurquin, Illinois Department of Education, there is a "need for research and having a national database or a common way that we can actually have and share research on the effectiveness of technology and that takes a long time to gather." With regard to statewide assessment practices, participants voiced needs for instructional as well as 'norm-referenced data.' This can be accomplished using such strategies as concurrent time series designs (Parette, 2005; Peterson-Karlan, Wojcik, & Parette, 2006) where multiple scores are attained using AT-assisted and non-assisted performance measures.

The current status was succinctly summarized by Caroline Van Howe when noting what Intellitools, Inc., encounters when working with schools across the country:

> All of the teachers that we speak to in the school districts…are being held to looking for data-driven decision making processes, so they're looking to vendors to provide that information that the data is out there to prove that this technology or this intervention strategy has been successful…there isn't a general national database of research that can prove this or that product or intervention.

However, developing such a database is fraught with problems. Outcomes of interest have yet to be clearly identified across the country (SEAT Center, 2004). This recognition was mentioned by Gayl Bowser, Oregon Assistive Technology Project, who observed, "I am always struck that one of the things I think we haven't yet done well is to really define what the outcomes we are talking about are." One of the most important outcomes of public education is graduation, though as Cindy Okolo commented, "that in all of the concern about more rigorous graduation requirements, people really don't think about assistive technology as a way to help kids achieve those requirements." Related to this issue was the concern regarding needs for information and professional development. Gayl Bowser stated that there is a need for professionals in the AT discipline to "figure out what we need to say to general education teachers about the technology they are using in their classrooms for instruction." However, in order to do this, there is a need to differentiate the contributions of various facets of instruction (e.g., technology, differentiated instruction, teacher quality) to understand 'cause' and communicate this to general education teachers. As observed by Ted Hasselbring, University of Kentucky:

> One of the problems we have is teasing out what really made the difference? Was it the actual technology because everything is taking place simultaneously. Was it the technology, they use that. We had good, good instruction, differentiated instruction and was it really that? Was it that the kids, you know….it could be a lot of factors. Do they feel really safe? Is this a great teacher where they feel the teacher cares about them, they can take risks, they can learn better?

Compounding the development of evidence-based research is the *technology implementation paradox*. That is, teachers and administrators are hesitant to implement AT in the absence of proof, though desired proof of effectiveness cannot be achieved without implementation. But as Don Johnston, founder of Don Johnston, Inc., suggested,

> …we should identify the fundamental thing that we're measuring and now let's apply some technology…let's put some money to that and say, "What does this solution cost and now lets put a research piece into this and now measure the fundamental thing."…We should all be doing that as part of everyday implementation.

Participants expressed concern that the 'features wars' (Burger, 2002; McFarlane, 2004), i.e., competition among vendors to develop complex devices with many features, has now culminated in a recognition that the AT field give consideration to 'proving' the features of technology. This need does not embrace a focus on the tool as a whole, but rather on critical elements of ecologically valid tasks, i.e., real world applications (Wehmeyer, Smith, & Davies, 2005). The research that is being conducted should include matching the features of technology to the elements of instruction in the same way that we are matching features of the technology to elements of the task.

At both the classroom and district level, evidence-based practice and its documentation was integrally linked to time, i.e., there has, to date, been little time to conduct research both on implementation and effectiveness of AT. Compounding this issue is lack of equity across schools with regard to available technology resources.

Need to identify common achievement outcome measures so that data sets can be aggregated. Participants identified two 'realities' that characterize current practices. First, little information is available, much less agreement on, important outcomes to measure AT effectiveness. Second, access to AT tools during assessment processes continues to be limited.

Specific needs for identifying common achievement measures were identified by participants. The context for this need was articulated by Dave Edyburn, who noted:

> …you have kids with disabilities and you leave school. The achievement gap is based on data. Current practices are not effective for all students. There is 50 years of data that says what we do doesn't work for some groups of kids so we do that and then next Monday I go on and you'd fail. That is what education is. We have been disenfranchising kids. Now, with No Child Left Behind, we have instituted another model here and let me have you guess the metaphor…is that on Monday I'm going to use state standards and benchmarks and that will tell you what you guys are going to learn this week. Then Tuesday through Thursday because I am highly qualified, I will do researched-based interventions all week and then on Friday we will do a quiz or a high-stakes assessment and then because of No Child Left Behind, you all pass.

Discussants noted that we must question the fundamental outcomes of education, i.e., what is the 'base level of technology' needed to do the research? As Don Johnston suggested,

> I think we need to design the outcome of what is the fundamental thing that you want to measure for success, so what's our ultimate goal with our students and how do we measure what that is? We get so caught up in let's measure spelling as a way to look at expression and it's not a good…it's not the fundamental thing that we're really measuring.

There was an acknowledgment that critical outcomes may be discrepant from instructional outcomes, and that educational outcomes/standards may be discrepant from critical life competencies.

Need to make better connections between research and development and research to practice. Current federal legislation and resultant trends in education emphasize the ongoing needs for translation of AT research findings, especially with regard to AT outcomes and benefits, into practice recommendations (Edyburn, et.al., 2005; Fuhrer, 2001; Lenker & Paquet, 200). Participants involved in research and development noted specific challenges with regard to AT and content areas. Jeff Higginbotham, University at Buffalo, observed that professionals should

> …make sure that we have a close and closer relationship between research and development of these technologies so that there is a research

> base to the…not that the technology works but that the technology fits the person that it is supposed to be working for.

Discussants also noted that content areas are not in the same research level and maturity with relation to the curriculum and related curriculum measures. In the discussions regarding math, for example, it would appear that this discipline is much more mature in its approach to curriculum and standards (vs. reading and writing where less consensus may be found). Widespread dissemination of research to practice strategies is also a recurrent need articulated by the field.

Not surprisingly, the lack of direction in the field regarding effective AT practices and documentation of outcomes raises questions regarding how to communicate with government and other decision-making entities. David Richmond, who is responsible for Constituent Relations for the 14th District of Illinois, provided insights for consideration:

> From a government standpoint…People always want to know where to go and what to do. I have always said is look at who has the authority. We talk about cost benefit analysis. Teachers answer to administrators, administrators right now are answering for the test scores of their schools to the states, and the states are answering to the No Child Left Behind and the federal government. Nobody wants to be labeled as a failing school. In turn, when those things happen and segments of their population are not meeting yearly annual progress and are being labeled that, then administrators say, "What can we do?" At that point, I believe you see administrators starting to say, "Is there some assistive technology out there?" The federal government No Child Left Behind, they want to see the benefit, they want to see the test scores, they want to see the children educated. The administrators--they want to see what it costs. The teachers and parents, who we've kind of left out of a lot of the equation, they a lot of times don't know where to go and what's available so I think it's important that we look at the cost benefit and I think in the future…

When queried further by Tracy Gray, National Center for Technology Innovation, who asked, "Could you just give us a consensus statement of what your perspective is as somebody working with a policymaker, what that research might look like?" David replied,

> When you're able to show, you know in the basic form, 'X' amount of dollars equals better students. 'X' amount of dollars creates assistive technology which creates better students for testing. Those are kind of the links that as a public policy looks at, you know whether it goes this way or this way, they all have to meet.

Professional Preparation

The importance of professional development of education professionals to effectively provide AT services has been frequently cited in the literature (Ashton, 2004; Ludlow, 2001; McGregor & Pachuski, 1996; Peterson-Karlan & Parette, in press; SEAT Center, 2004; Smith & Allsopp, 2005; Wojcik, Peterson-Karlan, Watts, & Parette, 2004). Continuing conversations regarding the AT consideration process (Center for Technology in Education, Johns Hopkins University; and Technology & Media Division [TAM] of the Council for Exceptional Children, 2005; Reed & Bowser, 2005; Zabala & Carl, 2005) and the ability of education professionals to effective 'consider' AT has yet to be realized in effective practices nationally. Despite meaningful dialogue, presentations in a plethora of professional venues, and scholarly publications, AT consideration remains a poorly implemented process in many school systems. All too often, a "failure criterion" is utilized, i.e., students with disabilities are allowed to demonstrate poor performance in academic areas before technology is even considered, much less implemented with these students.

In the U.S. the status of current teacher preparation efforts to address such problems was succinctly summarized by Cindy Okolo:

> I think we're doing a really lousy job with pre-service teachers and any kind of impact we can have or anybody else can have on pre-service teacher preparation--ways of making information more readily available to people who are teaching are teachers, so they can get this into pre-service classes…is really important.

Participants agreed that major changes are necessary in teacher education practices, although it was noted that negative attitudes towards technology remains a barrier to such changes. The challenge presented by existing attitudes was summarized by Don Johnston:

> I think proven results would be an amazing, powerful influence but it's more than that. I think there is an insidious, negative attitude toward technology because it takes a system that hasn't changed for 150 years and forces it to change fundamentally…So give me attitude….give me a change of attitude and I think that everything else will be the lags and will fall into place.

Attitude changes at the school level were also deemed to be a substantive area of challenge for the discipline. Denise Decoste commented that "….the thing that's important I think in professional development is an attitude shift, is a paradigm change for teachers--they have to think differently about planning their curriculum and they need curriculum support to do that." Jane Lurquin observed that:

> Curriculum does need to have the assistive technology built into it and also staff attitude has to be changed. That has to start with administration and superintendents because if they're not into, really into assistive tech, they're not going to get it into the schools.

Trainings focused on technology operations vs. effective implementation. Professional development has typically focused on 'basics of operation' vs. implementation of technology. As observed by Denise DeCoste:

> Even though we do lots and lots of training, I think training has to go beyond the software basics and move into implementation. Unless we teach teachers how to use the technology effectively, what are we collecting data on?

Disconnect between technology readiness of teachers and curricula, classrooms, and standards. The issue of standards also surfaced in discussions, and it was acknowledged that today's standards were socially validated for yesterday's needs. Sean Smith, University of Kansas, observed that:

> …some of the things that we would be instructing or the standards that we are trying to address may not be the really critical standards that we need to address for that transition to work and

> that really what we need for life competencies.

Resulting outcomes should be validated outcomes against 21st century skills given that new teachers--typically those from the Millennial or Net generations—are ready and willing to use new and emerging technologies. As observed by Denise DeCoste,

> …we have lots of new teachers that come into the district who are tech ready. They grew up with technology…, but then they enter a system where the curriculum is highly scripted and there is no reference to how to use technology as part of their curriculum. In addition…, there is no communicated expectations necessarily for that.

However, curricula in institutions of higher learning are not yet sufficiently organized and delivered to allow these future teachers to use the technologies for learning that are so readily available. This has an impact on subsequent teacher practices, as expressed by John Castellani, Johns Hopkins University:

> We've seen that In Maryland where we are trying to talk to teachers about 21st century skills and then you go back to the Maryland curriculum and start looking for where things like inventive thinking, problem solving, a lot of just the outcomes that you'd expect out of good technology integration. You can find it in elementary school, you can't find it hardly at all in middle school, and in high school it's nonexistent. It's an issue and teachers are to the point in some counties where their lessons are even scripted, at 9:09 this is what you are saying to a child, at 9:15 this is what you are doing, and in the last 10 minutes you are sustaining silent reading. You know, and that's the reality so the creativeness about integrating technology unless it is on an IEP where you say I have to do this and then you give that to the teacher for him or her to decide then how that fits into what they're doing with their IEP and then how the IEP fits into the state standardized curriculum and how, you know what their tests do to support or what their assessments look like.

Practitioners in the field also repeatedly lament the cost of inherent tools that are available to assist students with disabilities to participate effectively in the curriculum. As noted by George Peterson-Karlan:

> In some subjects, in this case math, there appear to be inherent tools, e.g., calculators, the other one brought up is the graphing calculator, that have been identified by content experts like NCTM (National Council of Teachers of Mathematics, emphasis added) and parents are actually providing these tools as part of the curriculum so it became obvious from looking at the other charts that we don't have the same inherent tools in writing and reading that have been labeled, that have been identified by national content experts.

Technology Generalization

Preparing students for the information technology world requires new thinking. Given that our Information Age society demands skill sets that public schools may not be developing in children with disabilities (Peterson-Karlan & Parette, in press; Peterson-Karlan & Parette, 2005), discussants reiterated that a discrepancy exists between schools and rest of world. In addressing the concern that there is a fundamental issue of preparing students for participation in an Information Age society, Don Johnston stated:

> Has anyone not used a spellchecker in the last week? I mean, so we want to put our energy to figuring out that every kid should be using a spellchecker and you know even as a business, the people who turn in their papers to me or some type of work with spelling errors, that's the problem. I don't care how they got something to me but if I have an employee….if I have an employee who is doing stuff, I don't care if they used a spellchecker or not.

From the professional development perspective, George Peterson-Karlan observed that undergraduates who receive AT professional development experiences

…are tech ready, they are tool users, but when they go out to the schools, the don't see those tools there. The students that are in middle schools are tech users and tool ready. So, as we keep talking about this, it is rather clear that the technology environment of the school doesn't match the rest of the world.

New technology tools require new skills for implementation. Compounding the problem is the challenge of developing new skills among new teachers for AT usage. As noted by Margaret Bausch, University of Kentucky:

> It seems to me that teachers are not coming out with the skill sets that they need to implement that technology. That seems to be something that we still need to address. Then if they have the technology and they know about the technology, then they can plan for that implementation of technology, whether it's assistive technology or instructional technology. Making that part of their planning process is planning…

Outcomes and Benefits: Next Step Themes

At the conclusion of the Outcomes Summit, participants were allowed the opportunity to identify three major issues they felt were critical for 'next steps' by the field. A total of five themes were identified (see Table 2). The following section presents a discussion of these themes.

Technology Integration

Although participants acknowledged the importance of professional development to create the broad AT skill sets necessary to more effectively provide AT services, it was

Table 2
Summary of Next Steps Themes

Theme	Issue
Technology Integration	Need to prove relationship between professional development and technology integration
	AT tipping point: Redefine AT as instructional or productivity tools
AT Outcomes Research	Need to connect researchers to school district data sets
AT Outcomes	Develop AT differentiated classroom outcomes protocols for research
Statewide Assessment	Technology differentiated assessments
Technology Generalization	General education market for AT tools

noted that there is still a need to prove that there is a relationship between professional development and technology integration, i.e., if people receive professional development, does it in turn result in more effective use of AT in classroom settings?

One issue that emerged that is of particular interest was an acknowledgment that the field of AT is at a 'tipping point.' This was summarized cogently by Denise DeCoste:

> I would say curriculum is actually is because we provide, for example in the real world, we provide lots of professional development and we can't get people to show up for this professional development. AT has crossed the tipping point. It's not as sexy as it used to be, it's not as seductive as it used to be, and quite frankly it's one more thing I've got to worry about as a teacher. Teachers tell us that.

But related to this was the recognition that AT should be redefined as instructional or productivity tools given current trends and issues related to statewide assessment and the emphasis on student achievement mandated by NCLB.

AT Outcomes Research

A key concern that permeated discussions was the need to both involve teachers in developing local data sets and connecting researchers to school district data sets. Caroline Van Howe stated the need for

> …action research…working with individual school districts on short six month projects to implement with them, according to their criteria, in a sustained implemental fashion and see what the benefits are from those short action research and then write up those studies, doing independently.

However, as observed by Tracy Gray, this cannot be accomplished without partnerships with higher education:

> In school districts there is a lot of data being collected but there's nobody there to help the schools or the state to look at what they're sitting on--trying to figure out some innovative way to connect universities, graduate schools, to get access to that data to see if there isn't some way to have more information coming out of the pipeline

AT Outcomes

Repeated conversations regarding assessment practices and current needs in the field clearly suggested the need to develop AT-differentiated classroom outcomes protocols for research. Such protocols hold the potential to provide comparable measures and scores using different levels of technology support for students with disabilities.

Statewide Assessment

Participants recognized the importance of statewide assessments and how they (a) determine initiatives state and individual districts have established, (b) dictate what building leaders note as primary objectives, and (c) determine what classroom teachers do on a day-to-day basis. Several panelists shared concerns about statewide assessments and the limitations these instruments offer students with disabilities, especially when restricting the use of technology-based supports used in a student's learning. During the course of this conversation several issues were presented and experiences shared concerning statewide assessments and technology access as an accommodation.

For example, Martha Thurlow offered recommendations to expand our understanding of AT as it relates to learning and specifically to testing. If we have data to share, we could further technology use within the statewide testing experience. Martha offered:

> … we could pull together research that has been done, even if it has not been published and try to begin to gather some of the evidence that is out there that may not be published out there and begin to try to gather a base of evidence that way…a set of policies related to assistive technology or technology, and we can go back in and dig that information out…I think that you need to get together other stakeholders, state policy people who are dealing with the test policies, test developers, and have this kind of discussion with them.

While there is a great deal of research to be done, anecdotal evidence suggests that technology-based supports can be instrumental in improving access to and success in state assessment experiences. For example, Ted Hasselbring offered comments concerning the State of Kentucky and their experience in providing screen reader technology to all learners for instructional as well as assessment experiences. Kentucky's experience suggests an increased independence on the part of the learner and an engagement in their own learning:

> Many of you know that the state of Kentucky has pushed very hard on this. They have made screen reader technology--I think through TextHelp--available to every school system in the state. Some of the anecdotal data….and these were for kids that...for example they had on their IEP the need for a human reader. They could supplant that with the screened reader and a lot of kids have. But the anecdotal data right now from these kids both in their classroom work and on the state test because some of these kids use a screened reader on the state test in lieu of a human reader, I would say 99% of the feedback is that they would much rather use the screen reader than the human reader and there are lots of different reasons for that. I think they are feeling good about it, about being able to use this; it frees them up. I don't think it is as much of a stigma for in-class work and tests when they have more control over what they are doing.

Other panelists agreed that technology-based solutions are offering increased supports that should be integrated into statewide assessments. The thought being that classrooms are differentiating instruction to further meaningful access to the curriculum and so, extending this concept to assessment is logical and appropriate. Joan Cunningham, of Kurzweil Educational Systems, Inc., shared her recent attendance at national conference where technology-based accommodations were being discussed.

> One of the things that came out at Large Scale Assessment Conference and a couple of the sessions that I was in this summer, was that accommodations actually ought to be by item so that…and kids could turn it on, turn it off, depending on what their needs were.

Discussion also focused on whether we assess in a manner appropriate to real-world application. That is, some participants voiced concerns over not permitting technology-based accommodations that these students would have access to and be expected to use in real-world settings. If they are expected to use a software or hardware device in post-secondary experiences, why then do we restrict this device use in testing situation? Don Johnston best captured this when he commented:

> You know, wouldn't it be cool if that mechanic that uses that diagnostic technology is truly better than the one that doesn't have the diagnostic technology. Wouldn't that be a statement for everybody in our school system and a fundamental change, not for just our struggling students but a fundamental thing for everybody.

He followed with:

> We're putting our energy towards…is this an unfair advantage. The issue is, we should let everyone use this technology and then it wouldn't really matter. If our students are smart enough to know what tools they need, more power to them and then they're going to be successful as adults.

A number of participants favored further exploration into ways technology can be used as an accommodation or an essential part of the testing experience, similarly, others shared thoughts about the components of the assessment experience. For example, Charles "Skip" MacArthur noted that assessments seek to measure not only knowledge but fluency:

> We talk about extended time as an accommodation on the test but time is a relevant factor. Fluency and speed which you can do things is not an irrelevant factor for performance in the real world.

While discussion continued on technology differentiated state assessments, conclusions appear to favor further examination and collaboration amongst educators, vendors, policy makers, and test developers. Without these ongoing discussions, technology as an integral part of the assessment, and many argued instruction (since instruction is focused on NCLB-directed statewide assessments), would continue to be considered as a supplementary tool not available to all students and restricted to components of the testing.

Technology Generalization

As statewide assessment continues to dictate classroom instruction, participants voiced a need to enhance the use of AT in the general education classroom. To do so, AT must be viewed as a tool for the general education market. Tom Freeman, of Freedom Scientific, explained that as a vendor they are attempting to cross over to the general education classroom and tying this via statewide assessment supports. He explained:

> Obviously, we would like for what we have viewed as an assistive technology market to grow into general education, and we feel like the tools that our technologies offer really are appropriate for more than just to the special ed market. We're trying to figure out a way to get there and it's very difficult to get them there but we'll continue to try those things. Another thing from a testing perspective and I guess from a perspective of research, we're always interested in doing research. We've got a couple of situations. One, I mentioned to John last night in South Dakota, where they actually used one of our products for state testing and experienced good results that has fed back into the classroom and they're actually increasing their use of our products in the classroom which I

> view as very positive. We're going to keep on top of those types of things and make them available to others so that we know the results.

A key point made by a number of participants was that AT is effective beyond a targeted disability population. Caroline Van Howe shared:

> I know that in fact the effects from technology can be a great equalizer, just anecdotal information but not statistical. On a project with a school actually in Chicago, one of the byproducts of actually implementing the intelligence technology for a six-month period was that it was across all children in all the classes so it was full inclusion. The children with learning disabilities actually had a private relationship with the software in their computer, so they were actually assuming the same appearance as everybody else in the class. They found it to be a great equalizer. The success rate went up, their social confidence went up, they were much more positive about learning, they looked forward to lessons so it had a whole different experience for them having the technology being delivered to them, served up privately and discretely as software can do so it wasn't as transparent as the other way.

However, simply having effective technology is not the deciding factor for successful integration. As participants have already reported, application is multidimensional and involves a variety of factors. Still, participants shared ideas related to infusing these tools into the general education market. For example, Carol Leffler, of School District 54, Schaumburg, Illinois, offered:

> …we keep talking about integration of technology but we don't have a lot of good examples out there. I don't think teachers really even know what that looks like. So maybe some really good models and some videotaped models that teachers can see so they can kind of model it because you don't see it everywhere and people don't even know what it looks like.

Cindy Okolo agreed but also felt that part of the solution concerned information dissemination:

> I think to some extent some sort of clearinghouse, some sort of way to make this information more broadly available to teachers about…and again I'm looking from the perspective of instructional technology, technology being used to facilitate high-quality instruction in ways that will help a diverse classroom.

The issue of cost also became a critical concern. If we are to access the general education market, it was felt we need to address cost benefit issues. Don Johnston shared:

> The biggest thing is cost savings. I think that's part of the paradox to be added to it is that it's expensive to implement technology in school systems that with $400 laptops, $500 laptops, whatever they are, that's just a laptop. You know, the core stuff I don't think is that expensive compared to…we could provide individual instruction by providing teaching resources. We don't have enough teachers trained for that and so what is the role? I think it's more of an attitude.

David Richmond agreed, offering the earlier-noted perspective from policy-makers and district and building leadership, i.e., that there is a need to demonstrate that government commitments of funding equates with better technology and students.

Closing Thoughts

The application of AT into the lives of individuals with disabilities can be of great benefit and expand placement, educational, and overall developmental options for individuals with disabilities, their families, and the professionals that provide supports to them. Participants at this AT Outcomes Summit shared a number of thoughts concerning AT and its impact on an individual's development and the outcomes that have been and should continue to be measured in instructional areas. However, participants agreed that we have a great deal of work ahead of us as a profession if we seek to integrate AT into meaningful instruction/assessment and to truly understand the outcomes of these applications.

Part of that work involves enhancing the integration of AT into the lives of students with disabilities whether it be via (a) standards-based curricula and accommodations in statewide assessments, or (b) through the extension of evidence-based practices that show the effectiveness of AT in improving student learning. Consensus from the Summit focused on building/extending upon what we know about AT and its use with students with disabilities. As a field, we need to confront misinformation on the effectiveness of AT via further research. Likewise, we need to educate professionals on the impact of these applications and to confront biases and misconceptions that use of AT presents 'unfair' advantages.

Educating professionals, a frequently cited need prior to this Summit, was further reinforced and contextualized within the discussion of research. Thus, as we learn more on outcomes we need to share and offer illustrations of what is possible to teachers and other professionals. While the "how to" or operations of a particular application will continue to be important, Summit participants ask that we extend and improve the connection between curriculum and technology.

Finally, in this standards-based environment and what statewide assessments mean to educational funding, we cannot ignore the issue of cost-benefit if we are to enhance AT integration. It is not simply an issue of 'building and they will use' but rather one of 'developing and seeking to integrate solutions that enhance learning in a manner more effective than traditional means yet sensitive to finite resources.' Thus, as a field we need to further our understanding on AT outcomes, improve upon the dissemination of this information to key users, and do so in a cost-effective manner.

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Perspectives of Outcome Data from Assistive Technology Developers

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Abstract: The assistive technology (AT) field acknowledges that different stakeholders vary in their perspectives of service delivery outcomes. While the literature delineates consumers, caregivers and providers as stakeholders with distinct views, very little research documents these unique perspectives. This study reports on the perspectives of (a) research-based federally funded, and (b) commercial AT product developers. Developers who received federal funding in 2001 were queried on their outcomes methodologies. Also, a random sample of manufacturers drawn from the ABLEDATA database and technology exhibitors at RESNA and AOTA conferences were surveyed. The data revealed that developers acknowledge the usefulness of outcomes data and relate that they would use outcomes information if available. Commercial manufacturers perceived cost as different from other outcome dimensions, interestingly, with lower importance. Also, formal research methods were used more frequently than anticipated. This same group of commercial manufacturers also stated a gap between outcome measures they used and what they would use if available. This study contributes an important empirical snapshot of AT product developers and their perspectives of AT outcomes.

Key Words: Assistive technology outcomes, Product developers, Manufacturers

The Assistive Technology Outcome Measurement System (ATOMS Project) has undertaken a comprehensive needs assessment related to outcomes measurement and assistive technology (AT). This study surveyed the field to better understand how AT product developers and manufacturers view outcomes measurement. The field of AT outcomes has long recognized that there are various stakeholder views. DeRuyter (1998) stated that the clinical service delivery system must respond to several different performance monitoring dimensions: goals attainment/results; functional status quality of life; satisfaction; and cost. DeRuyter recognized that, "Each of these different dimensions in turn have varied significance to each of the different stakeholders, agencies, and sectors. While all stakeholders seek a successful outcome, not all stakeholders seek the same outcome" (p. 9). This discussion is followed with charts that delineate the perspectives of different stakeholders in terms of importance of various outcome dimensions and aspects of AT service. The "administrator," "client," "clinician," and, "payer" (DeRuyter, p. 11-12) are on the list, but "manufacturers" or "product developers" are not. Lane (1997a) stated that, "while we often focus on assistive technology service delivery, there is a business context that is equally important" (p. 105). Addressing the needs for AT outcomes requires the consideration of what outcomes mean to product developers. This paper reports the results of a research effort to meet this need.

Background

The federal government funds technology-related research and development projects through multiple sources. The Small Business Innovative Research Program (SBIR), the

Small Business Technology Transfer Research Program (STTR), the NIDRR sponsored Rehabilitation Engineering Research Centers (RERC), and technology-related Research and Development (R&D) projects funded by the Office of Special Education Programs (OSEP) exist to promote state-of-the art development of AT. These investigators need to measure the success of their products under development. Similarly, private sector manufacturers and developers must do the same. In 1998, DeRuyter stated,

> Whether it is doing things right the first time or doing the right thing, accountability, performance monitoring, and the evaluation of outcomes has become the expected norm. While this has been embraced widely for many years by manufacturing, it needs to be fully embraced by the assistive technology community. (p. 8)

Fuhrer (2001), however, suggests that developers struggle to find appropriate outcomes instruments and methodologies for their products. Fuhrer, Jutai, Scherer, and DeRuyter (2003) list a variety of factors that may contribute to the shortfall of AT outcomes as compared to the growth of the AT industry. They comment that one of these factors is that there is a "greater emphasis of AT developers on demonstrating the technical performance of newly developed technology than on evaluating users' performance with it" (p. 1244). The need is identified, but what actually is the state of outcomes measurement from the perspective of product development? There is a paucity of published work on this subject.

The literature describes the importance of consumer input in product development and consumer evaluation during technology transfer to improve products. Multiple authors have discussed the importance of consumer input in the development of AT (Batavia & Hammer, 1990; Ryan, Rigby, & From, 1996; Vernardakis, Stephanidis, & Akoumianakis, 1994; Wessels, Willems, & de Witte, 1996). Compton (1995) states that many manufacturers test their concepts qualitatively to see how consumers perceive a potential new product before it is even produced. Lane (1998) describes the participatory action research approach of the Rehabilitation Engineering Research Center on Technology Evaluation and Transfer (RERC-TET) at the University of Buffalo. The Center involved individuals with disabilities in all aspects of its work, from grant development to program implementation. Consumers contributed to the evaluation of inventions, device commercialization, and the definition of ideal products. This last step resulted in a benchmarking process for AT product development. Benchmarking involves developing evaluation criteria using a methodology. Lane explains the value of this work.

> Manufacturers may use them [the benchmarks] to improve the product's capabilities and gain the most return by focusing their design modifications in areas most important to the consumer. Vendors can use the benchmarks to emphasize desired attributes – and possibly down play undesirable attributes – when communicating their product's value to customers. (p. 115)

In discussion of the universal design process, Sanford, Story, and Ringholz (1998) also emphasize the importance of consumer inclusion. Such participation, they state, "has the potential to result in a number of outcomes that directly and indirectly benefit participants" (p. 161).

The European AT sector has also published discussions of the importance of user-centered design in AT. Poulson and Richardson (1998) describe the development of the USERfit design methodology in the UK:

> General consumer research has much to offer the assistive technology (AT) sector, and it is apparent that many AT companies now adopt a more marketing oriented approach to product development rather than a purely engineering perspective. AT companies are generally aware of the importance of understanding their customers wants and desires, but as yet many are not expert in obtaining such information from users or obtaining user feedback about the quality of their products (p. 163).

They go on to state, "It is a common weakness of [product] design that little emphasis is placed on evaluation activities, as it can be both difficult and expensive to carry out effectively" (p. 167). Consumer involvement in the design process, however, is not an outcome but a method by which it is hypothesized that better outcomes may be achieved.

Similarly, the process of technology transfer provides some relevant discussion around the issue of outcome measures for AT product developers. Technology transfer is the process of taking product designs through the manufacturing process to maximize the success of the device in reaching the consumer. But again, this is a method directed towards improving outcomes. By itself, it does not produce outcome data. Lane (1997b) describes the sequence of the technology transfer process: (a) identification (of a technology and application); (b) research and development; (c) evaluation (testing with one or more clients); (d) transfer (of the technology to a buyer); and (e) commercialization.

Evaluation of the product speaks to multiple aspects of AT outcomes. In an earlier publication, Lane, Usiak, and Moffat (1996) list consumer product evaluation criteria as: (a) reliability, (b) effectiveness, (c) physical comfort/acceptability, (d) operability, (e) physical security/safety, (f) durability, (g) learnability, (h) portability, (i) securability, (j) maintenance/reparability, and (k) affordability. Krass (1997) also writing on the issue of technology transfer, but from the perspective of one manufacturer, provides a detailed description of his company's (Maddak, Inc.) two-step evaluation process:

1. Initial evaluation:
2. Does the invention fit current product line?
    a. Product type
    b. Estimated retail price
3. Is the product unique?
4. Does it provide a clear benefit for users?
5. Does product match Maddak's manufacturing capabilities?
6. In-depth evaluation:
7. Who are the expected users?
8. What is the market size?
9. What is the competition?
10. Is it safe to use?
11. What is the manufacturing cost?
12. Is tooling required and what is the cost of it?
13. What is the acceptable retail price?
14. Do the manufacturing cost and retail price match up?
15. What is the estimated profit/year?
16. Can tooling costs be paid for with two year's profits?
17. Is it esthetically pleasing?
18. Is it patented?
19. What is the "hunch" factor?
20. What is the level of potential 'ownership'? (p. 57)

However, as Tobias (1997) states,

> As important as product development is to the business process, it is only one stage in a product's life cycle and one element in its success. Product design lies within a constellation of activities such as market analysis, marketing, advertising and customer support. (p. 63)

And so, as we look at the issue of outcomes measurement for the developers and manufacturers of AT, there is very little information available.

> Many within the assistive technology community have developed the assumption that better outcomes are derived simply through improved technological solutions such as smaller, newer, faster, more portable and more sophisticated systems. Consequently, technological solutions have been looked toward for improved outcomes without data to support the assumption. (DeRuyter, 1997, p. 90)

This investigation attempted to identify gaps in the current state of outcomes measurement instruments and systems in the area of AT product development targeting both federally funded and private sector development.

Research Questions

Six primary questions directed the framework for this study. One general question focused on federal research projects: (A1) What methods for collecting AT outcomes data do currently funded federal projects project to use? Five questions focused on commercial product developers: (B1) What importance do product developers place on outcome dimensions of AT? (B2) How frequently do product developers use specific strategies to measure outcome during development? (B3) How frequently do product developers use specific types of formal instrumentation to quantify outcome? (B4) How do product developers perceive the appropriateness of different types of standardized instrumentation? (B5) How would product developers use valid outcome data?

Methods

Sample

Two samples were tapped to cover the two question domain areas.

Sample (A): Federally funded projects. Two sampling methods identified federally funded projects. First, we examined the Computer Retrieval of Information on Scientific Projects (CRISP) database maintained by the Office of Extramural Research at the National Institute of Health (n.d.) on "assistive" and "assistive technology." The search selected 32 appropriate projects. Second, the NIDRR Program directory web page (National Rehabilitation Information Center, n.d.) listed 61 records for their category "Research Priority: Technology for Access and Function." A review of these abstracts identified 24 appropriate projects. In all, 56 projects were identified (with 3 researchers having two funded projects each) to make up the federally funded product developers group.

Sample (B): Commercial product developers. Two methods were used to identify the commercial product developer group. The first method randomly sampled the "Directory of Manufacturers and Distributors" available on May, 2002, at the ABLEDATA (n.d.) website that provided a population of commercial product developers. It contained more than 2,500 listings. Prior to random selection, the list was limited to companies in the U.S. that were coded as (a) active, and (b) manufacturers. They totaled 1,124. From this, a statistical analysis software program generated a random sample of 500. The second method identified all U.S. based technology exhibitors from the RESNA 2001 Conference (*n* = 33) and the American Occupational Therapy Association (AOTA) 2001 Conference (*n* = 35). Some manufacturers exhibited at both conferences. The random sample (*n* = 500) was crosschecked with the exhibitor lists (*n* = 68), removing duplicates, for a final set of 555 companies.

Procedures

Procedure (A): Federally funded projects. Due to the proprietary nature of much of the content of grant proposals, only the abstracts were available as public information. To obtain the necessary information, the project sent the 53 identified principal investigators a letter explaining the purpose of the study and requesting the methodology to test the outcomes of their product(s) under development that was submitted with their proposal.

Procedure (B): Commercial product developers. The survey sent to commercial product developers (see Appendix) was drafted based on findings from the AT service provider and consumer/user focus groups (Taugher, 2004) and suggested by the literature set, some of which is cited in this paper.

Results

Descriptive analyses of results are presented separately for each of the two groups surveyed as the groups and survey methodology differed.

(A) Federally funded projects. Overall, the federal project survey obtained a 50% response rate. (Four letters were returned as undeliverable.) Questions were coded to

Table 1
Percentage of Methodology and Instrumentation Choices for 26 Funded Projects

Strategy/Method	% of uses
Strategies for measuring outcome during product development	
Testing in lab by developers	27%
Focus groups of providers	12%
Focus Groups of persons with disabilities	15%
User usability testing in lab	23%
General field testing soliciting feedback from persons with disabilities	19%
General field testing soliciting feedback from providers	12%
Formal research design: Single Subject design	35%
Formal research design: Group comparison	58%
Other	0
Use of formal instrumentation	
Standardized, valid measure of functional status	70%
A “homemade” or adapted measure of improved functional performance	62%
A measure of client satisfaction	23%
A measure of cost	15%
Other	0

correspond to the strategies for measuring outcome and types of measures, as were presented in the commercial developers' survey (see Appendix, Question #3 and reported in Table 1). Due to the number of variables and complexity of the development process it was not uncommon for a reviewed project to cite more than one method or type of instrumentation. Nine different strategies or methods were identified as being used by these developers, with formal group designs being the most frequent, occurring in 58% of the projects. Two methods that sampled providers rather than consumers were the least frequently occurring, at 12% each. Regarding formal instrumentation, the use of standardized measures (used in 70% of the studies) slightly eclipsed the use of "homemade" or adapted measures (62%). No respondents reported themselves as using "other" instrumentation. This demonstrates an element of the validity of these categories established during the ATOMS service provider focus group process. See Table 1 for the distribution of responses.

(B) Commercial product developers. Of the 555 mailed surveys, 135 were returned as undeliverable. Of the remaining 420 surveys, 10 individuals responded that they were no longer involved in production of AT devices or that they did not wish to participate. A total of 40 competed surveys were returned. The overall response rate was 12%. Interestingly, in 2003, the U.S. Department of Commerce Technology Assessment of the U.S. Assistive Technology Industry received a similar response rate. It mailed 1,600 surveys and received only 232 responses, or 14.5% initially.

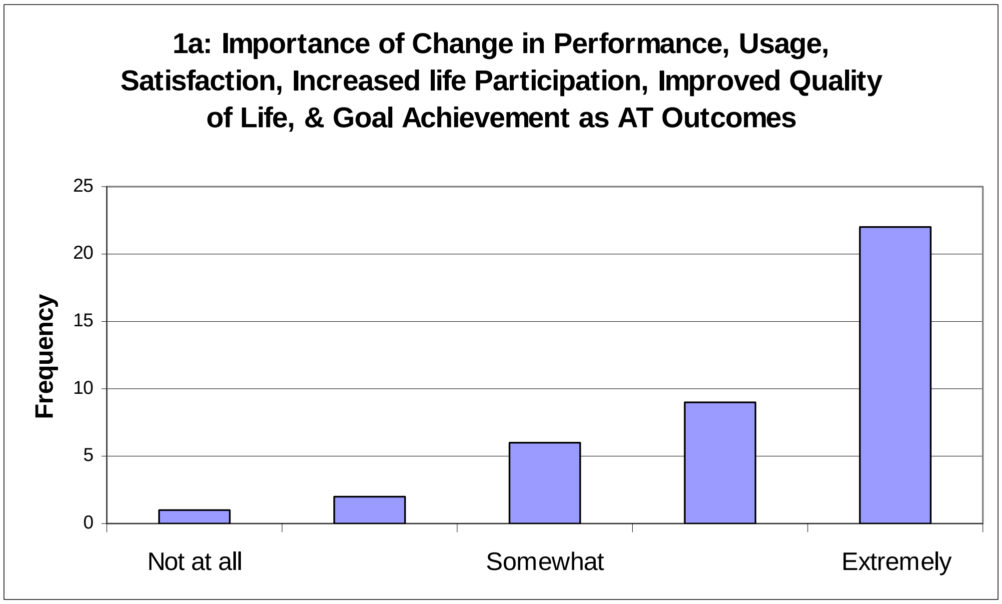
This low response rate was perplexing, but careful scrutiny provides a plausible explanation. It appeared that two different types of companies were reached through our sampling efforts. Indeed, the ABLEDATA (n.d.) Directory of Manufacturers and Distributors contains many companies who do not specialize in adaptive equipment (3M Co., Kohler Co., L.L. Bean, and Union Carbide Corporation, to list a few). It would not be surprising that these companies would not be motivated to respond to a survey about AT outcomes. Could we distinguish disability-focused companies and if we could, would that help explain the low response rate?

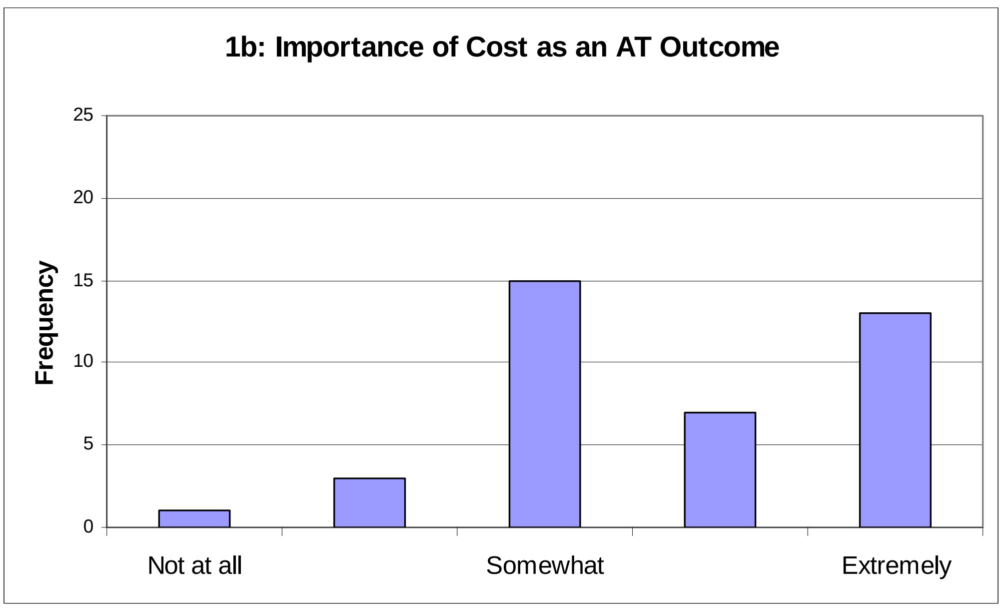
We first examined the origin of the 40 completed surveys to determine if they came from companies that were identified from the random sample of ABLEDATA (n.d.) companies or if they came from the specifically selected conference exhibitors. In fact, 38% (*n* = 15) of the 40 completed surveys came from companies that had exhibited at either the AOTA or RESNA annual conferences in 2001.

Table 2
Percent of Survey Response by Type of Company

Company Type	Responded	No Response
Disability Manufacturers	38%	62%
Non-Disability Manufacturers	9%	91%
Total	12%	88%

Figure 1. Distribution of product developers' responses for importance of AT outcomes. Six of seven categories show distributions similar to 1a. The importance of Cost (1b) demonstrates the seventh, a bi-modal distribution.





Secondly, we wondered if any companies in our sample, the 555 mailed surveys, were members of the Assistive Technology Industry Association (ATIA). We retrieved the membership list from the ATIA Web site to see if any of the companies in our sample were members. From the original mailing of 555, 15 of the surveys were sent to companies that belonged to ATIA. Two of these were returned as undeliverable. Five surveys (38%) were returned from the remaining 13 companies.

We then combined the identified exhibitor companies and the identified ATIA companies, removing duplicates, to form the

Table 3
Mean Responses to Importance of Specific AT Outcomes, Product Developers

Category	M
Change in performance or function	4.5
Cost	3.7
Usage: Why or why not used	4.2
Consumer satisfaction	4.6
Increased life participation	4.2
Improved quality of life	4.4
Clinical result/goal achievement	4.1

new category "disability manufacturers." The remaining companies became "non-disability manufacturers." See Table 2 for percentages of response rate for these two categories. Clearly, it appears that companies that are actively involved in marketing to professionals in the AT service delivery system and who are active in developing AT are more likely to take part in research regarding AT outcomes.

Descriptive statistics, as appropriate, were performed on the survey responses with SPSS (Statistical Package for the Social Sciences) version 11.5 for Windows. Data are discussed in order of the research questions delineated earlier.

1. What importance do commercial product developers place on outcome dimensions of AT? Respondents were asked to rate seven outcome dimensions of AT on a scale of "not at all important" to "extremely important."

Table 4
Frequency of Methodology Use, Product Developers

Methodology	Not at all	Less than half of the time	More than half of the time
Testing in lab by developers	12.5%	12.5%	75%
Focus groups of providers	25%	30%	44%
Focus groups of persons with disabilities	17.5%	32.5%	48%
User usability testing in lab	22.5%	22.5%	55%
General field testing soliciting feedback from persons with disabilities	10%	15%	75%
General field testing soliciting feedback from providers	20%	17.5%	62%
Formal research: Single-subject design	45%	15%	35%
Formal research: Group comparison design	45%	10%	37%
Other	0%	0%	0%

Table 5
Frequency of Use of Formal Instrumentation During Product Development for Commercial Product Developers

Instrumentation	Did not use	Less than half of the time	More than half of the time	Total
Standardized measure of functional performance	47.5%	12.5%	40%	100%
A "homemade" or adapted measure of improved functional performance	35%	15%	50%	100%
A measure of client satisfaction	25%	7.5%	67.5%	100%
A measure of cost	20%	22.5%	57.5%	100%
Other	0%	0%	0%	0%

Again, the seven categories evolved from the focus group process mentioned earlier, and correlate with DeRuyter's (1998) categories. The categories were: (a) change in performance of function, (b) cost, (c) usage-why or why not used, (d) consumer satisfaction, (e) increased life participation, (f) improved quality of life, and (g) result/goal achievement. The histogram of response to the category "Increased Life Participation" is shown in Figure 1a. It demonstrates the similar pattern of response that was observed for six of the seven categories. Cost, however, demonstrated a significantly different pattern with a bi-modal distribution, as demonstrated in Figure 1b.

Table 3 lists the mean responses to all categories in this question. While the mean score for the importance of cost is slightly lower than for the other categories, the bi-modal distribution of this variable suggests that the importance of cost as an outcome is important, but not for everybody.

2. How frequently do commercial product developers use specific strategies to measure outcome during development? Table 4 lists the frequency reported by the commercial product developers for their use of specific strategies. Formal research designs are the least frequently employed strategies for the commercial developers group. The results are not surprising as commercial companies may not have research-trained staff in-house. Consultation is costly. While it is difficult to compare the results of the open needed question responses of the federally funded researchers with the Likert-like scale responses from the survey, the PIs reported using single-subject designs 36% of the time and group comparison designs 58% of the time (see Table 1). Interesting, however, was one comment from a respondent from the federally funded group. That researcher, receiving SBIR funding, complained about how difficult it was to set up a solid research design to meet the requirements of the grant. She felt strongly that there are not adequate resources available for small businesses to achieve consulting services at reasonable costs.

3. How frequently do product developers use specific types of formal instrumentation to quantify outcome? Table 5 contains the aggregated response data from the question, "If you have used formal instrumentation as a form of quantifying outcome during product development, how frequently have you used…?" for those who responded that they used formal instrumentation.

Not surprisingly, commercial manufacturers infrequently use standardized measures. This is compared to a 70% use rate for the federally funded projects (see Table 1). Clearly, client satisfaction dominated as the type of instrumentation used by the commercial developers group,

Returning to the issue of cost, it is interesting that cost is reported as being used so frequently, despite it's low ranking on the importance dimension (commercial product developer research question #1, above). Considering that the survey question asks about use of formal instrumentation, it could be argued that cost data is much easier for commercial manufacturers to obtain.

4. How do product developers perceive the appropriateness of different types of standardized instrumentation? Figure 2 shows the commercial product developers' responses to the question, "If standardized instrumentation were available for each of the following outcomes. How appropriate would each of the following be for your product development?

Commercial product developers felt that self-satisfaction measures, cost measures, functional performance measures and focus group protocols would all be appropriate measures for them if standardized instrumentation were available. The mail and survey measures were not considered as useful. These findings reflect the "hands-on" perspective of manufacturers with less of a mandate for longer-term follow-up, presumably the function of mail and telephone surveys. Figure 3 shows the rank ordering of the categories when focusing only on those who responded "always" for potential use of each of the types of standardized instrumentation. It appears that standardized instrumentation for change in functional performance would be useful for product developers.

5. How would product developers use valid

Figure 2. Appropriateness of each type of standardized instrumentation, if available, for commercial product developers

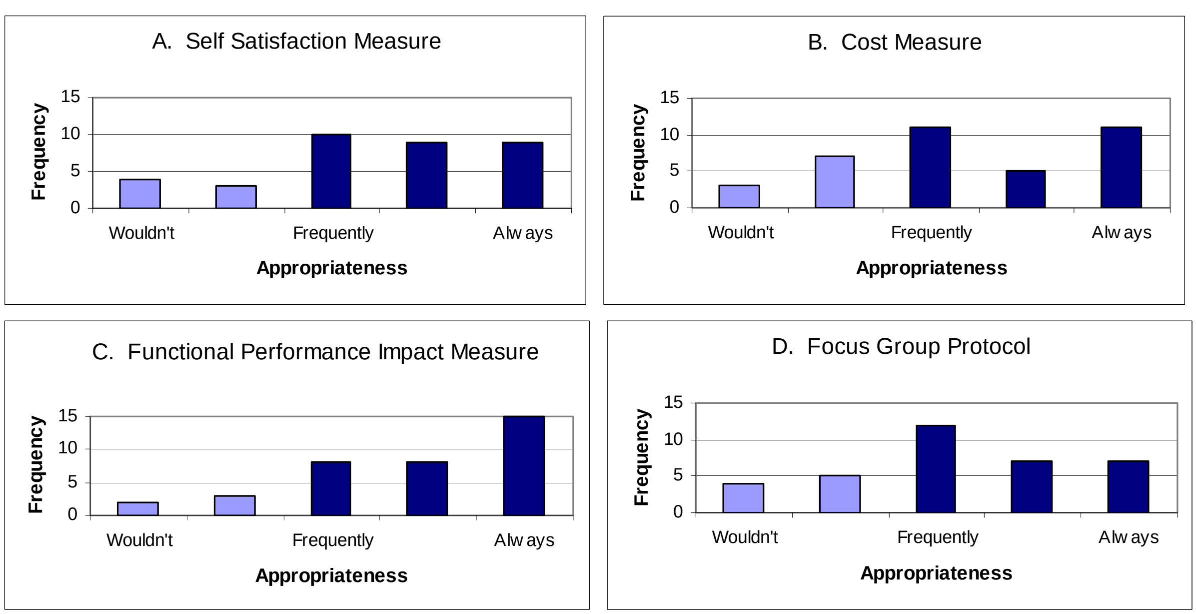
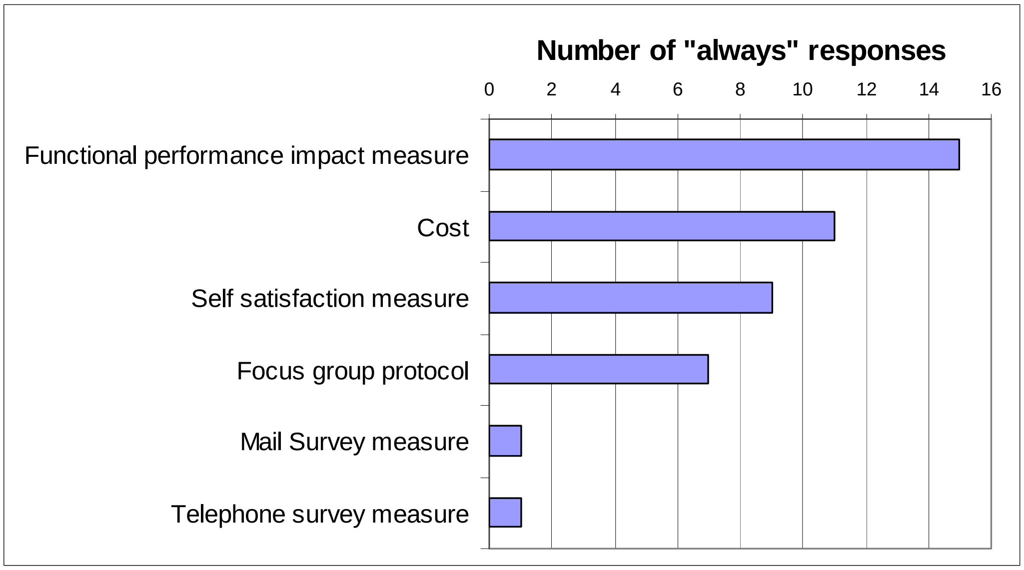


Figure 3. Number of product developers responding "always" (giving a score of 5) for potential use of each type of standardized instrumentation if available



outcome data? Figure 4 shows the distribution of responses to the question, "If you had valid outcome data about your products, how likely would you be to use it for the following business purposes?" The lines on each graph separate the responses and form two general categories, "wouldn't be used much" and "would be used a lot."

This shows that if valid outcomes data were available, commercial product developers would most likely use it for advertising and product development. It does not appear that there is a strong interest by this group to use it for funding or monies acquisition.

Discussion, Outcomes, and Benefits

This study investigated the current use of outcomes measures by two groups of AT developers, those who received federal funds for their development projects and those who developed AT within their businesses without federal support. The analysis of federally funded investigators was based solely on what they defined in the evaluation plans of their federal grant proposals that received funding. Commercial developers of AT provided specific survey data on their use and perception of outcomes measures. Perhaps one of the most surprising findings was the response of the commercial product developers to the importance of cost as an AT outcome dimension. While cost would seem to be overt and prominent in a business setting, the descriptive data demonstrates that commercial manufacturers saw cost as different from the other outcome dimensions. Its bimodal distribution demonstrates a lower importance for cost as an outcome. Also, the reported use of formal research design methods and data collection was more prominent than what we thought to be the case for "inventors." Finally, for the commercial respondents there is a gap between what outcomes measures they would use, if available, and what they currently use. This appears to be a technology transfer problem. Outcome instruments do not appear to be making their way to the commercial sector. Maybe this reflects the relatively young age of outcomes instrumentation and that many outcomes instruments remain in the research and development phase.

Figure 4. Commercial product developers likelihood of use of valid outcomes data if available

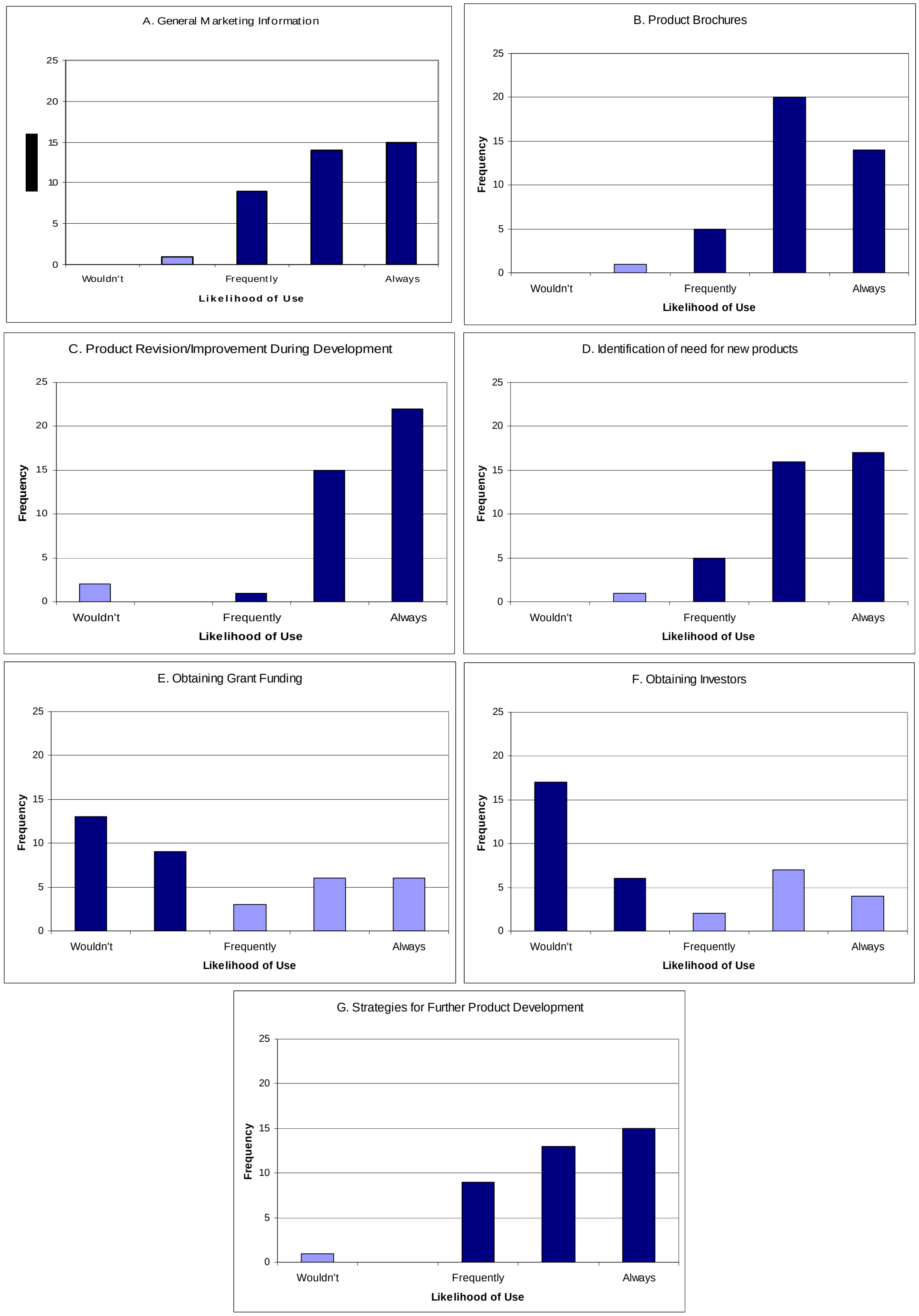


Table 6
Comparison of Objective (Funded Proposals) and Subjective (Commercial Developers) Data

Strategy/Method	Objective of Use[1] %	Subjective Report of Use[2] %
Strategies for measuring outcome during product development		
Testing in lab by developers	27%	87.5%
Focus groups of providers	12%	72.5%
Focus groups of persons with disabilities	15%	80%
User usability testing in lab	23%	77.5%
General field testing soliciting feedback from providers	19%	90%
General field testing soliciting feedback from providers	12%	77.5%
Formal research design: Single subject design	35%	47.5%
Formal research design: Group comparison	58%	42.5%
Other	0	0
Use of formal instrumentation		
Standardized, valid measure of functional status	70%	52.5%
A "homemade" or adapted measure of improved functional performance	62%	65%
A measure of client satisfaction	23%	75%
A measure of cost	15%	80%
Other	0	0

[1]Reported in federally funded proposals
[2] Commercial product developers survey

A post hoc comparative analysis of the data from funded R&D projects and commercial developers reveals interesting differences, but must be read with caution. Two different methods were used to gather the information in this project. The federally funded developers submitted the actual "methods" section from their grant proposals. We have no evidence that these are the methods they actually used as their projects evolved; it speaks only to their planned evaluation process intent. The commercial product developers, however, responded to a survey with Likert-like response scales, thus providing a subjective response to the questions as they have dealt with the questions in their businesses over time. Accepting these differences, we created Table 6. Data from the federally funded proposals are exactly as they appear in Table 1. To obtain the numbers for the commercial developers, we subtracted the percentage of "not at all" responses (Tables 3 and 4) from 100% to obtain the numbers in the right hand column of Table 6. Some interesting comparisons appear. Clearly, during product development for the federally funded researchers, there is a dearth of consumer or service provider input. This represents a rich source not being tapped without input from AT device users. Also, the instrumentation data for this group demonstrates a proclivity for performance, a somewhat myopic perspective of outcome. While these comparisons are presented for discussion purposed only, they are a reminder of the fact that a comprehensive model of AT outcomes information must consider both objective and subjective data.

A limitation of this study was the low response rate for the commercial product developers. Compared to federally funded projects, commercial developers did not use standardized methodology or instrumentation as frequently. However, they did express an interest in outcomes. The reporting of the use of homemade measures of functional performance and client satisfaction measures represent their current efforts to keep the consumer in mind as they advance their technological solutions. They acknowledge that standardized outcomes data would be useful and relate that they would use standardized outcomes data if it was available.

This investigation is an important first step in understanding the perspectives of AT developers toward outcomes. AT outcomes measurement activity has been a relatively new phenomenon and publications and discussions on AT instruments have only occurred in the past decade or so (Smith, Rust, Lauer, & Boodey, 2004). Their AT outcomes historical review highlights the impressive increase of attention in AT outcomes instrumentation. In future research it would be beneficial to specifically target disability manufacturers to attempt to improve response rate. Additionally, using the same survey methods for both groups would allow for reliable comparisons between the two groups. Finally, the data clearly point to the need to target research and development of AT outcomes instruments to and for product developers.

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Filling out this survey indicates that I am at least eighteen years old and I am giving my informed consent to be a participant in this study.

ATOMS

Product Developer AT Outcomes Survey

1. Please list up to 3 products you have recently developed or have in process.

2. The following are outcome dimensions of assistive technology. Please rate how important you believe each one of these dimensions is for product outcomes.

	Not at all Important		Somewhat Important		Extremely Important
Change in Performance or Function	1	2	3	4	5
Cost	1	2	3	4	5
Usage: Why or why not used	1	2	3	4	5
Consumer Satisfaction	1	2	3	4	5
Increased Life Participation	1	2	3	4	5
Improved Quality of Life	1	2	3	4	5
Clinical Result/Goal Achievement	1	2	3	4	5

Categories from ATOMS Service Directors Focus Group, April 2002

3. How frequently have you used any of the following strategies to measure outcome during your process of product development?

	Not at all		Half of the time		All of the time
Testing in lab by developers	1	2	3	4	5
Focus groups of providers	1	2	3	4	5
Focus groups of persons with disabilities	1	2	3	4	5
User usability testing in lab	1	2	3	4	5
General field testing soliciting feedback from persons with disabilities	1	2	3	4	5
General filed testing soliciting feedback from providers	1	2	3	4	5
Formal research: Single subject design	1	2	3	4	5
Formal research: Group comparison design	1	2	3	4	5
Other: ____________________	1	2	3	4	5
__________________________	1	2	3	4	5

4. If you have used formal instrumentation as a form of quantifying outcome during product development, how frequently have you used

	Not at all		Half of the time		All of the time
a standardized, valid measure of functional status?	1	2	3	4	5
a "homemade" or adapted measure of improved functional performance?	1	2	3	4	5
a measure of client satisfaction?	1	2	3	4	5

a measure of cost?	1	2	3	4	5
other? ____________________	1	2	3	4	5

5. If standardized instrumentation were available for each of the following outcomes, how appropriate would each of the following be for your product development?

	Wouldn't		Frequently		Always
Product self-satisfaction measure	1	2	3	4	5
Cost measure (device, acquisition, fitting, learning)	1	2	3	4	5
Functional performance impact measure	1	2	3	4	5
Focus group protocol and group survey measure	1	2	3	4	5
Mail survey measure	1	2	3	4	5
Telephone survey measure	1	2	3	4	5
Other: _________________	1	2	3	4	5
Other: _________________	1	2	3	4	5

6. If you had valid outcome data about your products, how likely would you be to use it for the following business purposes?

	Wouldn't		Frequently		Always
General marketing information	1	2	3	4	5
Product brochures	1	2	3	4	5
Product revision/improvement during development	1	2	3	4	5
Identification of need for new products	1	2	3	4	5
Obtaining grant funding	1	2	3	4	5
Obtaining investors	1	2	3	4	5

Strategies for further product development	1	2	3	4	5
Other: ____________________	1	2	3	4	5

Thank You!
Please use the enclosed postage-paid envelope to return your completed survey.

A Case Study Model for Augmentative and Alternative Communication Outcomes

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Abstract: Case studies are an accepted method for reporting treatment outcomes. However, to be useful and authentic, a systematic and principled approach to collecting, analyzing, and reporting case data must be observed. This paper proposes a basic case study format for documenting augmentative and alternative communication (AAC) intervention to ensure reliable and valid measurement of performance and outcomes for evidence-based practice. An example case study of an adult with cerebral palsy who relies on AAC is presented to show how the principles of evidence-based practice (EBP) and performance measurement were applied to the AAC assessment process. AAC service delivery requires performance and outcomes measurement to lead to effective communication and improved quality of life. Reliable and validated methods of reporting data allow for consistency and the comparison of performance and outcome measures so decisions are not based on impressions of effectiveness, but actual results.

Key Words: Augmentative and Alternative Communication (AAC), Evidence-Based Practice, Performance measurement, Outcomes measurement, Quality of life

"*First study the science, then practice the art.*"

-Leonardo Da Vinci

Introduction

Augmentative and alternative communication (AAC) teams with experience are aware that the assistive technology (AT) field has surprisingly little quantitative data regarding what is effective. Many treatment approaches and technologies in common use have never been evaluated, and many others that have been evaluated remain of uncertain benefit (Frattali, 1998). The growth in evidence-based practice (EBP) has made AAC teams aware of the importance of performance and outcome measures. Initially developed in the area of medicine, EBP is now part of every health care discipline and professional education program (Law, 2002). For AAC stakeholders, an important impetus for EBP has been the growing awareness of the limitations of expert opinion as the sole basis for decision making as indicated in the Technical Report on evidence-based practice released by the American Speech-Language-Hearing Association (ASHA, 2004a). Teams applying the principles of EBP require data that have been collected and analyzed using reliable, valid, and scientific methods.

Case studies provide a principled approach to reporting performance and outcome measures that have been accepted by the scientific community. Although case study data are not the highest level of evidence that can be collected and appraised to support decisions about AAC interventions, in some circumstances, a case study may be the best available evidence for a specific client

(Schlosser, 2004). The difficulty in conducting research studies with large numbers of participants due to the heterogeneous nature of individuals with disabilities may amplify the importance of reporting case study data for the field. Consequently, developing a model for reporting case study data for AAC performance and outcomes provides a standard to compare published and presented reports. By following a standard reporting format, AAC stakeholders can readily compare performance and outcome results, be confident that the data reflect similar standards of measurement, and find appraisal of evidence more convenient and efficient.

Improvement in quality of life is often stated as the ultimate outcome in rehabilitation services (Pain, Dunn, Anderson, Darrah, & Kratochvil, 1998). Individuals and families frequently regard maximizing potential and independence as an important outcome. When surveyed, individuals with disabilities and family members expressed a clear sense to be "the best they could be" (Pain et al.). Individuals with significant communication disabilities desire these same outcomes by achieving the most effective, independent communication. The Preferred Practice Patterns for Speech-Language Pathology document indicates that an AAC assessment is to determine and recommend methods, devices, aids, techniques, symbols, and/or strategies to represent and/or augment spoken and/or written language in ways that *optimize communication* (ASHA, 2004b). Measuring performance that leads to optimal communication, and reporting outcomes that document achieving optimal communication are expected of AAC teams conducting AAC assessment and intervention. Consequently, no additional knowledge and skills are required for case study reporting, and these skills are consistent with general AAC service expectations.

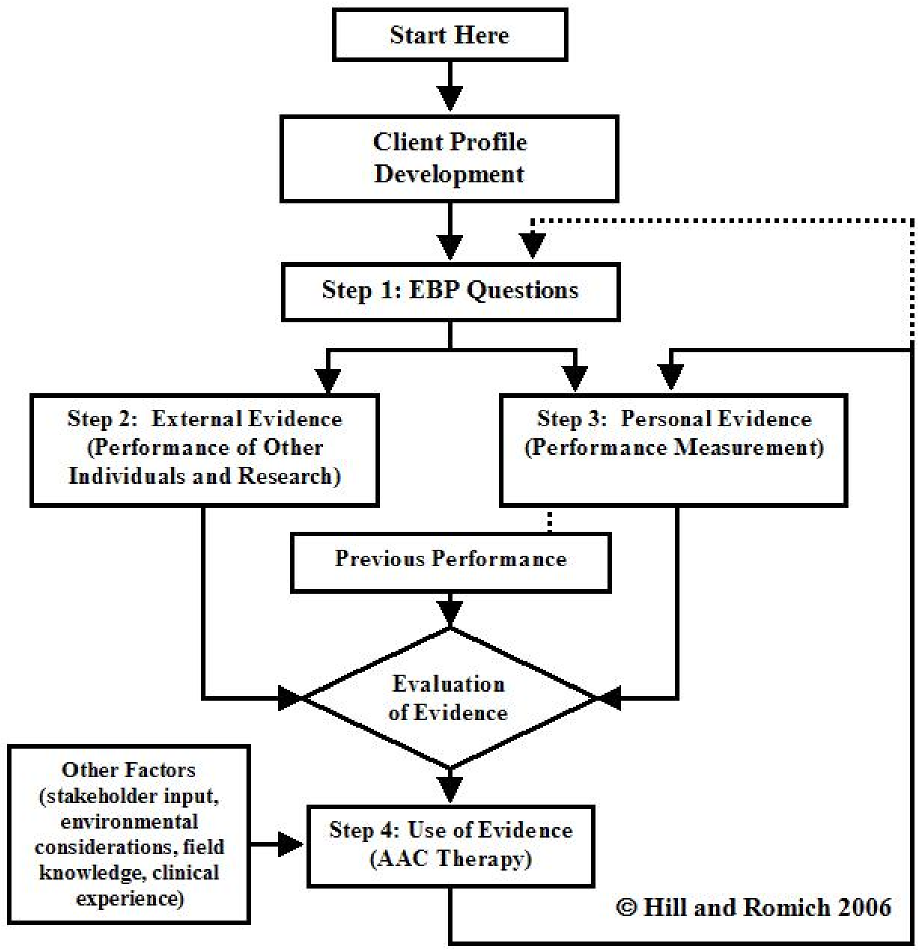
Case Study Reporting Format

The case study method developed out of clinical case histories. A case study, however, is more rigorous then the case history in making systematic observations and measurement. In addition, a case study is different from a single-subject research study in that it does not involve manipulation of any independent variables (Heiman, 1995). A thorough description of the individual, clinical problem, related conditions and variables set the foundation of a case study. Clinical practice stresses the potential power of clinical observations and the magnitude of characterizing the patient (Sackett, Haynes, Guyatt, & Tugwell, 1991). Therefore, detailed client profiles are required as a foundation for case studies to have clinical value and in order to move through the EBP process. The components of a client profile include basic or standard case history data (Alvares, 1998; Paul, 2002) in addition to data expected to be collected in a comprehensive AAC assessment (ASHA, 2001; Lloyd, Fuller, & Arvidson, 1997). Teams requesting third party funding for a speech generating device (SGD) will be documenting such information as hearing, vision, physical status, speech, language and cognition as listed in the client profile already.

A Process for Evidence-Based Practice

Figure 1 depicts a model for AAC evidence-based practice, which provides the framework for collecting and reporting case study data for field dissemination (Hill & Romich, 2002). The first section of the case study starts by reporting observations taken from characterizing the individual as part of client profile development. This client profile allows other practitioners and teams to compare their client with the client reported in the case study. The next sections of the case study report on the methods and results of collecting and analyzing data following the four steps of evidence based practice: (a)

Figure 1. Model for AAC evidence-based practice. Source: AAC Institute Press, 2006. Used with permission.



asking meaningful EBP questions; (b) locating and reviewing the external evidence; (c) collecting and reviewing the personal evidence; and (d) using the evidence for assessment and intervention (Hill, 2004). The model illustrates how the steps of EBP identified by Sackett and colleagues (1991, 1996), and others, when followed, provide for the collection of external evidence and evidence at personal level needed for decision-making.

The EBP steps in the model that follow creating the client profile are defined below along with the importance of the clinical summary for reporting case studies.

Step 1: Questions

Teams formulate the most meaningful questions based on the problems of the client. Teams need to pose specific questions of importance or questions that are considered vital to making a decision about treatment. Questions that are not client-oriented or well-formulated may fail to identify the best evidence to evaluate and apply to the decision-making. EBP questions form the basis for being able to use "client-oriented evidence that matters."

Step 2: External Evidence Review

Teams search and appraise (evaluate) the research that answers the most important questions posed. The search process frequently involves Internet resources and electronic searches for efficiency and time savings. Teams are committed to searching fairly and honestly for disconfirming and confirming the evidence (Gibbs, 2003). Research on clients with similar profiles to the client in question that reports specific performance and outcome measures are particularly valuable as evidence. External evidence containing quantitative data can provide the reference points to gage the success of intervention with a client. Gathered research is evaluated based on levels of evidence with the highest levels of evidence identified as peer-reviewed randomized controlled trials. However, studies at lower levels of evidence can be used and justified when limited research is available. The key is not to simply find related research studies, but to identify research that the team finds most relevant and meaningful for decision-making. Teams providing results of external evidence searches provide useful information for others to consider and for teams seeking research on similar questions.

Step 3: Personal Evidence

Personal evidence includes having the client and family identify their values, goals, and expectations related to quality of life and use of AAC devices and strategies. Personal evidence also includes collecting performance data on how someone uses AAC devices and strategies. This step provides for the reporting of baseline data prior to initiating any changes to current status. Without performance data, teams cannot compare a client with the subjects in the research studies found from a search or monitor the implementation of the recommended intervention(s).

Step 4: Use of Evidence

This step involves monitoring the progress or results of implementing the recommended intervention(s). The performance and outcomes data selected and reported as baseline data are collected, analyzed, and reported to make decisions about the success of the decisions by the team. When data are being routinely reported, timely adjustments and modifications to any AAC intervention can be made to ensure the client is achieving maximum benefit from the intervention.

Clinical Summary

Reporting of the performance and outcome measures at the end of the intervention period or at a predetermined time as in the annual individualized educational program (IEP) meeting for students receiving special education allows team members to draw conclusions and discuss the benefits and any problems with the recommended methods and approaches. The summary highlights the key findings that resulted from the EBP process for other teams to gain from the experience of the reporting team.

EBP assumes that practitioners will evaluate the evidence, and use the best evidence that will provide the most benefit to the client. Once an intervention is started, then careful monitoring of the intervention is required to document performance and outcomes. Sackett, Richardson, Rosenberg, and Haynes (1997) and Schlosser (2004) discuss the dissemination of results as a part of the EBP process. This sharing of case evidence advances the knowledge base for assessment and treatment that may be applied to clients with similar profiles. The case study format presented in this paper provides for reporting conclusions about the specific decision-making process and a summary of the results. Appendix A provides an example of information and data for clinical practitioners to complete the AAC Case Study Performance and Outcomes Summary Form. The purpose of this paper is not to provide a model specifying research designs, methodology and statistical analysis, but rather to provide a practical approach for AAC teams to maintain consistent, systematic documentation for routine clinical and educational application of the principles of EBP for reporting and dissemination.

Exemplary AAC practice becomes an ongoing process in which data are collected and information is gathered to make intervention and management decisions (Lloyd et al., 1997). This expectation goes beyond anecdotal or testimonial reporting of outcomes that frequently occur when promoting or marketing clinical programs and products. Case study reporting of the evidence used in applying the four steps of EBP should document the methods and operational processes involved so others duplicating any intervention can expect similar results.

A Case Study

The following case study is used as an example for this format. Primary emphasis is placed on the decision-making process for a high-technology AAC intervention using the approach presented in Appendix A. Depending on the referral, other case studies may focus on unaided or low and light technology AAC interventions.

Characterizing the Client

Brent was a 22 year-old sophomore in college when referred for AAC services to explore interventions to improve communication, particularly related to academic performance. He had a high school diploma and associate degree in accounting from another college when he transferred into a four-year university degree program. A review of high school and college transcripts, medical records, and documents that included standardized testing from the Office of Vocational Rehabilitation was used to report and confirm basic background history and abilities. Standardized screening confirmed no hearing or visual acuity problems, and oral and written language samples confirmed linguistic and communication competencies.

Brent was having difficulty completing communication tasks typical of classroom interactions, group projects, and faculty conferences. Brent was diagnosed with cerebral palsy characterized by severe spastic quadriplegia. He had limited vocalizations with no intelligible speech. Brent used a power wheelchair with joystick control for mobility. He used a desktop computer with standard keyboard for homework and email. A high technology AAC system recommended in high school was mounted to his wheelchair. Brent used an alphabet-based page with a QWERTY configuration for spelling and word prediction on a touch screen AAC system. He could navigate to a few customized pages based on activities of daily living and topics of conversation. Although a university program for students with disabilities made the referral for an AAC re-evaluation, Brent recognized that his current methods of communication were not meeting his needs and were not reflective of his abilities and potential. Both university officials and Brent feared that withdrawal was unavoidable, since Brent was having difficulty completing assignments and mid-term grades were poor. Brent became the central team member driving and approving the AAC services. His active participation in the assessment process was reflective of a consumer-centered service delivery model (Hill, Lytton, & Glennen, 1999).

Information about Brent's values and needs about his communication were identified and discussed. Brent's values were consistent with the goal of AAC, since he desired to be a "faster, more efficient" communicator. He indicated that he did not appreciate having his messages finished or "guessed" by other people, however, he understood that he took a long time to spell his messages. Finally, Brent expressed a strong preference for using his own words rather than pre-stored sentences. He said that he rarely navigated to the pre-stored messages set-up in his device.

Step 1: Questions

In order to be meaningful, EBP questions must support the values of the individual. Brent's values included (a) optimizing communication rate, and (b) generating his own sentences. His goal was for his communication performance to support continuing his university education. A variety of resources are available to support structuring EBP questions, and practice is needed to pose specific questions that are vital to a client's welfare (Gibbs, 2003). Well-built questions contain elements that are client-oriented, are practical, and facilitate the evidence search (Sackett, Richardson, Rosenberg, & Haynes, 1997).

Based on the information gathered during the clinical examination to characterize Brent and his identification of values and goals, the following EBP questions were formulated: (a) Is Brent's communication rate as fast as others of similar profile? (b) Is Brent's use of alphabet-based approaches the most effective language representation method possible? and (c) Is Brent's use of a touch screen, page-based display the most effective technology solution?

Step 2: External Evidence Review

As professionals identified research to support decisions required by Step 2, Brent was involved in searching for and appraising evidence from other sources, which included Internet resources. He joined the Augmentative Communication On-Line User Group (ACOLUG; links to ACOLUG as well as other AAC resources such as Achieving Success in AAC can be found at the AAC Institute web site at http://www.aacinstitute.org .) and observed other adults who rely on AAC.

Brent and his AAC team reviewed the external evidence. Table 1 summarizes the research appraised to support decisions about AAC systems to evaluate. Research on the communication performance using AAC touch screen technology based on individuals similar to Brent's profile was non-existent. Other research on AAC touch screen page-based displays did not strongly support use of this technology for interactive communication. The human factors research indicated that page-based displays might not lead to automaticity, and could decrease accuracy in target selection as the array changed.

Available performance data of individuals with similar profiles to Brent indicated that, using AAC systems with all three language representation methods, Brent could expect to achieve an average communication rate of 12 words per minute with a peak communication rate up to 47 words per minute. In addition, research shows significant differences in communication rate among the AAC language representation methods (LRMs) with semantic compaction as much as 6 times faster than spelling and word prediction (Hill, Holko, & Romich, 2001). Brent's search of the evidence led him to the conclusion that he wanted to explore a hybrid AAC device that supported all three language representation methods along with trials with alternative selection techniques.

Table 1
Research Studies Pertinent to AAC Touch Screen Systems

Authors	Participants	AAC System or Equipment	Results
Estes & Wessel (1966)	20 undergraduate Stanford students	Monitor with 8, 12, 16 letter display sizes	Advantages to reduced amount of visual information that needs to be processed by operator for accuracy and response time.
Mirenda (1985)	Review of students nonverbal, severely handicapped, yet physically able-bodied	Pictorial (single meaning picture) systems, ie communication book design and layout.	Reduce amount of visual information.
Mizuko, Reichle, Ratcliff, & Esser (1994)	Normally developing 4-yr-old children	Prentke Romich Express 3 with Picsyms. Comparing accuracy on 10, 20, 30, 40 location array size.	Having fewer symbols from which to choose in a fixed display resulted in increased accuracy.
Reichle, Ettling, Drager, & Leiter (2000)	Single-subject case study of experienced augmentative system user	Compared fixed, dynamic active, and dynamic passive displays.	Response time was the fastest and accuracy was the greatest for the fixed and dynamic active display types.
Hill (2001)	Twenty adults who rely on AAC, one subject used Vanguard	Collected language samples for 2 contexts.	Reported variety of summary measures and performance outcomes. Results available for adult who relies on Vanguard.
Drager, Light, Speltz, Fallon, & Jeffries (2003)	Thirty typically developing 2 ½-yr-old children	Compared 3 system approaches to vocabulary organization: taxonomic grid; schematic grid; schematic scene on Freestyle and Dynavox.	Poor performance across all conditions. More vocabulary located on schematic scene. Failure to generalize knowledge to learning novel vocabulary.
Hochstein, McDaniel, Nettleton, & Neufeld (2003)	8 children with cerebral palsy, 8 children without disabilities	Compared variables of single-level (Alphatalker) and dual-level (Dynavox) displays and vocabulary abstractness (concrete vs. abstract words).	Both groups demonstrated same pattern of acquisition making more errors on the dual-level display and making more abstract (category) errors in selecting symbols.
Hill (2003)	Single-subject case study of 3-year-old with cerebral palsy	Monitored performance on Vanguard with Unity One-hit.	Reported MLU-w, TNW, NDW, frequency of language representation method use, core and extended vocabulary acquisition.

Step 3: Personal Evidence

Traditional methods of observation and language activity monitoring (LAM) tools were used to collect and review personal evidence. The Performance Report Tool (PeRT, Hill & Romich, 2003) was used for analyzing language samples and generating a performance report. Although traditional methods of observation allowed for the collection of the multimodal aspects for Brent's communication, only LAM tools provided the accuracy needed to monitor change or make comparisons among interventions. Video recording is not accurate in providing data on how language and messages are generated using AAC systems. In addition, the measurement of communication and selection rate requires a time stamp for calculating standardized units of measure (Romich & Hill, 1999; Lesher, Moulton, Rinkus, & Higginbotham, 2000).

Based on the formulated EBP questions, the following performance measures were critical to obtain: (a) average and peak communication rate, (b) communication rate of language representation methods, (c) selection rate, (d) mean length of utterance, and (e) frequency of complete utterances. Brent's performance on his current AAC system showed that he used spelling 97% of the time to generate messages averaging 3 words in length. His average communication

Table 2
Performance Data Comparing Original and Recommended AAC Systems

Performance Data & Outcomes Measurement	Original AAC System	New AAC System
Frequency of LRMs:		
Spelling	97%	6%
Word prediction	2%	3%
Single meaning pictures	1%	1%
Semantic compaction	not supported by system	90%
Mean length of utterance in words (MLU-w)	2.8	5.5
Average communication rate: Direct keyboard	1.0 wpm	6.5 wpm
Peak communication rate: Direct keyboard	Not able to calculate	21 wpm
Average communication rate: Optical headpointing	N/A	5.3 wpm
Peak communication rate: Optical headpointing	N/A	17.4 wpm

rate was 1 word per minute (see Table 2). Communication partners frequently completed or attempted to complete his messages. Thus he had a frequency of 25% for complete utterances.

Step 4: Using the Evidence

The fourth step involved implementing the intervention. This step involved using the evidence to support moving through a language-based assessment model which included identifying the various language representations methods (LRMs) used to generate communication using AAC systems, determining specific outcomes based on selected LRMs, and evaluating how specific LRMs were supported on available technologies (Hill, 2004). Considerations of LRMs, outcomes, and technology issues were discussed and demonstrated before any AAC devices were introduced. Since Brent had an AAC device, his current system was used first to demonstrate these components and then compared with alternative AAC language application programs and technology features. This step involves monitoring or measuring Brent's performance by collecting quantitative data. Performance measurement provided a systematic and scientific approach for trial comparisons among AAC systems. Brent required three trial periods to make a decision about a possible recommendation for a new AAC system: (a) his current AAC device with modifications, (b) an upgraded touch screen AAC system, and (c) a hybrid AAC system. (Periodic performance measurement addresses the need to monitor the learning process. For some assistive technologies, peak performance requires training and practice. Decision-making based on short term trials or without performance data may not be valid.)

Table 3 compares the technology features between Brent's original and recommended AAC systems. In reviewing the results from the trial periods, Brent advocated for an AAC system that supported all three language representation methods. He selected the hybrid display, which included both a static keyboard and a touch screen rather than the full touch screen display. In addition, Brent wanted the option to switch between direct keyboard selection and optical head pointing depending on his physical status during the day. Other features or options on the new system that enhanced Brent's perceptions of the effectiveness and efficiency included: activity row on touch screen, infrared control for computer access and environmental control, data logging, icon prediction, icon tutor, and easy access to display status and

Table 3
Feature Comparison of Original and Recommended AAC Systems

	AAC System	
Technology Features	Original AAC System	New AAC System
Language Representation Methods	Spelling, word prediction, single meaning pictures	Semantic Compaction, spelling, word prediction, single meaning pictures
Language Application Program	None; standard alphabet display and customized pages	Unity 128 sequenced
Display Type	Grid-type touch screen display with location arrays ranging from 40 to 65 keys.	Hybrid, static display with 128 locations & touch screen display with 8 locations
Primary Voice Output	DecTalk (synthetic speech)	DecTalk (synthetic speech)
Selection Method	Direct keyboard	Direct keyboard and optical head pointing

tool box. Finally, considerations about the services offered by the manufacturer were included in Brent's choice. He rated favorably services such as access to technical support, regional professional support, and Internet training opportunities. The order of his priorities was: (a) language features to support fast and spontaneous communication, (b) other features, and (c) manufacturer services.

Finally, Step 4 involved a clinical summary that evaluated the results of the process. Brent was referred for an initial assessment session in the late fall. The trial period lasted through the winter months, with a significant break occurring between semesters. The funding request for his new AAC system was submitted in the early spring with training immediately occurring on a loaner system. Brent attended one 1-hour therapy session a week for three months.

By the end of the spring semester, performance and outcomes measurement showed that Brent was a more effective communicator. The built-in LAM or data logging feature provided an efficient and effective method for monitoring progress by both the client and the clinician, and prompted discussion about treatment outcomes (Hill & Romich, 2001). Within three months of treatment, Brent had learned his new language application program and was selecting words using semantic compaction 90% of the time with an average communication rate of 6.7 words per minute and peak communication of 21 words per minute with direct keyboard selection. For Brent, use of semantic compaction was 16 times faster than spelling. As noted in Table 2, use of PeRT allowed for precise and accurate reporting of performance measures during the intervention process. The performance reports provided an ongoing, reliable record of progress for treatment outcomes. In addition to improvements in Brent's communication performance in various social environments, his communication in classes was also considered to be improving. With an improvement in his grades, withdrawal was no longer considered necessary. Two years later, Brent graduated from the university majoring in Speech Communication Studies.

Becoming familiar with resources and supports that promote exemplary AAC practices provides the information necessary for individuals to measure and evaluate the outcomes of rehabilitation services and the use of the assistive technology. In Brent's case, after he was shown video clips of individuals using AAC systems, he shared that he had never met another person using a device. The team conducting his previous evaluation had never performed an assessment for an AAC system. During separate conversations, Brent and his mother both related that they had no idea that persons with disabilities like Brent were communicating so effectively and fast using a voice output AAC system. They also shared that they were surprised at the number of individuals using high performance AAC systems similar to Brent or with even more significant challenges. At the first assessment session, Brent was introduced to various Internet resources with the recommendation to join on ACOLUG. He was encouraged to post questions about the AAC assessment process to members of ACOLUG to be a better advocate for himself. Internet resources can provide access to information that is current and useful when sources are carefully and prudently evaluated. Examples of Internet resources available today include information and resources on AAC evidence-based practice, methods and tools to support performance and outcomes measurement, online AAC courses, information on conferences about assistive technology, directories of resources, and online discussion groups (AAC Institute, 2006). Various professional organizations provide information on exemplary rehabilitation practices to support consumers and advocates through web sites and/or email correspondence.

Outcomes and Benefits

According to evidence-based medicine, teams are expected to conscientiously and judiciously use the best evidence or data to support decisions (Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996). EBP places the client's benefits first when applying evidence of direct practical importance to planning (Gibbs, 2003). Quality of life is defined by outcomes--outcomes which compare interventions in order to make informed decisions regarding treatment (Ninni & Brownstein, 1999). Individuals who rely on AAC believe that the fundamental, desired AAC outcome of independent communication can be achieved with appropriate technology and appropriate long-term, often intensive intervention strategies (Creech, 1995). Systematic documentation of case studies reporting performance and outcomes data will contribute to the evidence base that practitioners need for decision-making. Quality of life can be dramatically enhanced when AAC teams desire the most effective, independent communication possible for an individual with significant communication disabilities. By providing a systematic framework and opportunity to compare AAC systems using evidence (research and quantitative data), the AAC team can ensure that resources are used most effectively and efficiently to achieve the best results. As in the case example, recommendations were based on quantified evidence and not impressions of effectiveness. AAC team members, families, and augmented communicators can feel secure that the client's benefits are placed first when evidence is used judiciously and conscientiously within an organized framework.

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Further Information

AAC Institute is a non-profit organization dedicated to the most effective communication for individuals who can not speak at http://www.aacinstitute.org.

ACOLUG Augmentative Communication on-Line User Group) is a listserve with primary participants being people who rely on AAC at: http://www.temple.edu/instituteondisabilities/programs/assistive/acolug/.

AAC CASE STUDY
PERFORMANCE & OUTCOMES SUMMARY

Client Profile Report client age, gender, ethnicity, diagnosis, disability. Describe basic characteristics such as abilities, skills, expectations, values, preferences, background, education, vocation. Identify any pertinent standardized test results or rating scales; report educational information such as grades, grade point average, test scores. Identify any accommodations and use of assistive technology. Detailed information should be provided for hearing, vision, physical, speech, language, and cognition.

Step 1: Questions Formulate 1-3 well-built questions that are client-oriented, practical, and will facilitate an evidence search. Suggested question elements include: 1) client type and problem; 2) what you might do (treatment); 3) alternative treatment options or course of action; 4) what you want to accomplish, e.g. performance and outcomes of treatment. Including specific performance data in a question to look for as dependent (outcome) variables will make appraisal of the external evidence more efficient.

Step 2: External Evidence Review Plan a search strategy to identify research and other evidence that address the questions asked. Look for both sides of an issue. Use of Internet databases is recommended. Search for research that reports the dependent (outcome) variables that are important for the client. Learn how to critically appraise the evidence. Become familiar with the levels of evidence to know the strength of the evidence you find.

Step 3: Personal Evidence Have the client confirm his or her values, expectations, preferences and concerns for baseline data. Collect performance and outcome measures for any current AAC strategies to use as baseline data. Monitor performance during any AAC device trials and interventions and measure outcomes at key decision-making points. Any qualitative and quantitative data should be distinguished and collected systematically so that the process is reliable and can be compared or duplicated.

Step 4: Using the Evidence This step involves putting decisions into action, monitoring the progress, and evaluating the results. Documents for this step may include diagnostic, treatment or lesson plans, an I.E.P., a Speech Generating Device (SGD) funding request. Principled and systematic methods of monitoring intervention allow for identifying variables that are influencing performance and outcomes and provide for timely modification to intervention when needed.

Clinical Summary Report final performance and outcomes data. Performance data should be consistent with previous data and reliable and valid measures for specific skills and goals of treatment. Comparison back to baseline data is important. Outcomes may be reported for 1) clinical results, 2) functional status, 3) quality of life, 4) satisfaction, and 5) cost. Outcomes may include perceptions reported not only by the client, but other team and family members.

References: Identify research articles from Step 2 to ensure references can be found by others or requested from original sources.

AAC, Employment, and Independent Living: A Success Story

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Abstract: It has been well documented that individuals with significant physical disabilities who use augmentative and alternative communication (AAC) face considerable challenges in finding and maintaining employment. This article documents the experiences of one individual, Anthony Arnold, a young man who uses a Pathfinder™ for communication and a power wheelchair for mobility. In his own words, Anthony shares his experiences growing up in North Dakota and the progression of factors that contributed to his education and communication development. External factors, including access to technology, opportunities to practice independence, and the collaboration of professionals and family members, came together with Anthony's internal strengths to produce positive outcomes in employment and independent living.

Keywords: Augmentative communication, Employment, Disabilities, Independent living

Advances in technology coupled with legislative and policy changes during the past three decades have made employment a realistic goal for many individuals with disabilities. Nonetheless, in 2003 fewer than 40% of adults with disabilities between 16 and 64 years of age reported being employed (Stern & Brault, 2005). Even more discouraging, it has been estimated that fewer than 15% of individuals with physical and communication disabilities who use augmentative and alternative communication (AAC) are employed (Bryen, Carey, & Cohen, 2005).

Employment Challenges for Individuals Who Use AAC

In the past decade, several research studies have explored employment issues for individuals who use AAC. In a 1996 study, researchers surveyed 25 adults who used AAC and who were employed in community-based jobs (Light, Stoltz, & McNaughton, 1996). The survey participants identified financial benefits, interactions with co-workers, and improved self-esteem among the positive impacts of employment. In addition, the financial benefits of employment provide individuals with greater autonomy and control over their lives (McNaughton & Bryen, 2002). Being employed impacts how individuals feel about themselves and how they are regarded by their neighbors and community (Blackorby & Wagner, 1996; Odom & Upthegrove, 1997). The benefits of employment for individuals with significant disabilities who use AAC are clear; yet, the road to employment is not.

Researchers have identified several factors that contribute to the bleak employment outcomes for individuals who use AAC. These factors include physical access barriers to workplace tools and environments, transportation problems, and personal care issues (Inge, Strobel, Wehman, Todd, & Targett, 2000; Light et al., 1996). Physical and communication disabilities place limitations on the ability of individuals to perform specific employment duties, thereby limiting the range of potential job categories, and, in turn, making it more difficult to find a good match between the individual's skills and employers' needs (McNaughton, Light, & Gulla, 2003). In addition, employers who are unfamiliar with augmentative communication may not provide applicants with an adequate opportunity to demonstrate their skills and abilities (Bryen, Carey, & Cohen, 2005). For this reason, networking has been recommended as a particularly valuable tool for individuals who use AAC, yet individuals who use AAC may have fewer network contacts than others (Carey, Potts, Bryen, & Shankar, 2004).

Literacy difficulties among individuals who have severe speech and physical impairments have been well documented (Koppenhaver & Yoder, 1992; Smith, 2005); many individuals who use AAC have not developed the literacy and problem-solving skills that employers are seeking (Bryen et al., 2005; McNaughton & Bryen, 2002). While growing up, individuals with significant disabilities receive little encouragement to explore job options; consequently, they often have not planned adequately for employment nor developed career aspirations (Odom & Upthegrove, 1997). A lack of prior job experience coupled with limited social experience may interfere with an individual's ability to fit into the workplace environment. Researchers have reported that some individuals who use AAC lack an understanding of workplace norms and have difficulty adapting to workplace culture (McNaughton et al., 2003).

Although many AAC users do not reach their full potential with regard to employment and independent living, a few success stories exist. The next section of this article explores the experiences of one individual with significant disabilities who uses AAC and who has overcome the barriers to employment described previously. It is hoped that sharing this story will stimulate ideas and strategies that can help other individuals who use AAC achieve their full potential and help families, teachers, and advocates for AAC users support them in their quest for employment and independent living.

A Success Story

The individual whose experiences are shared in this article is third author, Anthony Arnold. Anthony has athetoid cerebral palsy that affects all extremities; he has little or no functional use of unaided speech. He uses a power wheelchair and an AAC system to meet his mobility and communication needs. He accesses his AAC device with single-finger direct selection. The second author met Anthony when she was visiting Camp Courage in Maple Lake, Minnesota. At the time Anthony was a participant in "Teen Camp," a recreational camping program for teens with disabilities, primarily physical and speech impairments. She encouraged Anthony to apply to a program sponsored by the Disabilities, Opportunities, Internetworking, and Technology (DO-IT) Center. DO-IT Scholars is an award-winning program (DO-IT, 2006) that helps students with a wide range of disabilities transition to postsecondary education and employment through use of technology as an empowering tool (DO-IT, 2005; Kim-Rupnow & Burgstahler, 2004). Once he was accepted, the first two authors came to know Anthony through his participation in DO-IT Scholars activities, which include summer programs on a university campus, technology use, mentoring, college preparation, and work-based learning experiences. DO-IT is housed at the University of Washington in Seattle and is primarily supported by the National Science

Foundation, the State of Washington, and the U.S. Department of Education.

At the time of the writing of this article, Anthony had been employed for more than five years and lived in his own apartment. Because he had achieved a level of success uncommon for AAC users, the authors thought Anthony's experiences might provide insights that would benefit other individuals who use AAC, their families, and the professionals who work with them. An email conversation began that explored Anthony's experiences growing up and his transition to employment and adult living. Some of the information that Anthony provided came from material he had previously written and presented (Arnold, n.d.).

Much of this story is told in Anthony's own words. As conversations unfolded, the first two authors identified several broad topics to provide organizational structure to Anthony's story; those topics include employment, communication, family and school experiences, and independent living. Both external factors (e.g., technology access) and internal characteristics (e.g., career aspirations) are discussed.

Employment

Anthony lives in North Dakota and works for the Prentke Romich Company (PRC), a developer and manufacturer of AAC systems and other assistive technology (AT) devices.

> At the Prentke Romich Company, I'm currently a Remote Troubleshooter in the Technical Service Department during the nighttime and weekend hours, and I'm able to do this directly from my home in Grand Forks with the use of my telephone, computer, and Internet. I provide technical support for six models of communication devices. I serve all 50 states and sometimes get calls from Canada. The other Remote Troubleshooter and I have had great success. People usually enjoy talking to people who actually use the communication devices on a daily basis…. I'm also often involved in product testing, usually six months before official releases. This is something I enjoy being part of. It gets exciting … whenever something new is ready to get tested…. My other job at the Prentke Romich Company is as a Per Diem Representative for Eastern North Dakota and Western Minnesota. I offer presentations, demonstrations, and trainings, which is something I enjoy doing. I personally like working with younger children and give them hope for the future.

Early Work-Based Learning Experiences

Getting an AAC user's foot in the door, or, in this case, "getting your wheel in the door" (McNaughton, Light, & Arnold, 2002), can present challenges. We asked Anthony about his employment history and how he was able to get his wheel in the door at PRC. He told us that he found his first job while he was still in high school.

> My work experience started the summer right before I attended the DO-IT Summer Study in 1994. I was so encouraged by being accepted to DO-IT that I felt like I could do anything and accomplish it. I was determined to find a job for the summer, so my parents decided to give me a ride to Job Services, and let me do my own advocating. Because of my disability, I qualified for a summer job-training program for youth. There I attended classes on interviewing skills and how to hold down a job.

> Afterwards they placed me in a job at a computer store, doing data entry… I was at the computer store nearly 2 years, where I picked up some amazing technical skills, some of which I'm still using today at PRC.

After graduating from high school, Anthony enrolled in college at the University of North Dakota for a few semesters "until I realized that college wasn't for me at that time." Soon after leaving college he returned to Job Services and found a temporary job cataloging books at the University of North Dakota library. In addition, Anthony volunteered at local non-profit agencies, including the Options Independent Living Center in East Grand Forks. Anthony's success in the DO-IT Scholars Program (DO-IT, 2005) also provided opportunities that contributed to his self-confidence and broadened his range of experiences. For example, at the 1995 Closing the Gap Conference on technology for people with disabilities, he was a co-presenter with the director of DO-IT, teaching an audience of special education teachers how they could use the Internet to conduct research for themselves, as well as to enhance the academic programs of their students.

Goals and Aspirations

By this time Anthony was an exceptionally skilled augmentative communicator and had many ideas about how the technology could be improved to better meet his needs and the needs of other individuals who rely on AAC systems. Anthony decided to write to the President of the PRC with some of his suggestions and to express his desire to work in the AAC field.

> When I was in the DO-IT Scholars Program, I had a long list of things I felt needed to be improved and/or incorporated into AAC technologies. I ended up sending my ideas to Barry Romich for possible consideration, and saying that I wanted to be possibly employed or involved at the Prentke Romich Company in the future. I wrote a nice letter introducing myself and stating my suggestions and interests… I spent a couple of years communicating with Barry and several other people in the field.
>
> One thing I would suggest [to other AAC users] is that you state your wishes in a positive manner instead of coming on strong and demanding things. Individuals like Barry Romich want to help … but don't have time to listen to rude requests and are likely not to respond to them either. I must have written a very positive letter because I'm now employed at the Prentke Romich Company.

Researchers have reported that many individuals who have significant disabilities fail to set high goals for themselves and/or to plan for employment; pessimism about job prospects may limit their career aspirations (Odom & Upthegrove, 1997). In contrast, Anthony developed career goals and aspirations early on.

> As seventh grade rolled around…. this was when I began seriously considering working at either the Prentke Romich Company or somewhere else where I could help people communicate. Throughout my middle school and high school years, I remember continuously talking about this goal and boring people with talking about what I wanted to do in the future.
>
> However, I did have a teacher who loved saying, "Anthony, stop dreaming, you will never work at the

> Prentke Romich Company." And … this year I celebrated my fifth anniversary there, so I'm proud to say, "I taught the teacher something." I did meet up with her once at a conference where I was representing the company, and I received the best apology I have ever experienced. She thanked me for teaching her what's actually possible for people with disabilities.

Anthony reported that his family played a significant role in encouraging his communication, determination, and career goals.

Communication Development

By the time Anthony wrote to Barry Romich at PRC, he had been using AAC systems for over a decade; however, when he was a young child there were few AAC resources available. Nonetheless, even before he received his first communication board, Anthony was a creative communicator.

> Once I was sitting home with my parents, and I noticed that the first snow fall of the season was happening. Just like any other kid, I was excited and wanted to tell my parents, but I had no means of saying, "Look, look, it's snowing outside!" So I decided if I could point to the refrigerator and then to the outside window, I just might get that point across. As you can imagine, I drove my parents crazy with trying to figure out what I wanted to say until they looked outside themselves and saw that it was snowing. You can imagine how proud they were to realize that I knew how to communicate. Now, looking back on it, you might say communication has always been a priority for me. So it isn't surprising that I have made this a major part of my adulthood to serve others with communication disabilities.

Home and Pre-School Experiences

Anthony was born in a rural area of North Dakota. Between his first and second birthdays his parents drove hundreds of miles each week to take him to therapy appointments. Soon after his second birthday, his family decided to relocate to Grand Forks where more resources were available for Anthony's education and rehabilitation. In Grand Forks, Anthony began attending an inclusive preschool program at the University of the North Dakota.

> I have to remind you this was 1979, so IDEA [Education for all Handicapped Children Act of 1975, reauthorized as the Individuals with Disabilities Education Act of 1990] and inclusion were fairly new concepts. This preschool was almost like their test drive of the new system, and they were integrating special education students and regular-ed students all within one preschool class environment. It was nicely put together, and I feel that everybody involved had a positive experience.

It was soon after Anthony's communication about the early winter snowfall that he received his first communication board.

> My parents and therapists began noticing that I had the ability to communicate just a single point like "I want to eat" or "I need help," so they decided to work together and develop some means of communication. We ended up using six pictures taped on a clipboard, which was a great beginning step headed in the right direction, which is something I recommend for

> other children today. You don't want something that overwhelms them at first, and you can always expand with time.

After the preschool at the University of North Dakota, Anthony was enrolled in a public school program where he had access to school district resources and support personnel. Anthony qualified for special education services as a result of the educational challenges presented by his physical and communication impairments.

> After I left preschool at the University of North Dakota, I was enrolled in the Grand Forks Public Schools for another preschool program, where I had access to a teacher, a paraprofessional, a speech-language pathologist and an occupational therapist, who were a great addition to my parents and my other rehabilitation team. They all worked nicely together. It was then that we developed a communication board with more symbols, and we added the alphabet and numbers to it…. Another thing my parents felt strongly about was to try to make my communication boards as user friendly as possible, because they wanted others to communicate with me as well.... By the time I left preschool, I was putting together 10-12 word sentences, including every part of speech. Being a communication board user, I required somebody to always read what I wanted to say, and I used to frustrate people trying to read and remember what I was saying because my finger would move so quickly. Sure, I frustrated people by pointing so quickly, but they never stopped communicating with me just because of frustration. If they would have stopped wanting to communicate with me, they would probably have jeopardized my determination to communicate.

Elementary and High School Experiences

In elementary school Anthony was included in general education classes, but spent time in the special education resource room as well. Like many individuals who use AAC, Anthony struggled with literacy.

> I usually say that I had the best of both worlds instead of just one. I know that people tend to like and insist on having children included, which is great, but, besides my physical disability, I have some learning disabilities as well. So by going to the resource room I was able to focus on some of the harder subjects for me, like reading and spelling.

Fortunately, Anthony encountered teachers who recognized his potential and were persistent in their support of his literacy development.

> My resource room teacher was very determined in teaching me how to read – come hell or high water! Writing and reading are the most important things you can teach a student with disabilities, especially when you're hoping for other future successes. Sure, it's hard work at times, but in the end it's probably the most rewarding.
>
> During this time I was using a communication board with over 150 symbols…. We began to realize it would be nearly impossible to add more symbols on to my communication board and still

> maintain my independent use of it, so we had to start looking at other alternatives that would provide what we wanted. This again called for everybody's input, including the physical therapist's and the occupational therapist's.

High-Tech AAC Systems

In October of 1985 one of Anthony's speech-language pathologists attended the Closing the Gap Conference in Minneapolis. It was there that she saw a voice output communication device for the first time.

> She saw a TouchTalker™ by the Prentke Romich Company that had the ability of storing vocabulary words under sequences, and it also had a computer-generated voice. The moment she saw this, she said to herself, "I have the perfect candidate for this!" So she gathered the information and brought it back to present to my teachers, other therapists, my parents, and me. We all thought that this was something we should really consider, so we decided to drive down to Sioux Falls, South Dakota. I think that everybody who went down there would do it again, because we were very pleased with what we saw. We decided to arrange a trial period with PRC. Something that I like about the majority of the companies today is that they allow trial periods before purchase. I believe that we were allowed to keep the device for 6 weeks. The trial use of the equipment was a great success, so we ended up deciding to purchase. Purchasing a communication device back in 1985 was almost like investing in the stock market, you didn't know what you would get in return. Back then insurance companies and school districts weren't chipping in, so it fell back upon my parents to pay, which they did and I'm sure they would again if called upon.
>
> I received my TouchTalker™ in December of my second grade year, and I recall that was like the happiest day of my childhood by being given a voice I could independently use without needing somebody to read my communication board.

When I received my TouchTalker™ in 2nd grade, I was one of the first in North Dakota ... to actually receive a communication device of any kind. There was basically nothing to go by, so it was like "the blind leading the blind."

Back then, there were no preprogrammed vocabulary packages like there are today. We had to program our own, which again called for input from everybody on my team to figure out what needed to be programmed. My two speech-language pathologists worked well together…. It's always good to form working relationships with everybody because sometimes they might have ideas that you haven't thought about.

It took a couple of years before my vocabulary was totally built up in my TouchTalker™. During this time, my parents expected me to take and use my TouchTalker™ everywhere I happened to go and need a voice. My parents began to notice a big improvement in communicating with me. One time we were driving somewhere and realized it was the very first trip when my mom didn't need to get up to read my communication board. Everybody was

> happy I could hold a conversation with them while they were driving. During this time, I formed more friendships at school because I had a way to communicate with other kids. We often talked on the phone and made plans, which was something my parents encouraged.

Anthony continued to use his TouchTalker™ for several years. The TouchTalker™ was followed by a Liberator™, which incorporated additional features including a notebook, calculator, and print capability as well as some computer access and environmental control. Anthony continued to use his Liberator™ until he was hired by PRC.

> I was hired by PRC right at the time of the introduction of the Pathfinder™, and they had some bugs to still figure out, so I was offered one to help work the problems out.

Professional Communication

Anthony now uses a Pathfinder Plus™ for communication. He worked on product testing for the Pathfinder Plus™ at PRC before its release to the public.

> I must say these past five years working for the Prentke Romich Company have been some of the most powerful and best years of my life…. Since I started remote troubleshooting, I feel that we have gotten some great and positive feedback from customers that we have helped, especially parents of young children beginning to use a communication device and other assistive technology. I know that when they hang up after talking and being helped by me, they have a better outlook on their child's future, and probably begin working much harder to help them get more accomplished than they did before. To me, that's the biggest reward.

Independent Living

In addition to his communication device, the AT that has most impacted Anthony's independence and quality of life is his power wheelchair, an Invacare® Ranger. He reports that he received his first power chair at the same time as his first voice output AAC system.

> I was introduced to my first power chair (that was the 3-wheel scooter type) the very same month as my TouchTalker™ … which is something my parents and therapists would have probably done differently, like separating the two a few months apart, because I was too overwhelmed in excitement instead of focusing on the learning and the new responsibility of both. I must say that both my power chair and my communication device are the center core to my independence, but I feel that the education and rehabilitation that went along with the communication device and power chair were a greater element than these two material items. Communication devices and power chairs are like lumber, and when lumber is delivered, it doesn't mean your house instantly gets built. The lumber is just the material you need to build with.

Self-Advocacy

As part of the DO-IT Summer Study program Anthony met other highly motivated teenagers with disabilities and lived on the University of Washington campus for one or two weeks, for two consecutive summers. His

DO-IT Summer Study experiences coupled with his attendance at Camp Courage helped him develop skills for living away from his family, working with personal care attendants, and advocating for himself.

> At Camp Courage they have a well-trained staff to provide personal care attendant service, which is good for both parent and camper to realize that separation is possible and needed. My first year of attending camp, I was very home sick... The first summer I remember only receiving one shower the entire week, and I'm somebody who prefers a shower every morning. Then my second year there I requested my normal shower routine. They had no problem with doing that and I was a much happier camper with my daily showers. I think they wanted me to learn how to advocate for myself instead of just following their lead. When I attended DO-IT, I was much better at communicating my needs/wants to attendants.

In the DO-IT Summer Study Program Anthony lived in a dormitory on the University of Washington campus and had his first experience supervising an attendant and managing his personal care needs on his own. That experience provided him with practice that proved valuable when he later moved out of his parents' home into his own apartment. Through DO-IT, Anthony also made friends with other teenagers with disabilities who had goals for careers and independence similar to his own. He continued to develop self-advocacy skills as he communicated with peers and mentors via the Internet, year round.

Developing Leadership and Technology Skills

Anthony's experiences with DO-IT strengthened his technology skills and introduced him to online research and communications tools. As part of the DO-IT Scholars Program, Anthony participated in online discussions with other DO-IT Scholars and Mentors while he was still in high school. Today he is a Mentor to younger DO-IT Scholars and continues to participate in online discussions.

Technology, support from others, and his own determination have enabled Anthony to lead an independent life.

> I use my Pathfinder™ for my communication needs, my power chair for my mobility needs, a computer to help me with writing and stuff for work, a speakerphone to help me speak over the phone using my Pathfinder™, and an Infrared Receiver plugged into my computer to receive data from my Pathfinder™ so I can use my programmed vocabulary and word prediction to generate writings like this e-mail.
>
> When I was at Prentke Romich in June I got my cell phone integrated into my Pathfinder™, which lets me place and receive calls directly from my unit and has increased my level of independence and security dramatically.
>
> I'm very independent (surprisingly), with a personal care attendant coming in an hour in the morning, and then she comes back at noon and feeds me lunch. At suppertime, I usually go over to my parent's house and eat with them, or sometimes they bring supper over to my house, especially on evenings I work because I'm too busy with technical calls. Other than that, I'm pretty much by myself, something I like because I get to focus on my interests.

Anthony has his own website (Arnold, n.d.) and spends time keeping it updated. He enjoys learning about technology, and surfing and chatting on the Internet. He is also a hockey fan and attends games at the Ralph Engelstad Arena in Grand Forks. He has a modified bicycle that he enjoys taking on long rides. He also serves on the board of directors of the Options Independent Living Center in East Grand Forks, where he volunteered after he left college. Anthony continues to take on new challenges and set new goals for himself.

> The success that I have had helping customers has really encouraged me to try different things.... I decided to join a gym for weight lifting, which surprised everybody. I now can lift 10 pounds and use a machine called NuStep® without problems. I can balance myself for transfers, so nobody has to help me move anymore.
>
> I'm also thinking about trying college again now that I know I can do something if I truly work at it. If I do that, I would love to become a rehabilitation engineer…. I feel that could open up more doors for people in the long run. My point here is if we can give an individual a job or something they love to do, not only that area of their life improves, but other areas improve as well.
>
> It is an amazing feeling knowing what I have accomplished thanks to the right education, right rehabilitation, right staff and most importantly the right parents.

Discussion

Many factors – both internal and external – came together to support Anthony's successful transition to employment and independent living. The external factors include (a) advances in technology and opportunities to have access to that technology, (b) a family that supported his goals for independent living and a career, (c) a strong professional support network, (d) opportunities to practice independence away from home, and (e) opportunities to interact with peers who had goals and aspirations similar to his own. Internal characteristics include Anthony's persistence, positive attitude, self-determination, and hard work. Inherent traits and external supports converged to produce successful outcomes with respect to employment and independent living.

> My desire to communicate ... I would say, came internally. But keep in mind that no communication device was introduced to me until age 8, so I always had to depend on somebody to read my communication board, and, frankly, if nobody had shown interest in reading my board, my desire to communicate would have disappeared. I have seen cases where this has happened, where the device only gets used at school and therapy, but when it gets home it's placed on the shelf and isn't used there or in any other environment. Due to this the children suffer in both their education and independence, and their ability to carry on a conversation isn't fully developed.

While growing up, Anthony had the good fortune to meet with educators and professionals who were supportive collaborators; but even when he encountered individuals who were not supportive--as in the case of the teacher who discouraged his career ambitions--he reacted with neither anger nor discouragement. Anthony reported that his teacher's negative comments served to strengthen his determination to prove her wrong. When he encountered that teacher years later he welcomed the opportunity to reverse their roles and educate the teacher.

AT, computer applications, and Internet access were external factors that together played a critical role in Anthony's success; they were necessary components, but were not sufficient of themselves. As Anthony stated, technology provides the building material, but human interaction is required to transform that material into a solid structure. The collaboration of parents, teachers, rehabilitation professionals, and program personnel provided Anthony with many opportunities; and Anthony made good use of the opportunities provided. The interaction between an individual and his or her support community is reciprocal. Anthony's determination likely strengthened the commitment of those who supported him, just as their efforts and commitment strengthened Anthony's resolve.

Another important factor in Anthony's employment success was the career field he chose to pursue. As noted earlier, when an individual has significant disabilities, it can be difficult to find a good match between the individual's skills and employers' needs. Anthony chose to pursue employment in the field that most valued his specific strengths and skills. By seeking employment in the augmentative communication field, Anthony transformed his AAC experience into a career asset. His choice of career field connected Anthony with an employer who understood disability issues and was supportive of his accommodation needs. Nonetheless, it was Anthony's AAC expertise and strong self-advocacy skills that enabled him to secure employment in this field.

Anthony's story provides an example of independent living and employment outcomes that are possible for individuals who use AAC. The authors hope that Anthony's story will stimulate ideas and strategies for other AAC users, their families, teachers, and support personnel as well as encourage others to report on the experiences of successful individuals who use AAC. Qualitative and quantitative research is needed to identify critical factors that lead to positive academic, career, and independent living outcomes for individuals who use AAC.

Outcomes and Benefits

Anthony was able to overcome the obstacles to employment that have been reported in the literature for individuals who rely on AAC. As a child, he received AT that was appropriate for his communication and mobility needs. With family and professional support he became skilled at using that technology. Growing up, Anthony was included in general education classrooms and participated in the broader community; he had the opportunity to develop appropriate social skills and he became a capable communicator.

Anthony worked hard to achieve the academic and problem-solving skills he needed to become a successful, independent adult. He continued to develop self-advocacy and technology skills through participation in recreation and transition programs. He was eager to work and sought out job-training resources and opportunities while he was still in high school. After he left college he volunteered at nonprofit organizations and gained additional experience interacting in workplace environments. Anthony developed career aspirations early on and chose a field where he would be able to utilize his skills and strengths and where his communication methods and accommodation needs would be acknowledged and supported. He was proactive in creating a pathway into his chosen field. By developing the technology skills that allowed him to work effectively from home, he avoided the transportation and access challenges that often interfere with employment for individuals with significant disabilities.

Anthony is a determined individual who has made effective use of the opportunities that have come his way and has never let the obstacles he encountered interfere with his progress or with the quality of his life. In the DO-IT Scholars Program at the University of Washington, we often say that access plus attitude is key to academic and career success. Anthony Arnold embodies this principle.

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An Action Research Study of Computer-Assisted Instruction Within the First-Grade Classroom

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Abstract: This investigation examined the use of computer-assisted instruction (i.e., *WordMaker*) on students having different levels of reading ability. Of particular interest were the effects of *WordMaker* on the spelling performance of first graders in a co-taught classroom. In a short 10-week period, the *WordMaker* software program had a positive impact on children's decoding and spelling skills. Eighty-three percent of the students experienced gains between the pre- and posttest scores. Findings suggest that *WordMaker* is an effective complement to other activities associated with the first grade curriculum (e.g., spelling and decoding) and has the potential to enhance students' reading and writing skills.

Key Words: Action research, Computer-assisted instruction, Reading, First grade

Introduction

Technology provides students with multiple pathways to learning. As the number of computers increase in classrooms, students are provided with immense opportunities to engage in a variety of learning modalities (i.e., visual, auditory, and/or kinesthetic) during the learning process (Lee & Vail, 2005). For computers to have an impact on children's learning, computer activities need to support overall educational goals. When technology is infused within the curriculum, young learners are provided a set of learning tools to assist them in achieving developmental academic goals across the curriculum (Judge, 2001).

The complexity of learning to read is indisputable. Today there are numerous computer programs available to teach reading and reading readiness skills. Yet only a few of these programs have been empirically validated (Lee & Vail, 2005). This study attempts to evaluate the effectiveness of a reading software program for young children. Given the purpose of this study, it is important to review a rationale and outcomes of computer use.

Computer-Assisted Instruction

Over the past three decades, educational researchers have investigated the effects of computer use on student achievement and attitudes. This area of research is expanding to include computer applications in support of the academic curriculum (Lee & Vail, 2005; Simic, 1993). Terms such as computer-based education (CBE), computer-based instruction

(CBI), and computer-assisted instruction (CAI) are commonly found in the literature. CBE and CBI often refer to the general use of computers in the classroom setting. Such use may involve many facets of instruction and can utilize a variety of computer technologies and applications (e.g., databases, drill and practice, Web quests). CAI is used when describing more specific applications such as drill-and-practice, tutorials, or simulation activities offered either as a stand-alone activity or supplemental activities to enhance teacher-directed instruction (Cotton, 1991). A summary of 59 CAI research studies compiled by Cotton provides insight into the benefits and effects of CAI. A few of the research findings shared by Cotton include: (a) The use of CAI as a supplement to conventional instruction produces higher achievement than the use of conventional instruction alone; (b) students learn material faster with CAI than with conventional instruction alone; (c) CAI is beneficial for younger students; (d) CAI is more beneficial for lower-achieving students than higher-achieving students; (e) students with disabilities achieve at higher levels with CAI than with conventional instruction alone; (f) students' fondness for CAI activities centers around the immediate, objective, and positive feedback provided by these activities.

Hall, Hughes, and Filbert (2000) further investigated the effects of CAI on reading instruction for students with learning disabilities. Their research found: (a) the CAI software used in research studies where students made significant gains involved software that was carefully designed to incorporate systematic instructional procedures found to be effective in reading instruction (i.e., explicit, strategic, and scaffolded instruction, engaged time, success rate, and corrective feedback); (b) research reinforces the need to apply systematic, elaborate corrections for students to learn efficiently and effectively; and (c) the application of CAI as supplemental activities to teacher-directed instruction had significant outcomes favoring CAI over other interventions such as additional traditional teaching and workbooks.

Mioduser, Tur-Kaspa, and Leitner (2000) investigated specific features of computer technology related to targeted outcomes regarding children's acquisition of early reading skills. This research involved 46 at-risk kindergarten children. Software used in this study allowed concrete manipulation of letters and word components in activities and games involving the decomposition, recomposition and creation of words. Findings identified key features of the software learning environment, which were relevant to building early reading skills. Such features involved the concrete manipulation of language entities through the act of touching, hearing, seeing, constructing, playing and replaying auditory constructs. The features also held substantial potential for assisting young children to acquire needed skills in reading.

The balance of this article describes the components of an action research study that includes: (a) a broad overview of the Four-Blocks® Literacy Model (Cunningham, Hall, & Defee, 1998) that provided the conceptual framework in the development of the *WordMaker* software program; (b) a brief description of *WordMaker* software activities that engaged participants in the study; and (c) the methodology, findings, and outcomes of CAI, specifically *WordMaker* software, on the spelling performance of first graders.

Four-Blocks® Literacy Model

Cunningham et al.'s (1998) literacy program known as Four-Blocks® attempts to meet the needs of as many learners as possible through a multilevel, hands-on, developmentally appropriate literacy model. Based on earlier studies (Cunnigham, Hall, & Defee, 1991), their later research was designed "to figure out how to provide reading instruction to children with a wide range of entering levels without putting them in fixed ability groups." (Cunningham, Hall, & Defee, 1998, p. 652)

The Four-Blocks® model represents four components of reading to be taught to children to maximize reading acquisition. These components include: (a) *shared/guided reading*, which involves the use of basal readers along with other materials; (b) *self-selected reading*, where children have a choice of any book they like and respond to any part of that book they want; (c) *writing*, which is usually carried out in a Writers' Workshop fashion where the teacher models all the aspects of writing (e.g., looking at the Word Wall for spelling assistance); and (d) *working with words*, where children engage in reading and spelling of high-frequency words and decoding patterns (Cunningham et al., 1998)

This non-ability-grouped instruction has proven to be effective for students with minimal reading skills and does not hinder the progress of the top academic performing children. One of the reasons for its success is that the Four-Blocks® program provides a variety of ways for learners to approach reading and writing tasks (Cunningham, et al., 1991).

The "Making Words" block of this model is an activity in which children are given letters to make words. Typically, the teacher calls out a word to be made, children make the word with their individual letters at their desks, and one child makes the word with large letter cards at the board. During this activity children discover letter-sound relationships and learn how to look for patterns in words. They also learn that changing just one letter or even the sequence of the letters can change the whole word (Cunningham & Cunningham, 1992).

Research involving decoding by analogy supports spelling patterns used in the Making Words activities. Goswami and Bryant (1990) demonstrated that children can use words they already know how to read and spell while trying to figure out new unknown words. Aiken and Bayer (2002) discovered "the particular strength of Making Words is teaching students to notice patterns and make discoveries about written language that they could apply to other situations" (p. 73). Using of the Making Words activity resulted in children developing interest in making words and making progress on formal and informal decoding assessments in their classrooms.

Making Words is a powerful activity that provides an instructional format with endless possibilities for discovering how the alphabetic system works. It is a quick, every-student-responds, manipulative activity with which many children get actively involved (Cunningham & Cunningham, 1992).

WordMaker **Software**

The *WordMaker* software program, developed by Don Johnston Inc. (2003) in collaboration with Dr. Patricia Cunningham, is based on the Four-Blocks® Literacy Model (Cunningham, et al., 1991). *WordMaker* provides a systematic, sequential approach to teaching phonics and spelling while offering engaging activities, graphics, supporting sounds, and a motivating literacy environment for learners. Activities within the program encourage learners to engage in experiential learning, guided discovery, and knowledge transfer techniques. A wide range of learners are accommodated through creative and effective built-in scaffolds and customized feedback. The software is available in both PC and Mac platforms, is teacher-friendly, and easy to install. The program features extensive reporting of learner progress which provides an in-depth look at patterns and details of mistakes and successes.

WordMaker Activities

The lessons within the *WordMaker* software program are divided into 5-lesson units. Students begin using the *WordMaker* software on different levels/lessons according to the results of their pretests. Lessons 1-29 focus on beginning sounds. Lessons 31-140 focus on recognizing patterns in word endings and rhymes. During the lessons students have many different activities that can be divided into the following groups: manipulating letters to make words, sorting words by either beginning sound or by ending rhyme, and word recognition. When working with the pictures or the words the learner can place the cursor over the item to have it pronounced as many times as needed.

In the *Making Words* activity, students either have to (a) make a simple two-letter word (e.g., 'at') with the sounds that were introduced before; (b) move the letters around to spell another word (e.g., 'ring-grin'); (c) take one letter away and spell another word (e.g., 'can-cap'); or (d) add another letter to spell a new word (e.g., 'sad-sand'). Words are pronounced to provide learner support. The words are repeated three times: first in isolation, then in a sentence, and then again by themselves. If students make a mistake, the computer encourages students to listen to the first/last letter carefully or suggests that other letters should be used. After several trials, all the letters that the student already attempted fade away. This leaves only the correct choice, allowing the student to make the target word, thus, minimizing frustration and allowing the student to experience success. At the end of the *Making Words* activity, students explore a secret word. They must use all the letters from the lesson to spell it. In early lessons, all the letters are in place except for one so students can't get it wrong. In each unit, students randomly spell a secret word without any visual supports and find the right place for all the letters. If assistance is needed, students can use the check button and receive clues. After spelling a secret word, points are awarded (e.g., 5 points if the word was spelled without any clues, 4 points if spelled with 1 clue). These points are accumulated throughout the program. At the end, students are encouraged to do a better job next time.

The last lesson in each unit is a review where students have the opportunity to engage in not only making words or sorting words, but also word recognition activities such as *Find Words, Wordo*, and *Be a Mind Reader*. In the first activity (*Find Words*), students must find each word that is pronounced to them in a timed scenario. Before being presented with the timed scenario, students are offered an option to click on each word to hear it as many times as they wish. In order to adjust this activity to different learners the teacher can change the amount of time (i.e., 1, 3, or 5 min). After Lesson 10, students can participate in the *Wordo* activity where they play a bingo-like game against the computer finding the words that were pronounced. When students win, they are awarded 3 points that accumulate throughout the program.

The Literacy Challenge

P-12 classroom teachers (both general educators and special educators) are challenged to work together to meet the specific educational needs of every student. A careful examination of the *WordMaker* software program features and skill building activities allows teachers to make informed instructional decisions to determine if it would be a viable tool for their classroom. Software features were aligned with classroom curriculum goals, state standards, learning styles, teaching styles, and classroom routines. Using technology such as *WordMaker* software in providing CAI could give classroom teachers additional learning tools to extend learning opportunities needed to meet diverse needs and build necessary literacy skills for school success.

Research

Research Questions

The specific purpose of this study was to examine the advantages and/or disadvantages of the use of CAI program, *WordMaker*, among students with different levels of reading ability. Of particular interest were the effects of *WordMaker* on the spelling performance of first graders in a co-taught classroom. Research was guided by the following questions:

1. What impact does the *WordMaker* software program have on vocabulary and spelling skills of first grade students?
2. What impact does the *WordMaker* software program have on students with various reading ability levels, including those with identified disabilities?
3. How feasible is it to implement the *WordMaker* software program while delivering instruction aligned with a mandated state curriculum?

Setting

The research took place in a typical first-grade classroom in a primary school located in a rural school district of eastern North Carolina. Students are immersed in a literacy-rich learning environment through meaningful pictures, posters, word walls, and books that are strategically placed around the room. The major pattern of instruction within this first grade classroom involves small groups engaged in cooperative learning activities. The groups are not fixed but change according to the subject area, students' interests, and classroom themes. This primary school and county serve an economically depressed population where 75% of the students receive free or reduced lunch. The classroom where the research took place was a co-taught classroom where a special educator and general educator shared in teaching responsibilities.

Participants

Students. Participants were 18 students in this co-taught first grade class that included children with disabilities (n = 3); those at-risk for a disability label (n = 2); English Language Learners (n = 3); average performing students (i.e., academically performing at first grade level, n = 6); and students eligible for enrichment programs (i.e., advanced level of academic performance, n = 4). By gender the students included eight males and 10 females representing white, African American, and Hispanic backgrounds. Table 1 provides additional information on the participants.

Besides students who performed on grade-level with no additional service, there were four other groups of students identified by the services they were receiving within the school-wide system. The at-risk group included students (n = 2) who were in the intervention stage of the referral process for special education services. It is important to note that by the end of this study, it was determined that these students did not qualify for special education services. The enrichment group included students who were identified as gifted and talented within the school, thus allowing them to participate in school-wide enrichment activities. The English Language Learners group included students receiving English as a Second Language (ESL) services. The identified disabilities group included students with disabilities who received special education services under an individualized education program (IEP).

Teachers and classroom assistants. This study involved a general educator, special educator,

Table 1
Student Demographics (*N* = 18)

Gender	Ethnicity	Special Services or Abilities
F	African American	At-risk, receives speech and language therapy
F	African American	Average academic performance, receives speech and language therapy
M	African American	Average academic performance*
M	African American	Qualifies for Enrichment Program
F	African American	Average academic performance*
F	African American	Average academic performance*
F	African American	Qualifies for Enrichment Program
M	Hispanic	English Language Learner
F	Hispanic	English Language Learner
M	Hispanic	Developmental disabilities, Previously retained
M	Hispanic	English Language Learner
F	Hispanic	Qualifies for Enrichment Program
M	White	At-risk, receives speech and language therapy
M	White	Learning disabilities
F	White	Average academic performance*
M	White	Average academic performance*
F	White	Qualifies for Enrichment Program
F	White	Developmental disabilities

*Note: Average academic performance indicates that student is academically performing at grade level.

and classroom assistant. The general educator held a bachelor's degree in elementary education and had four years of teaching experience at the lower elementary level. This was her first experience co-teaching with a special educator. The special educator was a first-year teacher who had completed a master's degree in special education/learning disabilities. The teaching assistant had 15 years of working with first- and second-grade students. She had experience in working with students in small groups providing guided practice and supervising independent practice so she felt confident with monitoring and facilitating one of the stations during the station co-teaching model.

Co-teaching model. The co-teaching model was designed for the special educator to be in the room for an hour and a half every day, usually in the morning. The general and special educators shared teaching responsibilities and planned all lessons together. Instruction was provided and research conducted within the co-teaching station model (Cook & Friend, 1996; Vaughn, Schumm, & Arguelles, 1997) enabling teachers to work with small groups of students who rotated among the teachers, so each student received instruction from both teachers and a teaching assistant

Methodology

Categorization of students into the groups was strictly for record-keeping and research purposes to compare pre-/posttest scores. All students received the same instruction and participated in the same activities within the first-grade classroom.

The three guiding research questions involved different sources of evidence. To address the first and second questions, first-grade students were given a paper-pencil spelling pretest to determine on which lesson each student should begin working in the software program. This pretest was also used as a baseline by which post-interventions achievement was compared. As a result this exact pretest was used as both a pre-and posttest to compare achievement. The final question was answered through teachers' interviews, student interviews and written expressions of their personal use of the software program, and examination of the current first grade English Language Arts curriculum standards for the State of North Carolina (State Board of Education, n.d.).

General Procedures

One day a week, the class was divided into three groups to perform the station co-teaching model. Students were divided into three co-teaching groups randomly and not according to their ability level. In each co-teaching group there were students representing all ability levels. The general education teacher and her assistant had two-thirds of the students working on different skills in math, reading or writing at two stations. At the same time, in the third station (consisting of 3 computers) the special education teacher conducted this computer research with the remaining students for 10 weeks. During the computer time one-half of the students in the third station worked with the *WordMaker* software program while the other half remained at their desks to complete either spelling or vocabulary teacher-directed game-activities, waiting for their turn on the computer. The students rotated within this station until all had completed at least 1 or 2 *WordMaker* lessons on the computers. During the 1.5 hours of co-teaching block students strategically moved through all three stations spending approximately 30 minutes at each, allowing all 18 students to work on the *WordMaker* program in one day.

Pretest/Posttest Assessment

During the first day of this study students were given the *WordMaker* spelling pretest to

Figure 1. Pre-and posttest comparisons between various ability levels.

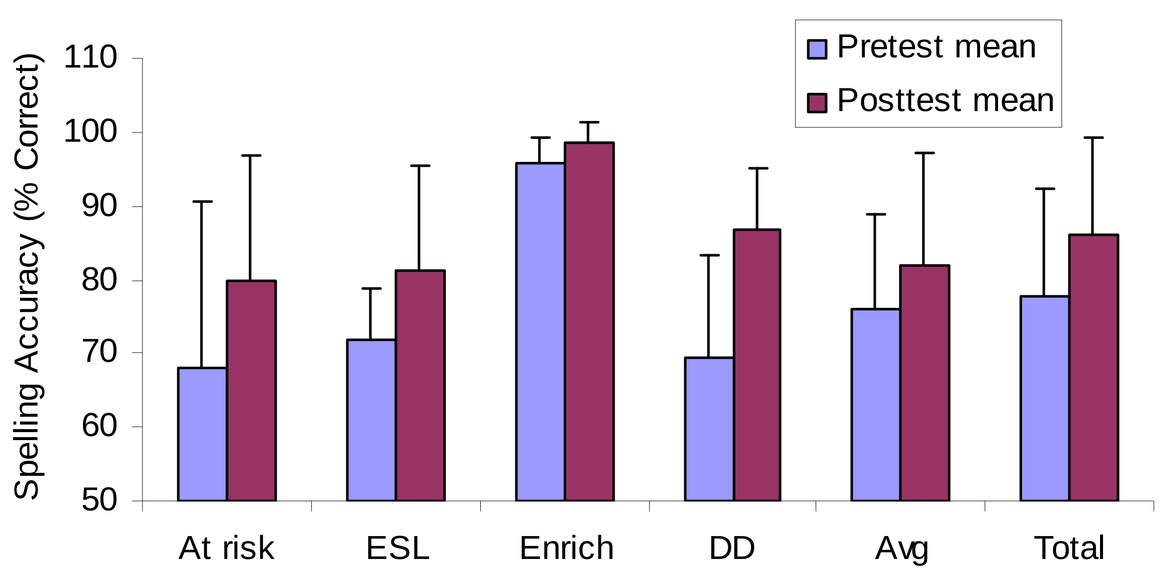


Table 2
Pre-/Posttest Spelling Accuracy (%) for Students Sorted by Group (*N* = 18)

Group (*N* = 18)	Student	Individual Pretest % Spelling Accuracy	Individual Posttest % Spelling Accuracy	Pre-/ Posttest Paired Differences	*M* of Pair Differences for Each Subgroup	*SD* of Paired Differences for Each Subgroup	Group *N*	*t*-value	*p*	*df*
Disabilities	1	84	96	12	17.33	6.11	3	4.914	0.0195	2
	2	68	84	16	--	--	--	--	--	--
	3	56	80	24	--	--	--	--	--	--
At- Risk	4	84	92	8	12	5.657	2	3	0.102	1
	5	52	68	16	--	--	--	--	--	--
ELL	6	68	68	0	9.33	8.326	3	1.94	0.096	2
	7	68	80	12	--	--	--	--	--	--
	8	80	96	16	--	--	--	--	--	--
Average	9	56	76	20	6	13.564	6	1.083	0.164	5
	10	72	80	8	--	--	--	--	--	--
	11	76	96	20	--	--	--	--	--	--
	12	92	96	4	--	--	--	--	--	--
	13	72	56	-16	--	--	--	--	--	--
	14	88	88	0	--	--	--	--	--	--
Enrichment	15	92	95	3	3	2.16	4	2.777	0.035	3
	16	98	100	2	--	--	--	--	--	--
	17	94	100	6	--	--	--	--	--	--
	18	99	100	1	--	--	--	--	--	--
Total	--	--	--	--	8.424	9.712	18	3.68	.0009	17

determine the appropriate starting level for each student within the software program. Before beginning the computer station, the special education teacher read the words for students to spell on their papers in a spelling test format. This multi-level pretest assessed the students' mastery of each word level. In order to move to the next level students must score 100% on the previous one. Fourteen students made errors in the first 25 words and started the program at Lesson 1. The four remaining students spelled the first 25 words correctly and moved beyond the first level. Those students continued to move throughout the pretest, spelling 12 more words on each following level. As a result, they each had a different number of words to spell and started the *WordMaker* program at different lessons (i.e., Lessons 26, 31, 36, 46). During the posttest, students were given the same words they had on the pretest and the percentage of words spelled correctly determined if improvement was made.

Results

In this 10-week study, students completed 16 out of 140 possible lessons. In response to the first research question, "What impact does the *WordMaker* software program have on vocabulary and spelling skills of first grade students?", 15 out of 18 children demonstrated improvement on the posttest. A one-tailed (Ho: $\mu D = 0$ vs. Ha: $\mu D > 0$) paired t-test was performed to measure the difference between pre-/posttest means to determine if there was a significant impact on the number of correctly spelled words as a result of using the *WordMaker* software program.

Pre-and posttest spelling accuracy percentages for each student sorted by group is reported in Table 2. Mean scores were calculated from the ratio of the correctly spelled words over the total words students had to spell. Due to the fact that the total number of words each student received was different, the score percentages were reported. The differences between the pre-/posttest scores for the data were found and the mean and the standard deviation of those differences were calculated (see Table 2).The average difference in pre-/posttest scores for the entire class was 8.424 ($SD = 9.712$) which was statistically significant (t=3.680, p=0.0009, df =17).

To answer the second research question, "What impact does the *WordMaker* software program have on students with various reading ability levels, including those with identified disabilities?", comparisons were made between various ability levels. Scores were divided into 5 different groups: identified disability ($n = 3$), at-risk ($n = 2$), ELL ($n = 3$), average ($n = 6$), and enrichment ($n = 4$). Figure 1 illustrates that all groups performed better on the posttest. As indicated in Table 2, the mean increase in words spelled correctly for students with an identified disability spelled was 17.33% ($SD = 6.110$) from pretest to posttest which demonstrated a statistically significant difference ($t = 4.914$, $p = 0.0195$, $df = 2$). Students in the at-risk group had a mean increase of 12% ($SD = 5.657$) of words spelled correctly which was not statistically significant ($t = 3$, $p = 0.102$, $df = 1$). Students in the ELL group averaged an increase of 9.33% ($SD = 8.326$) of words correctly from pretest to posttest which was not statistically significant ($t = 1.94$, $p = .096$, $df = 2$). The average performing group had a mean increase of 6% ($SD = 13.564$) from pretest to posttest which was not statistically significant ($t = 1.083$, $p = .164$, $df = 5$). Student in the enrichment group had a mean increase of 3% ($SD = 2.16$) of words spelled correctly from pretest to posttest which was statistically significant ($t = 2.777$, $p = .035$, $df = 3$).

In response to the third research question, "How feasible is it to implement the *WordMaker* software program while delivering instruction aligned with a mandated state curriculum?", teacher interviews revealed that the *WordMaker* software program is an excellent supplement to the first grade curriculum and enhances students' learning of phonics. One teacher stated, "*WordMaker* software corresponds well with the first-grade curriculum and provides extra activities for practicing essential first-grade skills." This program helps students to achieve the goals set forth by the state of North Carolina in language arts for first grade as outlined in

North Carolina Standard Course of Study (NCSCS; State Board of Education, n.d.). Teachers reported that it corresponds to the following competences of the NCSCS, Language Arts, First Grade: 1.01, 1.02, 1.04, 5.01, 5.02 (State Board of Education). With the help of the *WordMaker* program, teachers were able to apply technology not only in order to meet students' individual needs, but also to execute the NCSCS. Both teachers participating in this study stated that students were highly motivated by this program and benefited from the practice of essential skills though various activities.

Discussion

The purpose of this investigation was to examine the advantages and/or disadvantages of the use of the computer software program *WordMaker* on students with different levels of reading ability.

In the short time this study was implemented the majority (83%) of students experienced gains between pre-and posttest scores. The following paragraphs discuss three specific research questions that were addressed in this study: (a) What impact does *WordMaker* software program have on vocabulary and spelling skills of first grade students? (b) What impact does *WordMaker* software program have on students with various reading ability levels, including those with identified disabilities? and (c) How feasible is it to implement the *WordMaker* software program while delivering instruction aligned with a mandated state curriculum?

Increased Skills

Within the *WordMaker* program, students progressed in their spelling and decoding skills. The program is set up to provide opportunities to work with the same words in different ways. Obvious gains were accomplished by students. Benefits of this program can be seen through the following examples. For example, one student made a mistake in the words 'jump' and 'jumping' on the pretest. She also made the same mistakes in Lesson 12 where those words were introduced. In the computer lesson she learned how to spell those words correctly. In Lesson 15, when those words were reintroduced, she didn't make a mistake. When given the posttest, she spelled those words correctly. Interesting enough, when that student was given those words on the posttest she stated, "I saw these words on the computer. I know how to spell them." Students began to transition the skills from the software program to other writing tasks. Another example of how students progressed in skills throughout working with this program involved making mistakes with the words 'has' and 'had' on the pretest. The computer introduced the correct way of spelling them in Lesson 4 after the student repeated these mistakes. When those words were reintroduced in Lesson 5 there were no mistakes. In addition, the student didn't make the same mistakes on the posttest.

Throughout the use of the *WordMaker* software, students manipulated letters to make the words, which lead them to discover new word patterns. Students began to experience success while spelling unfamiliar words. For example, the word 'kittens' that was on the pretest was not a part of any lesson students in this study were able to complete. In Lesson 14 there was a word 'rabbits' that has a similar pattern. As a result, some students were able to spell the word "kittens" correct on the posttest. Interestingly enough, word pattern is not a part of the first grade curriculum. For that reason it was not introduced by teachers throughout the year. This leads the researchers to believe that such improvement on the posttest can be attributed to the use of the *WordMaker* software program (for further discussion see Outcomes and Benefits section).

Varying Abilities

The classroom chosen for this study is a snapshot of a typical first-grade classroom in a public school with children performing on different levels. When examining the effects of the *WordMaker* software program on students with various reading ability levels all groups showed different levels of improvement. One of the most interesting findings in this study was that the two groups that had a statistical significance in differences between the pretest and posttest scores were the children with disabilities group and the enrichment group. Such a finding supports that the *WordMaker* program benefits struggling readers as well expanding the abilities of the enrichment learner even further. Teachers in this study reported that the individualized pace of the software program provided the enrichment group practice of essential reading and writing skills while advancing them to more challenging word levels. Students in the children with disabilities group benefited from the practice of essential skills in a learning environment that reduced distraction and required hands-on learning. It's important to note that students in the children with disabilities group shared comments such as, "I like to pull the letters to the line" or, "it is fun because you have to drag the letters to make a word," when asked, " what do you like about this program?"

These findings suggest that *WordMaker* doesn't just work as a remediation tool for students with disabilities to work on specific areas of deficiency such as making words. It benefits all groups of students. Because of this finding, teachers in this study strongly agreed that *WordMaker* can be easily used in a typical first-grade classroom both for students with disabilities and typical students. The fact that overall difference on the pretest and posttest for all students in the class together was significant supports the idea that first-grade students of varying abilities may benefit from using the *WordMaker* software program.

It should be noted that throughout the use of the *WordMaker* program, the students' approach toward literacy tasks began to change. Teachers observed students exploring words in their environment and playing games to make new words. This appeared to be fostered by their use of *WordMaker*. All students stated when asked that they enjoyed working with the *WordMaker*. Each student found something that caught his/her attention in this program. Students liked different parts of the *WordMaker* software program. One student mentioned, "I like to play Find Words. We need to find the things that the computer says. We need to do it fast because the time is running out." Another student enjoyed Secret Word: "I like Secret Word because it is fun. It is like a mystery and it gives you hints. It makes you figure the word out. And when you get something right, they give you points." Many students liked Wordo, noting that "It's just like tic-tac-toe", or "It's fun because you can beat the laptop or the laptop can beat you."

Natural Fit

The *WordMaker* software program enhances the first grade curriculum. Literacy is the biggest part of any first-grade daily routine and takes the majority of the time in the academic year. For that reason the *WordMaker* software program is a natural fit in the first-grade classroom. However, existing research on assistive technology makes it clear that simply providing technology to teachers and students will not result in academic improvements. Careful thought and consideration must be taken in order to use any software program in a meaningful way for students. In this study, the use of the software program was to complement teacher-directed activities. Teachers were involved in planning and preparing literacy experiences throughout the entire day. The *WordMaker* software was infused into the instructional routine. It was a meaningful and useful tool that provided students with another opportunity to learn and use phonics and spelling skills.

Outcomes and Benefits

The specific purpose of this 10-week study was to examine the advantages and/or disadvantages of the use of the computer software program *WordMaker* on students with different reading ability levels. In order to determine the impact of the software program, the spelling performance of first graders in a co-teaching classroom was examined. Eighteen students in this study represented a variety of categories (i.e., average, at-risk, identified disability, ELL, and enrichment) that are typically found in a first-grade general education classroom. Differences in students' pre-/posttest scores for the children with disabilities group and the enrichment group were found to be statistically significant.

This study reveals similar results as the research review conducted by Cotton (1991) a decade earlier. In summary, the following findings for students working with the *WordMaker* software in this study were compared to the research literature review of CAI:

1. Previous research supports that CAI is beneficial for younger students. This study found that first grade students benefit from using the *WordMaker* software.
2. Previous research supports CAI is more beneficial for lower-achieving students than with higher-achieving ones. This study found overall differences in pre-and posttest spelling scores were significant for students with identified disabilities and students involved in enrichment programs, however the difference was greater for students with disabilities or at risk groups in other ways.
3. Previous research found students' fondness for CAI activities centers around the immediate, objective, and positive feedback provided by these activities. This study reports that students benefited from multimedia approach involving hands on activities of moving letters, engaging graphics and sounds.

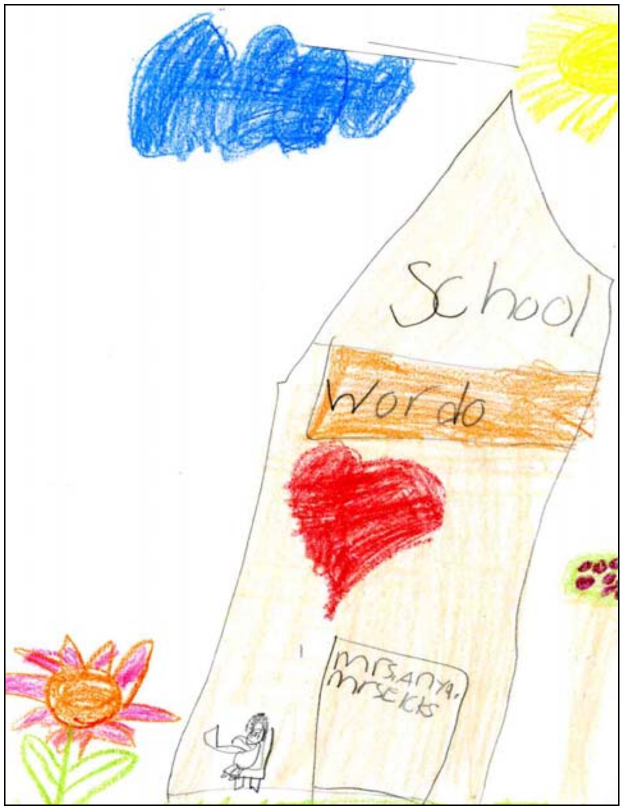
Limitations

One of the major limitations to this study is the lack of control group; therefore, it is difficult to attribute results to the specific intervention alone. However, several word patterns used on the pretest and posttest were not introduced in the first grade classroom. Thus we can suggest that the improvement on the spelling test can be somewhat attributed to the use of the *WordMaker* software. Another major limitation is the small number of students in each ability group. Nonetheless, we are encouraged by the increase in scores from the pretest and posttest demonstrated by the entire class. The final limitation to this study discussed here is the length or duration of the use of the software. Perhaps if this study were conducted throughout entire academic year significance might have been reached in all groups. Further research is recommended in order to challenge such limitations.

Software Feedback and Suggestions

Both teachers and students saw the many benefits of *WordMaker*. Immediate feedback was mentioned several times. Teachers stated that when a student misspells a word, the computer provides immediate speech feedback that serves the purpose of strengthening the reader's decoding and spelling ability and avoiding the possibility

Figure 2. Students express their feelings about using *WordMaker* software. This picture illustrates how one first-grader loves school, her teachers, and *Wordo*.



that errors go unnoticed. One student with learning disabilities mentioned that, "You hear every letter and word you click on so you can figure if something is wrong."

Teachers expressed that immediate feedback was important but it wasn't always enough. They would like to see the software program make adjustments within the current lesson. The special education teacher shared:

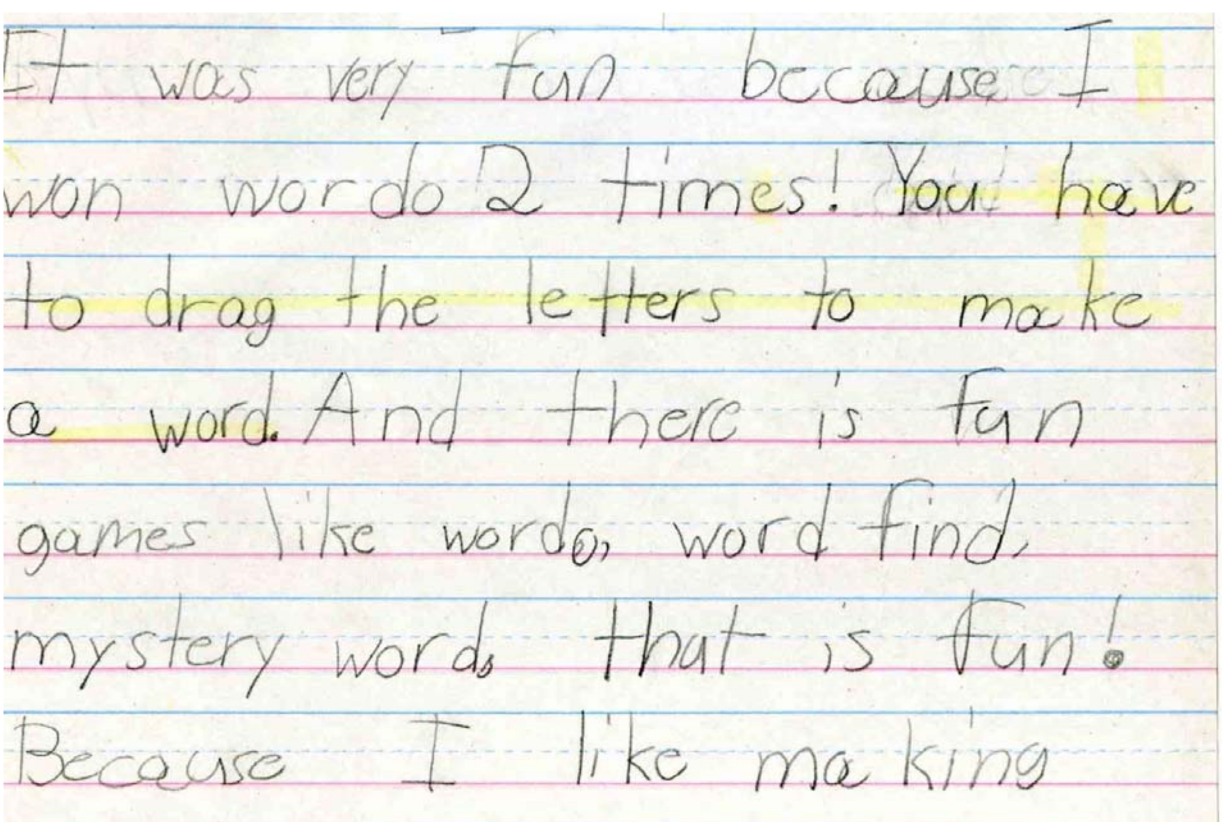
> I would like to see an improvement within the *WordMaker* program. For some students it wasn't enough to have the same words repeated a couple of times. It appeared that little or no adjustment was made within the lessons if students were not successful with words in the lesson. Students could benefit from some adjustment in the following lesson if they were not very successful in the previous one. For example, I observed that if one student scored 65% in one lesson while another scored 100% on the same lesson, both would have the next lesson with the same words regardless of level of mastery. It appears that *WordMaker* software does adjust the following lesson but only in case when a student failed the previous one completely. Ideally, I would like the software to provide an individualized bonus activity or a game throughout the program engaging the student to use the troublesome words until mastery was reached.

In further conversation, both teachers expressed how surprised they were to see the students really enjoying making words and exploring new words but on and off the computer. Yet teachers expressed that "regardless of the benefits of *WordMaker* it would probably be difficult to have every student work with the program everyday due to time limitation and computer availability."

When students were asked, "What did you like about the *WordMaker* program?" every student had positive things to say about it. One first grader shared, "I like *WordMaker* because I get to think and make words." Another student stated, "I like *WordMaker*. I can write difficult words. It's fun. I can spell easy words. I can spell hard words." Students were encouraged to work with this software because as one of the students noted, "I like *WordMaker* because it gives me points." When working in the Wordo, another student expressed that "Wordo is a fun game because sometimes I win. Sometimes she wins (in this case she refers to the computer)." Other examples of students' feedback in using the *WordMaker* software can be found in Figures 2 and 3.

Teachers observed first-hand that *WordMaker* engaged students in practicing decoding and spelling skills in a fun way. Every student enjoyed using the program and didn't feel it was tedious or too difficult. Other teacher comments in this study include: (a) enrichment students benefited from the individual pace and the opportunity to move beyond first-grade words; (b) although teachers are skeptical in their particular educational setting of how the software could be used everyday for every student; as a supplementary instructional tool it seems to

Figure 3. First-grade student writes about his *WordMaker* experience.


It was very fun because I
won wordo 2 times! You have
to drag the letters to make
a word. And there is fun
games like wordo, word find,
mystery word, that is fun!
Because I like making

works very well with the curriculum; and (c) both teachers and students enjoy using CAI.

Future Studies Needed

This action research study provides insight to the use of CAI, specifically *WordMaker* software, for first-grade students. Yet, the following questions still remain unanswered and need further research: (a) If students used the *WordMaker* software for an entire academic year, would academic growth increase or would children grow tired of it? Would student lose interest and motivation? If so, what could be done to minimize this occurrence? and (b) Is it possible in today's typical classrooms to integrate CAI for daily use by every student? If so what additional benefits would accrue to students?

In a 10-week period the *WordMaker* software program had positive impact on children's decoding and spelling skills. It was found to be an effective complement to other activities associated with the first grade curriculum (e.g., spelling and decoding) and has the potential enhancing students' reading and writing skills.

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Comparison of Semantic Versus Syntactic Message Formulation: A Pilot Study

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Abstract: Two prototype voice output communication aids were implemented to compare methods of graphic symbol message formulation; one emulated current devices that require syntactical ordering of icons (Default) and the other used semantic frames (iconCHAT). Message constructions of eight typically developing children (7-10 years of age) using both prototypes were compared in terms of accuracy, speed, complexity, and preference. Although there were slight differences in speed, all participants formulated equally complex and grammatically accurate sentences using both prototypes. These findings demonstrate that semantic frame-based message formulation may be a viable alternative to conventional methods based on syntax. Future research to assess whether these findings extend to children who use AAC is warranted. Outcomes and benefits of semantic composition are particularly relevant for children with emerging grammatical skills since semantic schemas provide scaffolding for constructing complete utterances that may in turn foster increased self-confidence and improved perceptions of communicative competence.

Keywords: Message construction, Semantics, Syntax, Symbol communication

Individuals with severe expressive communication impairments rely on alternative and augmentative communication (AAC). Rather than conveying information through spoken or written language, an individual can use gestures, eye gaze or picture symbols to represent underlying concepts. The use of picture symbols as a method of communication has gained increasing appeal as advances in technology enable access to larger vocabularies on dynamic displays. When paired with voice output, these devices serve as a powerful means for expressing one's ideas when speech alone is ineffectual. Most commercially available voice output communication aids (VOCAs) use a linear (syntactic) approach to message construction. For example, to generate the message, "I want soda," the user selects a series of icons that follow the ordering rules of English (*I*+ *want*+ *soda*). This method of message formulation requires that the user have at least basic knowledge of syntax and thus may be challenging for those with linguistic and intellectual impairments. Additionally, given that children learning to use an assistive communication device may also be learning language simultaneously (Sutton, Soto, & Blockberger, 2002), the system may play a "central role in the language acquisition process" (Sutton et al., p. 192). Clinicians often attempt to compensate for the user's emerging or delayed linguistic skills by arranging vocabulary in a grid display organized by parts of speech to facilitate serial ordering of icons from left to right. However, no experimental research supports the notion that this vocabulary arrangement assists in language learning (Beukelman & Mirenda, 1998). At least in non-disabled adults, Nakamura, Newell, Alm, and Waller (1996) found that participants can generate grammatically accurate utterances regardless of symbol arrangement. Thus, the use of syntactically ordered symbol arrays may actually limit morphological and syntactical learning by circumventing the need for developing of these linguistic skills.

Studies have shown that utterances formulated using AAC devices are markedly different than utterances produced through natural speech. Utterance length is typically limited to simple two- or three-word sequences (Bruno, 1989; Light, Collier, & Parnes, 1985; Udwin & Yule, 1990; Van Balkom & Welle Donker-Gimbrere, 1996; von Tetzchner & Martinsen, 1996). Atypical syntax is often a hallmark of even simple constructions (Grove & Dockrell, 2000; van Balkom & Welle Donker-Gimbrere) and more often for complex constructions with multiple clauses (Sutton, Morford, & Gallagher, 2004), thereby impacting message accuracy and grammaticality. Additionally, a review of commonalities in AAC message formulation across studies (cf. 1997, 1999) indicated that users often communicated in one-word utterances, and rarely used questions, commands, negatives, or auxiliaries.

Sutton et al. (2004) suggest that one factor contributing to limited grammaticality may be the design of the AAC display itself. The lack of morphological markers and function words, as well as the arrangement of vocabulary items may negatively influence the completeness of the utterances produced. Even when verbs and articles were readily available, users often neglected to use them in their constructions (Kelford-Smith et al., 1989; Soto, 1999).

Furthermore, communication partners may attempt to facilitate information exchange by "early interpretation" (Sutton, Gallagher, Morford, & Shahnaz, 2002, p. 206) of incomplete message constructions. This may lead to misinterpretation of messages constructed with atypical syntax (Sutton et al.) resulting in communication breakdowns. Practices such as early interpretation do not foster grammatical completeness and thus may ultimately impact communicative competence (Blockberger & Sutton, 2003; Sutton et al.; von Tetzchner & Martinsen, 1996).

Message construction methods that provide linguistic cues regarding semantic and syntactic relationships may encourage more complete and sophisticated utterances. There has been a long-standing debate among linguists regarding the syntactic versus semantic underpinnings of written and spoken language (cf. Chomsky, 1965, 1986; Filmore, 1968; Steinberg, 1993). While AAC methods of message construction typically follow the syntactical approach, perhaps meaning-based methods should be considered as an alternative approach for at least some users.

Case grammars focus on the relationships between the verb and all other sentence constituents. The semantic schema associated with each verb dictates the essential sentence constituents. The notion that the verb is central to message formulation has been supported by empirical evidence (Griffin, 1998; Griffin & Bock, 2000). The use of semantic schemas may facilitate message construction by making the rules of grammar more transparent and thus perhaps easier to learn. Semantic frames may also be effective for reducing keystrokes, easing the cognitive burden associated with message construction, and improving access to vocabulary.

The present study aimed to compare message formulation using a semantic frame-based approach versus the conventional syntactic approach. To pilot the stimuli and experimental protocol, we began with a group of eight typically developing children. To control for interface design and implementation issues, two prototype devices were built, one in which messages were constructed using semantic frames (iconCHAT) and the other which required serial ordering of icons (Default). Message formulation using each prototype was compared using the following outcome measures: formulation rate, accuracy, complexity, keystrokes per utterance, and user preference.

Method

Participants

Eight typically developing children between seven and ten years of age (mean age 8 years, 5 months) were recruited from the Greater Boston area. There were four female participants (S1, S4, S6, S8) and four male participants (S2, S3, S5, S7), all of whom were native English speakers. Parental interviews indicated that all children had no documented speech, language, or hearing impairments and had at least average academic performance and intellectual ability. Prior to data collection, informed written consent was obtained from each child's caregiver. In addition, verbal assent was obtained from each child. At the completion of the experiment, participants received an honorarium.

Materials

The iconCHAT and Default prototypes were implemented on a tablet computer. Icon selections for both prototypes were made using a stylus. For speech output, both prototypes used IBM speech for Java, with the IBM Viavoice core.

Prototype Systems

The iconCHAT prototype employed a semantic message formulation schema (Dominowska, Roy, & Patel, 2002; Patel, Pilato & Roy, 2004). Rather than selecting words based on serial ordering, a message was constructed by first selecting a semantic frame

Figure 1. iconCHAT screenshot while constructing the phrase "I wear red shirt."

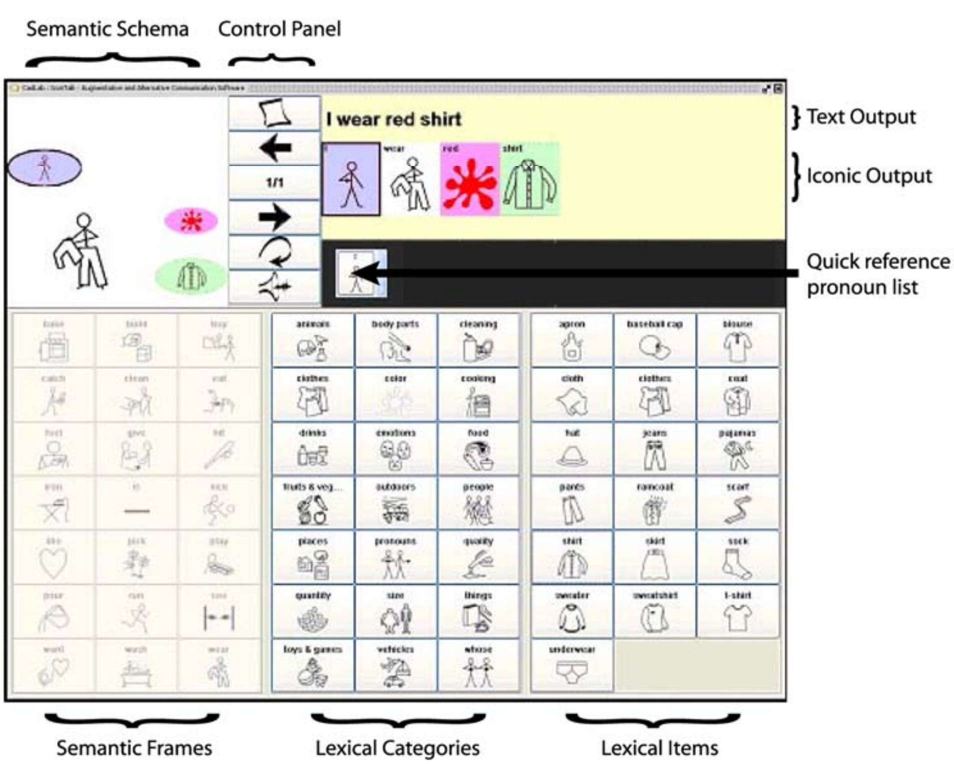
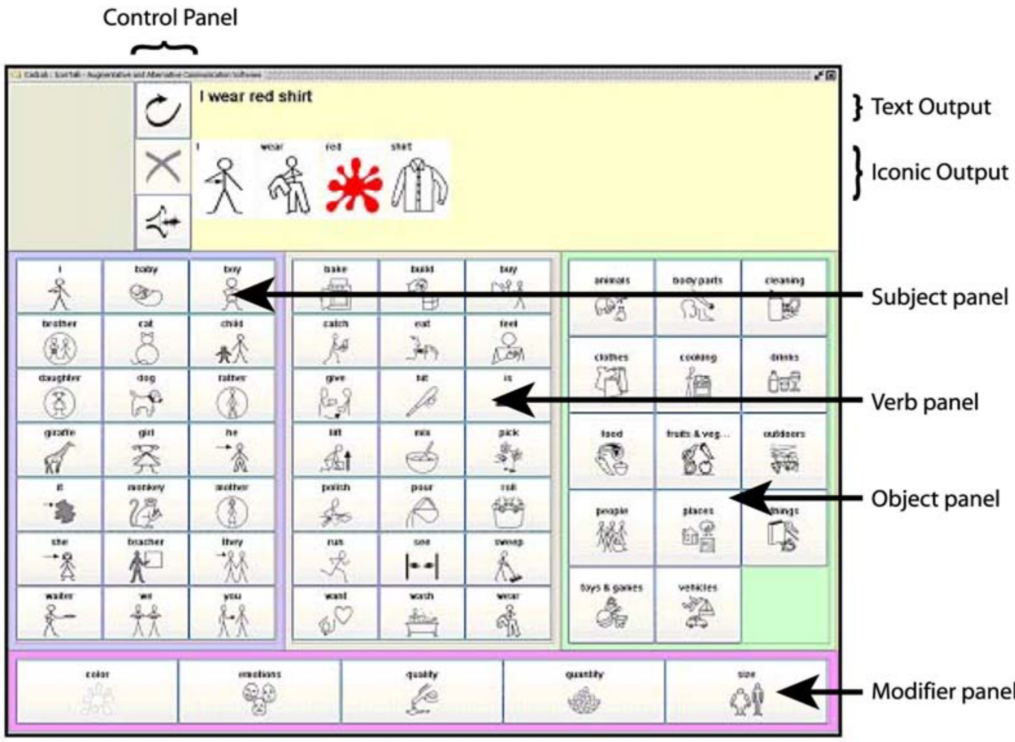


Figure 2. Default screenshot while constructing the phrase "I wear red shirt."



which is based on the predicate. This instantiates a frame with unfilled slots for specifying the agent, object, and other predicate-dependant components (based on case grammars in Fillmore, 1968). For example, to construct the sentence "I wear red shirt", the user first selects the "wear" frame. This frame minimally requires an agent that is performing the action and an object on which the action is performed. Either agent or object roles may also be further modified. The message-in-construction was displayed as a two-dimensional spatial schema to convey relationships between thematic roles. In addition, serial ordering of icons, similar to that used in conventional VOCAs, served as backchannel feedback of the speech synthesizer output.

Within iconCHAT, the vocabulary was arranged in three panels: semantic frames, lexical categories, and lexical items (see Figure 1). Once a semantic frame was chosen, the lexical categories were made accessible. Choosing a category revealed specific vocabulary items within that category in the lexical items panel. Lexical items included a variety of agents, objects, or modifiers grouped by category. Additionally, a quick reference drop-down menu could be used for faster access to pronoun vocabulary. The control panel allowed for deletion of a word or message, reuse of previously constructed messages, and generation of spoken output using the text-to-speech synthesizer. See Patel, Pilato & Roy (2004) for a detailed explanation of the iconCHAT prototype.

The Default prototype emulated the message formulation technique available on most commercially available VOCAs. In particular, a message was constructed by serially ordering, from left to right, the constituent components. In English, the minimal sequence of selections would include subject + verb + object (SVO). Additionally, the

Figure 3. Sample picture stimulus for eliciting "Boy catch ball."

subject and object roles could be further modified. Vocabulary in the Default prototype was organized in four panels: subject panel, verb panel, object panel, and modifier panel. The object and modifier panels had two levels of depth; the first displayed object (modifier) categories, and the second displayed items within that category. Selecting an object or modifier revealed its specific vocabulary items within that same panel. Agents, verbs, and object categories were arranged sequentially on the screen, while the modifier categories were arranged along the bottom of the screen (see Figure 2).

For the formulation "I wear red shoes", the user would first select "I" from the subject panel, then "wear" from the verb panel, then "red" from the 'color' category within the modifier panel, and finally choose "shirt" from the 'clothes' category in the object panel. The control panel allowed for deletion of a word, traversing between layers of panels (i.e. to the topmost level of the modifiers or into the colors category within modifiers), and generation of spoken output using the text-to-speech synthesizer.

In order to ensure that the mode of message

Figure 4. Sample stimulus for eliciting "They build snowman."

Figure 5. Sample three-step picture sequence for eliciting consecutive sentences.

construction (semantic vs. syntactic) was the only independent variable contributing to the measured results, several variables were held constant. Both prototypes had dynamic displays with similar visual components including identical overall display size, graphic symbol set, icon size, icon resolution, icon shape, spacing of icons, color coding scheme, font, and font size. Since iconCHAT and Default were implemented on the same tablet computer, the orientation and angle of display was also identical. Selection of icons was done directly via stylus, and activation feedback, in the form of light/dark shading, was identical within each prototype. In addition, the same type of synthetic voice output (IBM speech for Java, with IBM Viavoice core) was utilized for each prototype.

Both prototypes had the same vocabulary size and types of words available. Although many commercial systems include multiple pages of vocabulary, it was important to limit the vocabulary depth to two levels and to allow access to all vocabulary categories (i.e., subjects, verbs, objects, and modifiers) on the topmost level in order to fairly compare iconCHAT and the Default system. Both prototypes did not include grammatical morphemes, function words, conjunctions, or articles. The vocabulary items embedded within each lexical category were identical for both prototypes.

Stimuli

Cartoon images of activity scenes were used to elicit simple sentence constructions using each prototype. Picture cards were chosen as stimuli in order to provide a simple context and to elicit active message formulation. Two stimulus lists (A and B) balanced in semantic and syntactic complexity were created to control for practice effects across prototype use. Within each list, there were 18 pictures, consisting of six individual scenes and four three-step sequences. The three-step sequences provided a means for assessing message formulation within a simple narrative. Presumably, some of the constituent components across the three sentences within a sequence would be constant and thus may be accessed easier or faster.

The child was shown each picture scene and was asked to use the prototype to describe what was happening in the scene. The child was instructed to first verbalize the message to the experimenter in order to ensure that his/her vocabulary choices were possible. The experimenter prompted the child to think of another way to describe the scene if the vocabulary item(s) was not available. Otherwise, the experimenter simply encouraged the child to proceed with formulation. The order of use of the prototypes systems and the stimulus lists was counterbalanced across subjects. See Figures 3 and 4 for examples of individual scenes, and Figure 5 for an example of a three-step sequence.

Table 1 lists the simplest complete messages that can be constructed based on the pictures in each stimulus list. Agents such as “boy”, “girl”, “man”, “woman”, and “child” could be used in place of pronouns. Additionally, optional modifiers could be used to further describe subjects (agents) or objects.

After participants completed all phases of the study, a qualitative survey was administered to assess ease of use and the satisfaction associated with both the iconCHAT and Default prototypes. The survey was composed of nine closed-ended questions and two open-ended questions. The closed-ended questions assessed overall perceived ease of use, ease of sentence construction, vocabulary search, and understandability of graphic buttons for each system. In addition, one question about iconCHAT asked whether participants used the colored ovals in the top left corner (i.e., the spatial schema) versus the colored rectangles on the right (i.e., the serially ordered icons) when formulating sentences. The open-ended questions asked which aspects of each system the participant liked and disliked.

Analysis

Each prototype captured a real-time log of the experimental session. The following dependant measures were calculated and analyzed for each message constructed:

Table 1
Simplest Message Formulations for Each Picture Stimulus

Stimuli List A	Stimuli List B
1. Boy catch ball.	1. They wash window.
2. They build snowman.	2. Girl ride horse.
3. Girl buy ice cream.	3. They eat cookie.
4. They pick tomato.	4. They fly kite.
5. She polish shoe.	5. They ride bicycle.
6. She sweep floor.	6. Monkey steal hat.
7. Boy see shirt.	7. Chef read cook book.
8. He wear shirt.	8. He stir batter.
9. He wear pants.	9. He bake cake.
10. She pour water.	10. Boy see dog.
11. She lift dog.	11. He want dog.
12. She wash dog.	12. He buy dog.
13. Woman roll dough.	13. She see birthday cake.
14. She bake pizza.	14. She blow candle.
15. She eat pizza.	15. They eat birthday cake.
16. Boy hit ball.	16. Man dig hole.
17. He run home.	17. He plant seeds.
18. He touch base.	18. He water ground.

1. *Construction time per linguistic unit* was calculated by dividing the total time for message construction by the number of linguistic units. Message construction time was measured from the initiation of a new message to the command for spoken output. A "next" button was implemented to control for inter-message discussion or breaks. After the experimenter showed the participant the picture stimuli, she asked the participant to indicate when he/she was ready. At that time, the experimenter selected the "next" button. The number of linguistic units corresponded to the number of individual vocabulary items (i.e. icons) within an utterance. For example, the utterance, "she buy ice cream", was counted as three linguistic units although there are four words in the sentence. Within both prototypes, "ice cream" was listed as a single vocabulary item, meaning that there were three linguistic units in the utterance: "she", "buy", and "ice cream". The available vocabulary was identical within both iconCHAT and Default.
2. *Time per button click* was calculated by dividing the message construction rate by the number of button clicks to complete that utterance. Number of button clicks was counted from the first button pressed after initiation of the new message until the button commanding spoken output was pressed. This measure is differentiated from the calculation of linguistic units as button clicks apply to both vocabulary selection and activation of commands.
3. *Button clicks per linguistic unit* was calculated by dividing the number of button clicks by the number of linguistic units in the utterance.
4. *Percentage accuracy* was measured by analyzing the semantic accurateness of the subject (agent), verb (predicate), and object. If all three components were correct, then the message was considered 100% accurate. The participant was credited for only the main semantic constituents.
5. *Complexity* was measured by analyzing the use of modifiers within constructed messages. One point was awarded for each optional modifier.
6. Use of the *quick reference panel* was a binary measure that was analyzed only for the iconCHAT system, as Default did not have this capability. If the participant used the quick reference panel to select an agent or pronoun, she was credited one point per utterance. The measure was out of 18, since there were 18 utterances constructed.
7. *Reuse of prior message constructions* was a binary measure that was analyzed only for the iconCHAT system, as Default did not have this capability. If the participant used a previously constructed message to reduce the number of keystrokes, she was credited one point per utterance. The measure was out of 18, since there were 18 utterances constructed.

Paired *t*-tests were conducted to examine differences between the iconCHAT and Default prototypes in terms of time per linguistic unit, time per button click, and button clicks per linguistic unit. The remaining outcome measures could not be compared numerically since some features (e.g. the quick reference list, utterance reuse button) were not available in the Default prototype.

Results

The heterogeneity of participant strategies for message formulation is evident in the results (see Table 2). While some participants were faster and required fewer keystrokes to formulate utterances using iconCHAT, others performed better using Default. All participants were 100% accurate in terms of grammatical completeness using both prototypes. Sentence structures used in both prototypes were either in the SVO, SVMO, or SVMMO forms. Furthermore, there were no significant differences between stimulus list A and B in terms of accuracy, speed, or number of keystrokes.

There were no statistically significant differences between the prototypes in terms of time per linguistic unit (p = 0.21). Although there was a statistically significant difference in time per button click [$t_{(143)}$ = 2.32 ; p = 0.022] between the two prototypes, the difference was rather small. Participants required on average 5 seconds per button click using iconCHAT compared to 4 seconds per button click using Default. While six of the eight participants (S1, S2, S4, S5, S7, S8) accessed buttons slightly faster using Default, there was no difference in time per button click for the other two participants (S3, S6). There was also a statistically significant difference in the number of button clicks per linguistic unit [$t_{(143)}$ = -3.28 $_{(143)}$; p = 0.001] with iconCHAT requiring fewer clicks (average = 1.9 clicks per linguistic unit) compared to Default (average = 2.1 clicks per linguistic unit). This pattern was noted for all participants except S2 for whom the average button clicks per linguistic unit was identical for both prototypes.

Participants varied in the complexity of utterances they generated. When using Default, S7 and S8 were keen on elaborating on messages using modifiers. In fact, they were the only participants who used SVMMO constructions ("He see one green shirt"). In contrast, S1, S2, S3, S4 and S6 formulated more complex utterances using iconCHAT.

When using iconCHAT, all participants used the quick reference panel to a large extent; five participants (S2, S3, S5, S6, S7) used the panel for all utterances, and the other three children used the panel for the majority of utterances. However, only one child (S5) reused a prior message construction.

Results of the qualitative survey varied across participants. Overall, two participants (S1, S3) thought that iconCHAT was easier to use, four participants (S2, S4, S6, S8) thought that Default was easier to use and the other two participants (S5, S7) rated both equally in terms of ease. Five of the eight participants (S1, S2, S3, S4, S5) said that they used the semantic schema as opposed to the serially constructed message when formulating sentences using iconCHAT. In the open-ended questions, six participants (S1, S2, S3, S4, S5, S7) mentioned relying on the "bubbles" (i.e., semantic schema) rather than the serial ordering display in iconCHAT. Additionally, all participants reported that they liked using the quick reference panel to access pronouns on iconCHAT. Four participants (S1, S2, S5, S7) mentioned that they liked how iconCHAT "showed what needed to be filled in." Some positive feedback regarding Default included "faster to learn," "liked the details (modifiers) along the bottom," and "liked having all the categories on one page." Overall, the children reported having fun at the task and "liked making sentences and hearing it talk." There was very little negative feedback for either prototype. Two participants (S2, S5) commented on the need for more vocabulary items on both prototypes. One participant (S2) noted that having to select the verb first was odd in the

Table 2
Quantitative Differences in Message Formulation Using iconCHAT Versus Default

Participant (Age_Sex)	System	Avg. Time per LU[1] (sec.)	Avg. Time per Button Click (sec.)	Ave. Button Clicks per LU	Avg. % Accuracy	Total Complexity Points	Quick Reference Panel	Prior Message Viewed
S1 (8_F)	I[2]	14	7	1.9	100	5	16/18	0/18
	D[3]	16	6	2.3	100	4	n/a	n/a
S2 (10_M)	I	11	5	2.0	100	6	18/18	0/18
	D	8	4	2.0	100	0	n/a	n/a
S3 (7_M)	I	14	7	1.9	100	7	18/18	0/18
	D	16	7	2.3	100	1	n/a	n/a
S4 (7_F)	I	11	6	1.9	100	5	17/18	0/18
	D	8	3	2.2	100	3	n/a	n/a
S5 (8_M)	I	10	4	2.2	100	7	18/18	1/18
	D	7	3	2.3	100	11	n/a	n/a
S6 (8_F)	I	6	3	1.8	100	9	18/18	0/18
	D	6	3	2.1	100	6	n/a	n/a
S7 (10_M)	I	7	4	1.8	100	8	18/18	0/18
	D	6	3	1.7	100	14	n/a	n/a
S8 (10_F)	I	7	4	1.7	100	5	17/18	0/18
	D	7	3	2.0	100	14	n/a	n/a

[1]L.U. = linguistic unit
[2]I = IconCHAT
[3]D = Default.

beginning because it was "not what I'm used to" but that "it was cool though, I guess" because it "helped me."

Outcomes and Benefits

The present study compared two methods of message formulation using graphic symbols in terms of accuracy, speed, and complexity of constructions with a group of eight typically developing children between 7-10 years of age. Two prototype VOCAs were implemented--one that required serial ordering of icons in terms of English syntax (Default) and one that used semantic frames (iconCHAT). Although individual participants differed along quantitative measures and in their qualitative impressions of the two methods of message formulation, both prototypes were easily mastered by all participants. This group of typically developing children had no difficulty formulating grammatically and semantically accurate sentences using either prototype. Message formulation using the iconCHAT and Default prototypes differed somewhat in two ways. Although the time per button click was slightly faster using Default, fewer button clicks were needed per linguistic unit when using iconCHAT. These findings are relevant for users of AAC because fatigue is often a rate limiting factor (Smith, 1996). Some users with severe motor impairments may be willing to compromise time to conserve energy.

Message formulation using graphic symbols differs from both written language and speech (Nakamura et al., 1998; Smith, 1996; Soto 1997; Sutton & Morford, 1998). Most currently available VOCAs, however, impose written language (i.e., syntactical) norms as the benchmark. Results of the present study suggest that semantic-based approaches to message formulation are at least as effective in facilitating accurate and complete utterances for typically developing children. Future research to assess whether these findings extend to children who use AAC is warranted.

It is noteworthy that all participants were relatively adept at learning to use the semantic-based system despite its difference from the way they are used to composing written text. Similar to Nakamura et al.'s (1998) findings, we found that users can readily adapt to the organization of the visual display. This adaptation may be facilitated by the iconCHAT interface which provides backchannel feedback about message construction in two ways. First, a two-dimensional semantic schema illustrates the relationships between icons and second, the serial ordering of icons provides the user with feedback regarding the output of the speech synthesizer. Six of the eight children indicated that they relied on the semantic schema more than the serial ordering. They noted that the semantic schema was useful in cuing them as to what was required to make a complete sentence. This feature may be even more beneficial to children who use AAC given that their constructions are often limited to single word utterances and marked by atypical syntax (Bruno, 1989; Grove & Dockrell, 2000; Udwin & Yule, 1990; Van Balkom & Welle Donker-Gimbrere, 1996; von Tetzchner & Martinsen, 1996).

With regard to message complexity, there were individual differences in linguistic abilities and styles. While some children formulated elaborate utterances using iconCHAT, others tended to rely on modifiers in the Default prototype. It should be noted that not all utterances in iconCHAT could be modified because only simple semantic frame structures were used in this initial usability test. For example, although the "eat" frame can take "agent," "count noun," "modifier," and "object" roles, the "count" and "modifier" roles were excluded for simplicity. In contrast, potentially all utterances could have been modified using Default since there were no restrictions on when modifiers could be used. It may be worthwhile in future implementations of iconCHAT to include a modifier panel along the bottom of the interface.

While simple sentence forms were used in the present study, using more complex sentence formulations (as in Sutton et al., 2004) may yield more striking differences between semantic and syntactic formulation techniques. Since iconCHAT enables a two-dimensional representation of the relationships between sentential constituents, message formulation via semantic schemas may make clausal ambiguities more apparent. For example, when constructing the message, "The girl who pushes the clown wears a hat" the semantic role assigned to "girl," "clown," and "hat" are tied to the placement of the icons. Semantic-based formulation may be especially useful for those children who struggle with grasping grammatical constructs since semantic frame facilitate complete sentence production through visual cues.

The quick reference pronoun list was a unique feature of iconCHAT and one that users appeared to like as indicated by their usage patterns. For children who use AAC, this feature may reduce the cognitive load and search time associated with filling the agent role.

Although the iconCHAT prototype also allowed for reuse of previously constructed messages, only one participant used this feature. This may be due in part to several factors. First, consecutive trials in the present task always involved a different predicate, thus the reuse feature would not be beneficial. Second, because the utterances were so short and simple, the reuse function was not deemed as useful. Last, since typically developing children are not constrained by physical limitations, this cost saving measure may not have been particularly salient. Perhaps children for whom movement is strained, may benefit from this feature. Future extensions should include numerous stimuli with a smaller set of predicates.

Overall, the results of the present investigation are promising in that a semantic frame-based method of message formulation appears to yield accurate and rich constructions while requiring slightly fewer keystrokes in typically developing children. While these findings are encouraging, it remains to be assessed in children who use AAC with emerging language skills.

Limitations and Future Directions

In order to expand upon the findings from this set of typically developing children and to obtain data that is relevant to the direct stakeholders, future studies need to include children who use AAC. Similar to previous studies on message formulation (cf. Nakamura et al., 1998; Smith, 1996; Sutton & Morford 1998; Sutton et al., 2000), the stimuli and procedures were initially piloted on typically developing children to assess the effectiveness of the methodology in eliciting the desired outcome variables. For example, it was important to determine whether the cartoon stimuli were easily understood and whether they were effective in eliciting the target descriptions. Additionally, the two interfaces had to be proven equivocal in terms of design, layout and functionality such that message formulation was the only factor being manipulated. Findings from the present study provide benchmarks for outcomes studied and suggestions for modifications to the stimuli and procedures. First, the stimuli should be expanded to include a broader range of sentence complexity in narrative and conversational contexts in order to highlight differences between the syntactic and semantic methods. Furthermore, to assess the usefulness of the reuse feature in iconCHAT, multiple stimuli with the same predicate should be included. User performance and preferences suggested that the two interfaces were relatively well matched in terms of graphical variables thus requiring minimal modifications in future extensions. If data from children who use AAC parallels the results found in the present study, then semantic message construction may prove to be an effective technique for some users. Particularly for children with emerging grammatical skills, semantic composition may provide greater scaffolding for constructing complete utterances. This in turn, may foster increased self-confidence, improve perceptions of communicative competence, and ultimately feedback to affording richer linguistic experiences for the child.

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Seeing Chemistry Through Sound: A Submersible Audible Light Sensor for Observing Chemical Reactions for Students Who Are Blind or Visually Impaired

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Abstract: In order to enable students who are blind and visually impaired to observe chemical changes in solutions, a hand-held device was designed to output light intensity as an audible tone. The submersible audible light sensor (SALS) creates an audio signal by which one can observe reactions in a solution in real time, using standard laboratory glassware such as test tubes or beakers. Because many observations in the chemistry laboratory are visual, the SALS device enables students who are blind and visually impaired to perform a broader range of experiments independently. It is believed that this active participation will inspire more of these students to pursue careers in the science, technology, engineering, and mathematics (STEM) professions. The SALS device can be further refined to provide vibratory and visual outputs for students with learning or physical disabilities.

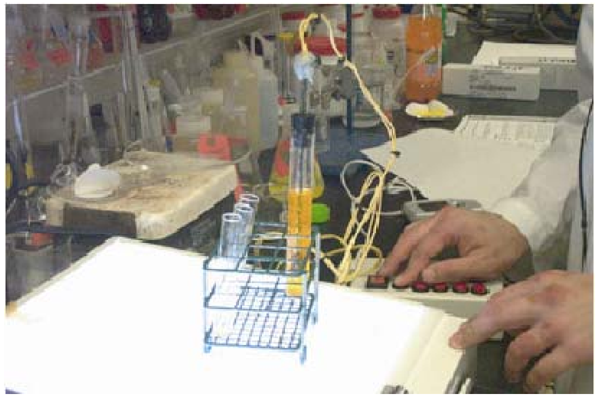
Key Words: Audible, Blind, Visually impaired, Chemistry, Reaction, Sensor

Introduction

One of the main problems for students with blindness or visual impairments who wish to participate independently in a laboratory curriculum is the lack of talking and/or accessible tools (Scadden, 2005). The most common adaptation is for the student to work with a sighted laboratory assistant. The assistant's responsibility is not to do the experiment, but rather to carry out the student's instructions. This is to be done even if the student gives an incorrect instruction. The only exception to this guideline is when the safety of those directly involved is compromised (Burgstahler, 2005; Flair & Setzer, 1990; Lunney & Morrison, 1981; Miner, 2001; Pence, Workman, & Riecke, 2003; Supalo, 2002, 2005; Tombaugh, 1981).

Most sighted students do not have difficulty making laboratory observations at the level of an introductory chemistry course. However, many of the observations in the chemistry laboratory are visual in nature. The goal of this project has been to design a simple and inexpensive tool that will allow students with blindness and visual impairments to perform

Figure 1. Monitoring a color change in a chemical reaction using the SALS and a light box.



their laboratory experiments in the same independent manner as their sighted peers. Such tools may allow these students to get involved in laboratory experiments at an earlier age (Tallman, 1978), and could help them stay involved and interested in science.

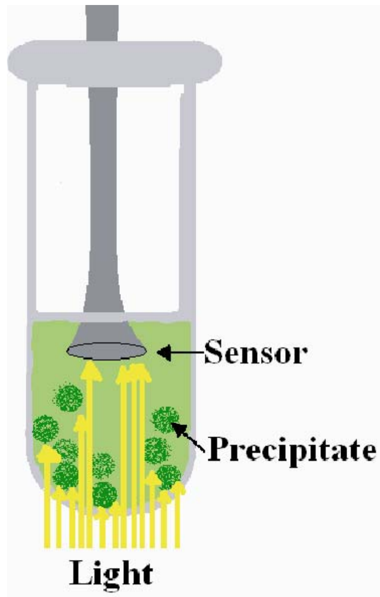
The submersible audible light sensor (SALS) is a device that qualitatively registers color change or precipitate formation with sound. The design is user-friendly, cost-effective, and functions in real time. The SALS is based on a photocell that measures light intensity changes. The photocell is encased in a transparent "wand" that is small enough to allow measurements to be made in ordinary test tubes or beakers. The test tube or beaker is placed over a light box, an inexpensive white light source normally used for tracing or drawing, as illustrated in Figure 1. As a reaction proceeds, the varying light intensity at the tip of the sensor wand is converted electronically to an audible tone. The chemical change (e.g., how cloudy or dark the solution becomes) is indicated by a more pronounced change in pitch, usually from high to low.

Device Design and Use

As Figure 2 illustrates, light from the light box travels upward through a test tube or beaker to the photodetector in the sensor probe. If a precipitate is formed or if an initially colorless solution becomes colored, some of the light will be blocked. The output pitch, which corresponds to the intensity of light reaching the sensor, can be measured by using a standard chromatic tuner available in music stores.

The SALS may be used in conjunction with a camera phone, the Nokia 6620, which has unique software, called the Mobile Color Recognizer, available from CodeFactory (2006), that works with Mobile Speak. The user takes a picture, and the phone, via the speaker, tells the user the color. This color recognition feature can help the user interpret the observations. If the SALS has the same reading for two different solutions or suspensions (e.g.. sand in water, and a blue solution of copper sulfate), the camera phone can provide the user with additional color information. In a qualitative analysis experiment, a precipitate can be distinguished from a homogeneous color change by decanting the solution into an empty test tube and testing again with the SALS. The user knows by comparing the output tones if a precipitate has formed, and the color recognizer can inform the user of its color.

Figure 2. Schematic drawing of the operation of the submersible audible light sensor (SALS) in detecting the formation of a precipitate in a test tube.



Most of the experiments done in the general chemistry laboratory (titrations, qualitative analysis of solutions, oxidation-reduction, precipitation, flame tests) involve visual observations. Experiments from the Addison-Wesley Chemistry Laboratory Manual (Wilbraham, Staley, & Matta, 1995) were used as a representative set of experiments for adaptation with the SALS. The performance of the SALS was tested in detail by using one of these experiments, the iodine clock reaction. In this reaction, a starch-iodine indicator signals the changes that occur as an oxidation-reduction reaction proceeds. The times at which these relatively abrupt changes occur depend on the initial concentrations of reagents. The reaction involves sequential changes from colorless to blue, green, brown, and ultimately black, corresponding to an absorbance that appears initially in the red spectral region at about 600 nm and then gradually shifts to cover the entire visible spectrum. The tone output from the SALS changes by more than one octave over the 1-2 minute course of the reaction. In this adaptation of the Addison-Wesley experiment, a test tube is held by a test tube rack above a light box, with the SALS probe immersed in the solution as shown in Figure 1. The changing tone from the speaker can be compared to a reference tone stored in the SALS control box, or tracked more quantitatively by using a chromatic tuner. Once the student hears the change in tone, he or she can also use the color recognizer to determine the color of the solution in the test tube. This reaction can be performed while using a talking timer in order to record the times at which the color changes occur.

Construction and Operation of the SALS Device

The SALS system consists of three basic building blocks. The first is a cadmium sulfide (CdS) photocell. The second is a microcontroller with its power supply and user controls. The third is an audio amplifier and filter, which is used to power either a small speaker or headphones. The combined cost of the components (excluding the light box) is approximately $100.

Photocell. The heart of the SALS system is the CdS photocell. These devices have existed since the late 1800s. They are sometimes called photo resistors, photo conductive cells, photocells, or light dependent resistors. They should not be confused with silicon photocells. Unlike silicon photocells, which actually produce an electrical current when exposed to light, CdS photocells are really resistors whose resistance decreases in visible light. They were used as light sensors for early cameras because they are simple and sensitive. They also match much more closely the human eye's color sensitivity than any other inexpensive sensor in common use. The photocell is mounted inside a borosilicate glass tube, which is joined to a flat circle of glass at the bottom. The glass housing allows the sensor to be immersed in a wide variety of solutions. Photographs of the photocell in the glass tube and the controller box are shown in Figure 3..

Microcontroller. The microcontroller used in the SALS sensor is a PIC device from Microchip, which contains a built in analog to digital converter (A/D) and a hardware pulse width modulator (PWM). By placing the CdS cell in series with a fixed resistor, a voltage, which is dependent on the light incident on the CdS cell, is produced. This voltage is read by the A/D converter and converted to a number that is used by the software to produce a tone via the PWM.

Because micros can do only one task at a time, it is important that a micro with a built-in hardware pulse width modulator be chosen for this task. A PWM can be used to produce a tone completely in hardware, freeing the micro to do other tasks - such as polling the input buttons.

Power. Power for the SALS is provided by two 'AA' batteries in the controller box. A switching regulator converts power from the batteries into a stable five volt power supply for the microcontroller. At normal audio levels, battery life should be about 60 hours with alkaline batteries. Rechargeable NiCad or NiMH batteries may be used but charging is

Figure 3. The SALS sensor and controller box. The CdS photocell is encapsulated in a glass tube with a flat bottom window. An insulated cable connects the photocell to the controller box (right)

not provided by the unit.

Because the SALS is to be used by students who are blind and visually impaired, a power-on LED is not appropriate. Often these devices are left in the power on condition when not in use. To alleviate the problem of constantly replacing batteries, the SALS unit incorporates a software timer which shuts the unit off if no switches have been pushed for eight minutes.

Light source. Since the SALS unit uses light to measure reactions, the source of the light is important. The unit does incorporate some filtering, but if the light source is not constant, the tone produced will not be a pure tone. The most constant light source is natural daylight, but this is inconvenient for most chemistry experiments. Incandescent light sources generally have lower optical noise than the light from fluorescent lamps. However, a fluorescent light box placed below the test tube or beaker is most convenient experimentally. It is also possible to provide too much light (e.g., if an overhead projector is used as the light source), and in this case the sensor will saturate. No harm will be done, but the tone will not change if the sensor is saturated.

User controls. There are seven switches and a volume control associated with the SALS system. The switches are described in the following sections.

Power switch. This switch toggles the power. If the power is off when it is pushed, it turns the power on. The unit also sends the letter 'R' in Morse code to let the user know that the system is now running. If the unit is on when the power button is pushed, the unit sends the Morse code for 'PWR' and then shuts off the power. If no switch has been pushed for eight minutes, the system sends 'TIME' in Morse code and then shuts off.

Play. Samples the CdS cell and produces a tone proportional to the light incident on the cell when the switch is released. This button provides real-time tone readings that can be compared with tones stored in Memories 1 and 2, as well as the reference high and low tones.

High. Outputs the highest tone that the unit is capable of producing (2400 Hz). This reference high tone is used to obtain a qualitative comparison with the observed tone.

Low. Outputs the lowest tone that the system is capable of producing (250 Hz). This reference tone is also for comparison with the observed tone.

Store. Prepares to store the present condition of the sensor into one of two memory locations. If neither memory location is specified within eight seconds, the unit sends the letter 'L' in Morse code and returns to its normal tasks.

Memory location one (M1). If this button is pressed immediately after the store button, the present condition of the CdS cell is stored in memory location 1. If it is pushed at any other time, the value of the tone stored in memory location 1 is sent to the speaker. Note: Not all tones can be heard. On power up, the unit may contain a value outside the human hearing range. Only after a store has been done can one be sure the unit contains a 'reasonable' tone value.

Memory location two (M2). This is the same as M1 above but for memory location 2. This can be used to store an additional reference tone to be compared to the high and low tones, and any other observed tone.

Outcomes and Benefits

The SALS allows students with blindness and visual impairments to observe chemical reactions in 'real time.' By way of its audio output, the SALS provides an accessible medium that allows these students to experience chemical reactions in the laboratory in a manner similar to their sighted peers. It is the goal of this project to provide new opportunities for students to gather their own observational data directly. Such tools remove their barriers to entry in the study of laboratory science, and ultimately may help students with blindness and visual impairments to choose science, technology, engineering, and mathematics (STEM) careers (Miner, 2001; Pence, Workman, & Riecke, 2003; Scadden, 2005). Good problem-solving skills are an essential quality for a person who is to be successful in a STEM profession. Persons with disabilities are constantly honing their problem-solving skills by resolving accessibility issues they face in their daily lives. As a population, they are very effective problem solvers and their increased participation in STEM professions would add to the skilled workforce in these fields.

Assessment and Future Directions

The SALS has been tested in a number of adapted laboratory experiments from the Addison-Wesley laboratory manual, but so far it has not been used by students in an actual learning environment. Field tests and assessments of learning effectiveness will be carried out over the next two academic years at the Indiana School for the Blind. Based on feedback obtained from teachers and students who use the SALS, both hardware and software improvements will be made. Additional functionality will be added in future designs, allowing users to connect the sensor to a PC and obtain frequency data. This will allow for more quantitative comparisons of tone to frequency. An on-board visual display illustrating sound waves with respect to the output tone will be incorporated to aid students with learning disabilities, and other students who have difficulty learning through only one channel and require both a visual and audio input. A vibratory output device will be incorporated into the handset of the probe, thus allowing a student who lacks both visual and audio interpretation abilities to experience tactile output. This output will change in intensity as the color illustrated in the chemical reaction changes. Inexpensive complementary devices may be designed and built along the same lines as the SALS. For example, an inexpensive real-time color sensor is now in the final stages of prototyping.

Conclusions

The SALS is an inexpensive device that can be easily replicated for classroom use. The device reliably alerts the user to the formation of a precipitate and indicates color changes in solutions in real time. The sensor probe is small enough to fit into most standard chemistry glassware. The user can listen to the device through its internal speaker or with headphones.

The SALS will be tested with other chemistry laboratory experiments in order to determine its range of applications and limitations. We expect to adapt the SALS to a diverse range of chemistry experiments and non-laboratory applications. The SALS should allow a greater number of students who are blind and visually impaired to obtain their own observational data. Independent active learning in the laboratory may inspire these students to study science at more advanced levels, and ultimately to pursue careers in the STEM professions.

Acknowledgments

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CALL FOR PAPERS

Assistive Technology Outcomes and Benefits

Fall, 2007
Submission deadline: March 31, 2007

Assistive Technology Outcomes and Benefits is a peer-reviewed, cross-disability, transdisciplinary journal that publishes articles related to the outcomes and benefits of assistive technology (AT) across the lifespan. The journal's purposes are to (a) foster communication among vendors, AT Specialists, AT Consultants, and other professionals that work in the field of AT, family members, and consumers with disabilities; (b) facilitate dialogue regarding effective AT practices; and (c) help practitioners, consumers, and family members advocate for effective AT practices.

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Guidelines for Authors

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- *Voices from the Field.* Articles submitted under this category should come from professionals who are involved in some aspect of assistive technology service delivery with persons having disabilities, or from family members and/or consumers with disabilities.
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Within each of these two categories, authors have a range of options for the type of manuscript submitted. Regardless of the type of article submitted, primary consideration will be given by the journal to work that has *quantifiable results*.

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- **Design.** Conceptual or physical design of new assistive technology models, techniques, or devices.
- **Marketing Research**. Industry-based research related to specific AT devices and/or services.
- **Project/Program Description.** Grant projects, private foundation activities, institutes, and centers having specific goals and objectives related to AT outcomes and benefits.

In all categories, authors MUST include a section titled 'Outcomes and Benefits' in which a discussion is provided related to outcomes and benefits of the assistive technology devices/services addressed in the article.

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(Note: These guidelines apply to all *Voices from the Field* and *Voices from the Industry* submissions)

All articles submitted will be refereed by the Editorial Review Board. Recommendations on suitability for publication will be taken as final by the Editor.

All other items would not be reviewed, but the editors reserve the right to refuse or (with the approval of contributors) to edit copy.

- Each manuscript must reflect style guidelines of the *Publication Manual of the American Psychological Association* (5th edition, 2001).
- 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 either Microsoft Word or rich text (RTF) formats. The following information should be provided on the cover page of each manuscript:

    - Author'(s') full name(s) and title(s)
    - Name of corresponding author
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    - Full contact information of the corresponding author, including email address, postal address, telephone and fax numbers
    - Each manuscript should have at least the following components:
        - Title (up to 10 words)
        - Abstract (75 to 150 words) presenting the main points of the paper and the contributor's/s' conclusions regarding outcomes and benefits
        - Four keywords
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- Submissions should be double-spaced.
- Articles should be subdivided into unnumbered sections, using short, meaningful headings according to *Publication Manual of the American Psychological Association* (5th edition, 2001).
- Footnotes and endnotes are **not** accepted; all such information should be included in main text.
- The keywords (just after the abstract) should be separated by **commas**, and each keyword phrase should have initial caps (for example, Communication devices, Families).
- Authors should not use underline to highlight text, but rather use *italics* instead.
- For figures, BMP, GIF, and JPG are the preferred formats. Figures should be included in the text at appropriate places and centered horizontally. Captions (maximum 6 to 8 words each) must be provided for every figure (below the figure) and must be referenced in the text. The figures must **NOT** be larger than 500 pixels in width. **Authors must supply separate**

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- The References section should contain appropriate citations noted in the APA Manual (5th ed.)

Sample citations

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James, P., & Tatem, J. J. (2003). Assistive technology benefits. *American Journal of Occupational Therapy*, *39*, 336-337.

Paper presentation

Stuart, S. K., & Kemp, L. M. (2003, January). *Native Americans and AAC issues*. Paper presented to the Annual Meeting of the Assistive Technology Industry Association, New Orleans, LA.

Book

Kalyanpur, M., & Harry, B. (1999). *Culture in special education. Building reciprocal family-professional relationships*. Baltimore: Brookes.

Book chapter

Soto, G., Huer, M., & Taylor, O. (1997). Multicultural issues in augmentative and alternative communication. In L. Lloyd, D. Fuller, & H. Arvidson (Eds.), *Augmentative and alternative communication* (pp. 406-413). Boston: Allyn and Bacon.

Legislation (please cite any law that is described in the manuscript narrative; see p. 404 of APA Manual)

Individuals with Disabilities Education Act Amendments of 1997, 20 U.S.C. § 1400 *et seq* (West, 1993).

Individuals with Disabilities Education Act of 1990, Pub. L. No. 101-336, § 2, 104 Stat. 328 (1991).

Web site

Institute for Matching Person and Technology. (2003). *Matching person and technology (MPT) assessment process*. Retrieved February 27, 2004, from http://members.aol.com/impt97/mptdesc.html

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- Authors are encouraged to write in the third person and use "person-first" language, i.e., the individual *precedes* the disability. For example, phrases such as "persons with disabilities," "students with mental retardation," "and "adults with cognitive impairments" are more appropriate than such phrases as "the disabled," "learning disabled students," or "mentally retarded adults." Consumers and family members who submit manuscripts describing specific practices may use the first person.
- A cover statement in the submission should indicate that the manuscript has not been published in whole or substantial part by another publisher and that it is not currently under review by another journal.

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