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Published in:
ACM Transactions on Computer-Human Interaction

DOI:
10.1145/3446205

Publication date:
2021

Document Version
Peer reviewed version

Establishing Context: Augmentative and Alternative Communication Device Adoption and Support in a Special-Education Setting

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Current mechanisms for adopting and supporting high-tech augmentative and alternative communication (AAC) within special-education appear limited in their success, despite recognition of the potential benefits they represent for young emerging communicators. Prior research in this field has been restricted to discrete survey or interview methodologies. We present a five-month mixed-methods ethnographic study in a special-education school to explore the facilitators and barriers experienced by those using technology, with children who have little or no functional speech, to stimulate communication and language comprehension. Our analysis supports the outcomes of earlier studies, but also furnishes novel insights into the scale and urgency of addressing the problem - with implications for user-centred design within this community. We highlight infrastructure, policy, and recruitment deficits, and propose a two-fold solution: i) An increase in engagement with this population through the provision of enhanced, user-centred support. ii) Induction of the cross-disciplinary role of Assistive Technologist, to serve as mediator between teacher, aided communicator, and their assistive technology. This work represents a contribution toward establishing more effective operational, interactional, and pedagogical support for learners using high-tech communication devices.

CCS Concepts: • **Human-centered computing** → **Ethnographic studies**; **Accessibility technologies**; *HCI design and evaluation methods*; • **Social and professional topics** → *Children*;

Additional Key Words and Phrases: augmentative and alternative communication; assistive technology; special-education; human-computer interaction; user-centred design; language acquisition; early intervention

ACM Reference Format:
Christopher S. Norrie, Annalu Waller, and Elizabeth F. S. Hannah. 2021. Establishing Context: Augmentative and Alternative Communication Device Adoption and Support in a Special-Education Setting. *ACM Trans. Comput.-Hum. Interact.* 1, 1, Article 1 (January 2021), 29 pages. https://doi.org/10.1145/3446205

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1073-0516/2021/1-ART1 $15.00
https://doi.org/10.1145/3446205

1 INTRODUCTION

Communication permeates and enriches, in one form or another, every facet of our lives. The potential of high-tech augmentative and alternative communication (AAC[1]) to make a transformational difference to the lives of those with highly complex communication needs is profound [Dressler et al. 2016; Sennott et al. 2016]. Pervasive artificial intelligence in rapidly developing digital technology promises increasingly responsive, empathic interactions which should bolster inclusion and support more intuitive, swift, and increasingly seamless communication opportunities for people living with speech-language disabilities [Black et al. 2016; Waller 2019].

Currently, however, systems delivering the full realisation of this promise remain frustratingly elusive. Despite the proliferation of technological progress, and the efforts of human-computer interaction (HCI) researchers, and regardless of concordant progressive legislation to boost support for inclusion, people with communication disabilities often remain passive and ill-supported in their efforts to communicate [Williams et al. 2008]. High-tech AAC devices remain generally cumbersome and slow to operate [Baxter et al. 2012a]. This is particularly relevant given the restrictions many people who use communication aids experience with their dexterity [Fager et al. 2012]. In addition, the layers of complexity that people with developmental disabilities must negotiate in order to acquire even rudimentary communication and literacy skills remain intimidating and substantive.

Prior research in this domain indicates that early intervention may be a good candidate path toward bolstering equity [Light 1997; Mann 2014; Williams et al. 2008]. Such interventions typically take place in a special-education (SE) environment. Every effort should thus be made to ensure that schools provide effective support for emerging communicators. However, we found no examples of researchers being embedded in a classroom environment as an attempt to understand how support might be improved. Dominant methodologies involved surveys and discrete interviews [Kling et al. 2010; Mary Watson and Pennington 2015; Murray 2016; Wilcox et al. 2006]. We therefore decided to embark upon a qualitative study with strong ethnographic features [Cohen et al. 2002]: In this article we present results collected by a researcher in situ which explore the roles and record the day-to-day activities of educational practitioners and their learners, with a broad range of communicative impairments, as they participate in the SE classroom.

2 BACKGROUND AND RELATED WORK

A review of the literature was undertaken, with a focus upon understanding barriers and facilitators to successful outcomes in language and literacy acquisition among people with complex communication needs (CCN). Consistent with the exploratory nature of qualitative research methodologies in general, a "snowballing" search strategy (following references of references, and serendipitous discovery) was adopted. This was intentionally distinct from a protocol-driven approach which may have missed important resources and therefore proved less efficient [Greenhalgh and Peacock 2005]. Initial search terms on databases such as Google Scholar included general AAC nomenclature (for example high-tech AAC, speech generating device), terms relating to education (such as early intervention, vocabulary acquisition) and impairment terms (such as cerebral palsy, developmental delay), or some combination of these. The results of these searches are detailed below.

2.1 Communication Disabilities

From our earliest days as infants, we begin communicating to express our wants, our needs, our ideas, to bond with those around us, and to attempt to exercise influence over our surroundings

[1] AAC is an area of clinical practice that attempts to compensate (either temporarily or permanently) for the impairment and disability patterns of individuals with severe expressive communication disorders (i.e. the severely speech-language and writing impaired) [Light and Drager 2007]

[Sevcik et al. 2004]. Such conventional paths of development and social interaction, however, may not be routinely accessible for some individuals living with disabilities that affect their ability to engage in or understand speech communication [Sennott et al. 2016]. Expressive impairments may be congenital (e.g. cerebral palsy, autism spectrum disorder, Rett syndrome) or acquired in later life (e.g. traumatic brain injury, neurodegenerative conditions such as motor neuron disease). In some conditions seen in children with developmental delay, the causes are indeterminable or remain the focus of much debate [Lopez-Pison et al. 2014]. Communication disabilities are debilitating at any age, but for young, emergent communicators with CCN, the repercussions are particularly acute [Sturm et al. 2006] - with ensuing implications for language development and literacy, access to social, learning, fiscal and health resources and opportunities; and engendering potentially harmful passivity and lifelong disconnection from their communities, impacting severely on quality of life.

The proportion of children and adults who potentially may benefit from support in this area is recognised to be expanding as a consequence of improving survival rates and life expectancies across the population [Creer et al. 2016; Light and McNaughton 2012; Ratcliff et al. 2008]. Related to this trend, the number of people with complex and severe disabilities is also increasing.

2.2 AAC Research and Practice

AAC is a term that encapsulates the diverse range of strategies and technologies adopted by people living with CCN to support (augment) or replace (alternative) spoken communication and promote enduring independence.

These interventions have great potential value, delivering positive outcomes for young children with CCN - including improved communicative interactions, amelioration of challenging behaviours, facilitation of social relationships and enhancing of educational opportunities [Johnston et al. 2004; Light and Mcnaughton 2015]. Use of AAC is also a vital pathway towards building their understanding of the fundamental mechanisms of communication such as personal narrative, turn taking and conversation repair. However, despite an increasing number of AAC devices being available[2], the actual impact of these communication aids as a means of developing communication competencies within their users remains disappointing [Waller 2019]. The attrition rate through abandonment of assistive technologies remains unacceptably high, and appears - historically and to date - bound in the complex nature of these devices, their usability, candidate match, and the availability of support [Johnson et al. 2006; Murphy et al. 1996].

AAC supports are commonly divided into unaided and aided modalities. Unaided modalities include gestures, pointing, vocalisations, body language, eye contact, facial expressions, and sign language. Aided modalities are those communication strategies that involve external components, and may be divided into two categories:

Low-technology aided AAC These are physical apparatus that support communication but do not require a battery or wall plug power supply to operate. Examples include: objects of reference[3]; communication boards; schedules; picture exchange communication systems (PECS[4]); E-tran frames[5].

[2]In particular with the advent of consumer touchscreen devices and Apple and Google Play app stores - over 130 billion apps were downloaded onto Apple devices alone between 2008 and 2016 [Perez 2016].

[3]A physical object used to physically represent a person, action or concept e.g. using a wooden spoon to represent cooking or a paintbrush to signify an art lesson.

[4]PECS [Consultants nd] is a low-tech aided AAC system that utilises pictures to encourage communication via a transactional mechanism.

[5]A low-tech means of attaching letters or symbols to a board so that a communication partner can track where an aided communicator is looking.

High-technology aided AAC These are powered devices, either from battery or a wall plug power supply. They are typically computer-based solutions that act as the user's "voice" by generating digitised, synthesised or recorded speech in response to the operator's input (called speech generating devices or SGDs). Access to their vocabulary is generally achieved via a graphic symbol- or text-based interface [Beukelman and Mirenda 2013]. An example is shown in Figure 1 below.

Fig. 1. Tobii Dynavox VOCA featuring Communicator 5 software with eye tracking access, photographed during the study.

A mix of these modalities might be implemented in order to accommodate circumstances such as situational impairment [Sears et al. 2003], technology malfunction, or communication partner diversity. Speech generating devices have the advantage of their output being more intuitive to understand by a wider range of communication partners, but are less portable than non-technical devices, often require significant operational competence, and are susceptible to technical failure. They also tend to be more demanding and labour-intensive to maintain, and - for emerging communicators - to keep up-to-date with pedagogical needs [Beukelman and Mirenda 2013]. Nevertheless there is some evidence that high-tech AAC could be particularly beneficial in enhancing and supporting communication for people with expressive impairments [Baxter et al. 2012b].

A key message is the wide range of AAC equipment and strategies now available, some of which are very complex (though potentially offering significant advantages for their users) - with additional tools and apps added to the mix daily. Yet as noted in this paper's introduction - in considering outcomes for their users - questions on the efficacy of these products in deployment must remain.

2.3 Communication Development in Children with CCN

However technically advanced an AAC device may be, sensitive implementation - i.e. observant of the individual user's requirements - should be recognised as an indispensable element of service delivery. In this section we consider the considerable challenges that young emerging communicators with CCN must overcome in contrast to their non-disabled peers.

A communication impairment may refer to difficulties with any or all of the following linguistic competencies: language comprehension, understanding or expression of vocabulary, and understanding of sound structure (phonological awareness) [Larsson et al. 2009]. Neaum [Neaum

2017] claims that spoken language is instrumental in underpinning all teaching and learning, with children requiring "rich language experiences that include adults who say more than is necessary... and interaction that enables them to engage in talk".

For naturally-speaking children, such interactions with adult mentors typically occur quite seamlessly in an iterative process manifesting throughout childhood and early adolescence [Sennott et al. 2016; Tomasello 2003]. However, there are critical differences in the early experiences of language acquisition for children with CCN, and their skills must be built within the context of their accompanying "physical, sensory, or cognitive constraints" [Beukelman and Mirenda 2013].

Assuming an adequate level of service provision and coordinated support, the child should ideally have access to an AAC solution [Williams et al. 2008] such as a speech generating device to assist them in their learning and expression of communication. Historically, however, such devices have themselves been difficult to both access and learn, and limited in their use by a multiplicity of factors [Baxter et al. 2012a; Hodge 2007; Murphy et al. 1996; Sigafoos et al. 2016]. Common barriers for adoption often cited include costs, operational and programming demands, speed of use, heterogeneity of client base, situational and ergonomic restrictions, poor motivation, and inadequate support or training leading to abandonment [Judge 2002; Murphy et al. 1996].

Young emergent communicators rarely observe adults modelling the use of their technology expressively [Sennott et al. 2016], and their opportunities to interact using their devices is significantly, and damagingly, curtailed in comparison to the dynamic learning experiences of their speaking peers [Jennische et al. nd]. Evidence suggests that children who are nonverbal need to be presented with a minimum of 200 opportunities per day to interact via aided-language stimulation [Baker et al. 2011]. Being unable to speak has a detrimental impact upon the development of literacy [Black 2011; Dahlgren Sandberg et al. 2010; Von Tetzchner and Grove 2003]. It has been suggested that up to 90 percent of individuals with CCN reach adulthood without functional literacy [Foley and Wolter 2010]. There is also evidence of a causal dynamic between vocabulary acquisition and reading comprehension, and the building of cognitive and linguistic skills. Van Balkom and Verhoeven refer to a "Matthew Effect" - whereby the "gap between better readers and poorer readers widens rapidly through the school years" [Van Balkom and Verhoeven 2010]. This mechanism is inevitably exacerbated in children with CCN. There is, however, a growing corpus of evidence that AAC interventions, sensitively applied, can successfully equip even pre-school children with basic literacy skills [Holyfield et al. 2018]. The costs to individual learners, their families, and society at large of not taking full advantage of these tools may be enormous, and therefore profoundly consequential.

2.4 AAC Assessment - Intervention

When assessing people with communication disabilities, practitioners aim to accurately gauge each individual's communication potential and match them to the most suitable AAC solution for meeting their needs [Scherer and Craddock 2002].

The fast pace of technological change is a complicating factor and is highlighted by numerous studies [Baxter et al. 2012a; Lund et al. 2017] - emphasising the requirement for ongoing review of each individual's needs [Light 1989]. Lund and Light [Lund and Light 2006] highlight the need to document long-term outcomes to "ensure accountability, justify costs, guide clinical interventions and establish best practices to improve services to individuals with complex communication needs". Yet it appears that there has been little research undertaken in the field as to how coordinated practitioners are in making clinical decisions [Schlosser and Raghavendra 2004] and where it exists, indicators are that time constraints, workload and skill levels all impact on the ability of practitioners to pursue evidence-based practice (EBP) [Humphris et al. 2000].

Beukelman and Mirenda used the metaphor of mastering a musical instrument to illustrate the folly of superficial assessments oriented towards provision of a device or solution without accommodating ongoing support and evaluation ("...a piano alone doesn't make a pianist") [Beukelman and Mirenda 2013].

Janice Light employs a similar metaphor - that of balance and harmony in a musical score - to explain her Framework of Communicative Competence [Light 1989]. She defines four interrelated communication competencies as:

(1) Linguistic: mastery of the language used in the individual's respective community.
(2) Operational: sufficient proficiency in operating the AAC system in question to allow adequate focus upon the message being constructed.
(3) Social: sufficient skill in the use of pragmatic language, and understanding of the mores of social communication to engage in discourse effectively.
(4) Strategic: the knowledge to adopt effective compensatory/repair strategies where communication difficulties are encountered.

Adapted from [Light 1989]

Light argues that lacking any one of these skills will impact on the ability of an individual to become a skilled communicator.

It has long been recognised in the literature that an holistic approach to intervention is essential: Savignon [Savignon 1983] insisted that communicative competence is an interpersonal, as much as an intrapersonal, trait. That is, opportunities must be made available for the AAC user to communicate. If communication partners, friends, family are not engaged and supportive in this activity then the effect on an individual's capacity to learn may be detrimental - and the intervention's success may be severely impacted [Hodge 2007].

2.5 User-focused System Design with Children with CCN

For any high-tech AAC system or technical tool, there may be multiple end-users - from the children receiving the support, to the parents, educators, and clinicians who must maintain, update and, indeed, oversee learning via these devices. Each of these users may have different requirements in terms of how they interact with the technology, and they all need to be included in any user-centred product or service design process [Long 2009].

In designing such systems we are confronted with a plethora of approaches: For example, user-centred design (UCD), participatory design, empathic design, action research, and human centred design. At the core of these allied methodologies is the integration of the participant's perspective into the end product, exemplified by the International Standards document, ISO 9241-210 [DIS 2009] (Figure 2 below).

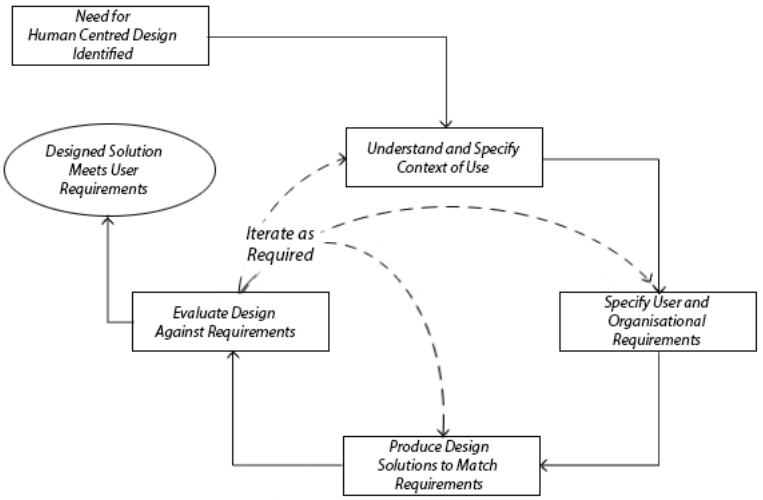

Fig. 2. ISO 9241-210 Workflow diagram

When that participant has a communication impairment, where feedback or collaboration may be more time consuming [Hornof 2008] or otherwise problematic, the approach encounters additional complexity. Many experienced and respected researchers in the field have circumvented this issue by working with naturally speaking children or other surrogate participants, citing "behaviour, attention, seating challenges" [Caron et al. 2016], communication difficulties and potential "fatigue" [Waller et al. 2009], in their target user audience.

However, that a non-speaking person has the capacity to learn, to participate, and to understand has been described as the "least dangerous assumption" to make [Bal et al. 2016; Emerson and Dearden 2013]. It thus remains incumbent upon designers to find the most empathic way of eliciting constructive feedback from this population.

With that in mind, Mankoff, Hayes and Kasnitz [Mankoff et al. 2010] advocate participatory design as a solution in assistive technology design, but only cite its effective application with disabled adults. Children with CCN, who have yet to acquire sophisticated communicative or linguistic skills, represent a particular obstacle - but with appropriate resources, not an insurmountable one.

Using their Inclusionary Model for example, Guha et al [Guha et al. 2008] report many successes, and indeed highlight some advantages[6] in working with children with complex needs as design partners - given adequate levels of support.

Benton and Johnson [Benton and Johnson 2015] identify informant design, and experience-centred design as participatory approaches that attempt to keep this group of vulnerable end-users involved in the technology design process, aiming to foster "empathy and aesthetic engagement" while reducing the demands of traditional UCD placed upon them. This is largely achieved through allowing adult designers to take decisions where deemed necessary, but ensuring that the children contribute meaningfully where possible and appropriate.

The Children in the Centre Framework [Kärnä et al. 2010] recommends a number of practical approaches to working successfully with children with CCN, including expanding the range of semiotic resources used to stimulate engagement.

[6]They enthusiastically cite lateral thinking advantages emerging from cooperative inquiry with children - who are often creatively unconstrained by norms or conventions.

Numerous researchers [Hornof 2008; Kärnä et al. 2010] recommend designers increase investment in time to achieve fruitful outcomes with special-educational needs participants. Hornof [Hornof 2008] also warns of systemic obstacles to collaborative design that may further complicate matters, often unrelated to a child's disability - "structural, institutional, social, geographical, financial, legal, and attitudinal". This echoes the preceding section's insights of both intrinsic and extrinsic intervention challenges to be accommodated or overcome in working successfully with this population.

Until relatively recently, truly collaborative research with emerging communicators has been very limited. Light and Drager observed in 2007 [Light and Drager 2007] that assistive technologies continued "to reflect the conceptual models and priorities of non-disabled adults", raising important questions about the lack of true UCD engagement occurring in collaboration with this population. Some of the research identified here suggests that well-designed UCD projects run by motivated designers and their community partners can and do have the capacity to address these concerns. Nevertheless, greater engagement with these vulnerable populations and more widespread application of user-driven methods in the development of their assistive tools and technologies may yet be necessary, if abandonment issues are to be addressed.

As evidenced in earlier sections of this review, for these exceptional users, that engagement may require seamless extension beyond the development phases of any technical tool - anchored in the recognition that service delivery involving community collaboration, and ongoing, reflective support may be a critical element of any UCD process targeting this sector.

2.6 Summary

The incidences of people experiencing some form of communicative impairment during their lifetimes is increasing, and with potentially severe impact upon the opportunities and outcomes available for affected individuals, and those around them. Young emergent communicators with developmental delays are particularly vulnerable. AAC strategies and devices exist in many forms, with varying levels of sophistication and complexity, to support this diverse population. A mixture of these solutions is typically adopted by users, to meet their diverse needs. Technical tools appear potentially beneficial, and are being developed in increasing numbers, particularly since the advent of touchscreen-equipped mobile technology platforms and their accompanying commercial app stores. Persistent device or app abandonment rates, however, remain unsatisfactory and these indicate that conventional UCD techniques are sometimes poorly implemented for this population, requiring motivated partnerships and more time to implement effectively - with better results when these requirements are met. Whichever device is deployed, the appropriate level, and manner, of pedagogical support appears essential. We hypothesise that this service delivery process should be seen as a logical - perhaps integral - extension of any UCD process targeting this sector. Although in the special-education (SE) community numerous assessment/intervention frameworks have been developed, these must be tailored to meet the needs of this vulnerable group, and also be suitably supported by practitioners in the field.

3 THE ETHNOGRAPHIC STUDY

3.1 Introduction

Our motivation for this ethnographic study was based on evidence of the importance of early intervention [Sevcik et al. 2004]; the benefits of access to high-tech AAC for young aided communicators [Baxter et al. 2012b; Light and Drager 2007]; and the disappointing prevalence of device abandonment. This focused our interest on establishing a deeper insight into the means and efficacy

by which such technologies are adopted by emerging communicators within SE, and the levels of support made available to them.

3.2 Aims

We aimed to answer the following questions:

(1) What are the facilitators and barriers for educators currently using technology to stimulate functional communication and language acquisition in children with CCN in the SE setting?
(2) How is the technology procured, implemented and monitored in SE?

3.3 Methodology

3.3.1 A Qualitative Approach. The complexity of this domain makes a compelling argument for a qualitative study design. The following section describes an ethnographic study at a SE school to gather data intended to inform subsequent phases of an AAC development. We hypothesised that the immersive nature of such an approach could yield novel insights that prior research had missed, with a participant observer becoming an increasingly familiar figure among such a sensitive user community.

3.3.2 Context and Recruitment Strategy. The Dundee AAC Research Group maintains links with special-educational needs schools throughout Scotland, and a partner school was approached during spring 2017 to collaborate in the study. The chosen school occupies a modern building, and has approximately 180 pupils aged from five to 18 years of age with additional support needs. This number includes a diverse range of young emerging communicators, many with physical, developmental and/or communicative disabilities. Approval was sought and received from the Headteacher, the local authority's education department, and the University Research Ethics Committee. The principal investigator (PI) also applied for and received confirmation of enhanced disclosure from the Protecting Vulnerable Groups (PVG) Scheme.

3.3.3 Data Collection. Work commenced in the school August 2017 and continued throughout the autumn and winter of 2017/18, encompassing 21.5 weeks in total (inclusive of seasonal holiday breaks), with 18 full-day visits. The duration of the study - initially scheduled for four to six three-day weeks - was extended as a result of accommodating the partner school's timetable and circumstances, and in response to the complexity of the story gradually emerging as data collection advanced.

Attendance typically involved full mornings and afternoons embedded into different classes for participation, observation, informal canvassing, note-taking, and artefact collection. These were interspersed with formal lunchtime or post school-day interviews with key adult stakeholders.

3.4 Participants

3.4.1 Child Participants. The children (n=180) in the study represented a heterogeneous range of ages, genders, and developmental disabilities.

3.4.2 Criteria for Selection. Almost all of the children attending the school were at risk of experiencing the social isolation, the passivity, the impacted quality of life described earlier in this article. This study was intended to examine the wider environment they inhabit, and to understand the interactions between pupils and the adult stakeholders implementing policies and practices on their behalf.

3.4.3 Adult Participants. Adults in the study were selected from the multidisciplinary mix of staff, and parents with children in attendance at the school.

Table 1. Adult participant characteristics

ID	Age	Education	Role	Years Experience	Specialism	Tech Comfort Rating+
P01	45-54	Postgrad	SLT*	11	PMLD	Very
P02	18-24	Undergrad	SLT	3	N/A	Moderate
P03	45-54	Undergrad	SLT	25	High Tech AAC	Very
P04	35-44	Postgrad	Teacher	5	Art Therapy	Moderate
P05	55-64	Undergrad	Teacher	41	Autism Spectrum Disorder	Nil Response
P06	45-54	Postgrad	Teacher	7	PMLD	Moderate
P07	25-34	Other	Teacher	10	Autism Spectrum Disorder	Moderate
P08	35-44	Undergrad	Teacher	7	Primary	Nil Response
P09	35-44	N/A	Parent	N/A	N/A	Minimal
P10	45-54	N/A	Parent	N/A	N/A	Very
P11	55-64	Other	LCA**	20	Early Years	Nil Response
P12	45-54	Other	LCA	27	Makaton++ Mentor	Moderate
P13	35-44	Other	LCA	15	N/A	Very

∗ Speech and Language Therapist | ∗∗ Learning and Care Assistant | + Data for this column captured from member-check survey | ++ A simple language programme mixing signing and symbols

3.4.4 Criteria for Selection. It was important to ensure the canvassing of a full and representative range of adult protagonists in the complex setting under investigation [Morrow et al. 1993]. Criteria for selection evolved as the study progressed, with the PI monitoring outstanding requirements in the collected data - e.g. accruing awareness of the structure and organisation of the school - and adjusting identified candidate interviewees responsively to target gaps.

Adult stakeholders were typically identified in the school[7], and invited to participate on the basis that:

- they had experience of working with children with CCN either as a practitioner or as a parent;
- they had at least one year of association and/or familiarity with the partner school either in a pedagogical, support, or parental context;
- they were personally comfortable to commit to one interview session of circa 60 minutes, with a possibility of a follow up member-check contact at a later date [Fereday and Muir-Cochrane 2006].

The peripatetic nature of some of the professionals working within the school also provided data concerning practices further afield.

3.4.5 Characteristics. Four distinct adult stakeholder groups were identified, with subdividing characteristics based upon specialisms where applicable. Table 1 above details these, and records some demographic characteristics of the participants.

Thirteen adult participants were selected in total for supplemental interview - speech and language therapists[8] (n = 3), teachers (n = 5), learning and care assistants[9] (n = 3), parents (n = 2). Each was assigned a number (Px) to preserve anonymity. Participants ranged in age from 24 to 62 years of age (M = 44); and the professionals ranged in experience from three to 41 years (M =

[7]The exceptions to this arrangement were the two parents whose contact was orchestrated via a member of staff.
[8]An SLT is the UK equivalent of a speech language pathologist elsewhere e.g. North America.
[9]An LCA is a role equivalent to an educational assistant, or classroom assistant elsewhere.

15.5) although these figures may include years in mainstream education in addition to SE. All were native English speakers. All formal interviewees were female: This was a result of the asymmetric gender balance within the school, a recognised phenomena [Szwed 2010].

3.5 Data Collection Methods

3.5.1 Classroom Observation. A major strand of this investigation was to participate in individual classes with return visits to especially productive or challenging cohorts where required. In addition to a brief pilot study, a total of 21 separate classes, across a mix of primary (n=8), secondary (n=5) and autism spectrum disorder (n=8) departments, were visited. Six were selected for at least one return visit (with the most visited class receiving four half day visits in total). This encapsulated 77.78 percent of the total school population (27 classes).

Written field notes included metrics of scheduling and activities, assistive technologies observed in use, and informal interactions between and with staff and pupils. As a formative exploration of the problem area, this observational approach allowed the children to make a positive contribution to our study while relieving them of any particular pressure to perform or divulge specific feedback. Physical artefacts such as relevant documents and objects of reference examples were gathered, and photography used extensively to capture items that could not be collected (see Figure 3). Video and audio recordings were not captured due to privacy concerns.

Fig. 3. Artefacts, including (clockwise from top left, not to scale) Canaan-Barrie signs, BIGmack communicator switch, Object of Reference, Boardmaker PCS visual schedule, documents, SGD with eyegaze, interactive plasma screen.

Spreadsheets recording all assistive technologies, computer software programs, devices and assessment/teaching tools and strategies encountered or described were set up and maintained.

3.5.2 Interviews. Individual, face-to-face interviews were conducted between late August and late November 2017. These were intended to complement the classroom observations as a collaborative interaction with practitioners [Cohen et al. 2002], and provide clarity for any questions arising during the school day. The interviews were audio recorded, with a total extent of ten hours and 22 minutes (M = 47 mins 51 secs). The shortest interview duration was 30.21, the longest 52.36.

Six questions guided the interview structure:

(1) Which AAC strategies or resources, unaided, aided, low- or high-tech, do you use/are you aware of being used within the SE context?
(2) How are communication aids and support strategies administered/maintained within the school?
(3) Which instruments or tools do you use/are you aware of being used to assess vocabulary/language acquisition with these children?
(4) Do you think the aided vocabulary acquisition device under consideration would be beneficial for your children?
(5) Do you have any practical advice for how to elicit feedback from your children/the children that you work with effectively?
(6) From the children you are familiar with, can you identify suitable candidate participant(s) to help develop a new AAC device?

The interviewer aimed to establish respective backgrounds, attitudes, competencies and approaches towards working within the school to deliver effective educational outcomes for pupils; and to gather comprehensive information about AAC in situ. The breadth and complexity of the environment meant that the interviewer encouraged participants to elaborate in order to explore and unveil novel issues, and to validate responses. A strategy of recasting was employed to prompt clarification, and further explication. Key topic questions were predominantly open-ended with supporting follow-up questions. Efforts were made to explore the informant's attitudes and accounts of their practice objectively and empathically.

It was anticipated that an in-depth, semi-structured approach with probing questions within a conversational setting would shed light on wider policy issues - thus identifying barriers and facilitators to vocabulary acquisition at a more systemic level.

3.5.3 Member-Check. In qualitative studies capturing data from human participants, a member-check refers to a means of confirming narrative or interpretive accuracy [Long and Johnson 2000]. For the current research, member-checking was an iterative process, encompassing classroom discussions and during the formal interviews themselves. In order to bolster the overall rigour of the work, follow-up contact via email, a Survey Monkey [Surveymonkey nd] online questionnaire targeted at interviewees (and a scheduled meeting with the assistant headteacher) continued this process beyond the conclusion of the main study. Data in the final column of Table 1 were collected in this way.

4 DATA ANALYSIS

Audio recordings of the interviews were transcribed using open-source transcription software [van Gennip nd]. This process generated 130 pages of textual data, extended a further 30 pages by the inclusion of the information-rich bullet-pointed field notes log. Access to these data were limited to the researchers, and steps were taken to ensure anonymity was preserved. An inductive thematic analysis of the data was then undertaken.

The overarching goal of any thematic analysis is to forge understanding and meaning from measurement via constructive interpretation [Joffe 2012]. Broadly following the phased approach described by Braun and Clarke [Braun and Clarke 2006], we commenced the process of data coding and identifying themes, actively engaging with the data, with the aim of extracting meaningful insights from the subjective viewpoints and activities of our target population.

4.1 Phase 1 Familiarisation with the Data

Braun and Clarke describe transcription as an interpretive act, placing the researcher in an active role synthesising meaning almost from the moment data collection commences. For the current project, the PI had a central role throughout, which assisted progress towards the next phase.

4.2 Phase 2 Generation of Initial Codes

The analyst read and re-read the transcriptions and field notes to systematically identify relevant data items. Sixty-five initial codes were generated from the raw data, with 852 respectively linked data extracts, each contextual, easily accessed and cross-referenceable. This provided access to a richer, interpretive understanding of issues - increasing opportunities to identify those that Braun and Clarke [Braun and Clarke 2006] refer to as "latent", or implicit, codes.

4.3 Phase 3 Searching for Themes

The long list of codes became a source of candidate themes - summative categories that might collate a number of codes to convey a broader, overarching message. The outcome was seven candidates themes, with a number of ancillary sub-themes.

4.4 Phase 4 Reviewing Themes

With candidate themes in place, a process of refinement commenced. Braun and Clarke [Braun and Clarke 2006] describe a two tier approach, with the first level reviewing the coded data extracts against their associated theme to gauge coherence, and the second level reviewing the themes themselves against the context of the entire data set.

The analysis was undertaken recursively. Significant amendments were made to the structure of the analysis, consolidating, merging and/or discarding a number of themes that either did not map to the explicit aims of the study, or that upon reflection lacked adequately distinctive traits.

Where necessary, themes were assigned a new, appropriately descriptive, title. For example, data collected in the field regarding interventions gradually coalesced under the umbrella of "AT Interventions Require Expertise". This reflected the overarching message expressed both by informants (literally and interpretively), and from class observations (e.g. limited engagement with AAC users in class; training deficits; restricted uptake of high-tech AAC).

The output was a final thematic map with two main themes: (Figure 4).

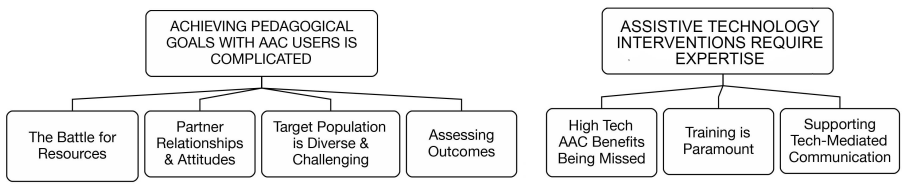

Fig. 4. Final thematic map

4.5 Phase 5 Defining and Naming Themes

The final stage of the reflexive thematic analysis was to continue a responsive refinement of the generated, finalised themes, to describe each one's core essence. The focus of this exercise was to establish each theme as a tangible, discrete semantic unit which occupied a coherent space within the unfolding narrative of the wider data set.

5 RESULTS

The data set analysed included the study field notes - a log composed of personal observations, and accounts of short, informal conversations in situ - and this proved valuable, often acting to triangulate phenomena described by formal interviewees (and vice versa) as well as delivering valuable insights of its own.

Two major themes were generated: 1) *Achieving Pedagogical Goals with AAC Users is Complicated*; and 2) *Assistive Technology Interventions Require Expertise*. Each are now considered in turn.

5.1 Main Theme: Achieving Pedagogical Goals with AAC Users is Complicated

A special-education school is a unique and complicated mix of disciplines - pedagogy, therapy and technology - which requires careful management of responsibility, and coordinated routines. All adult participants had some role or input into the teaching of the children in their care. They came from a variety of backgrounds, and occasionally expressed contrasting views even within their respective areas of responsibility.

The study found evidence of both harmony and disagreement, as one might encounter in any organisation. We observed a strong culture of camaraderie within the school - but we also saw disputes over roles and responsibilities; noted challenges wrought by the necessary demands of accommodating diversity; and heard accounts detailing the impact of resource scarcity - all of which potentially affect the core purpose of the school i.e. giving pupils with highly complex needs a life-enhancing pedagogical experience with proficient support. Four important sub-themes illustrate these issues in more detail.

5.1.1 Sub-Theme: Target Population is Diverse and Challenging. At the centre of the parent theme's complexity are the unique individuals - the young people - who attend the school. Classes are small (mean = 6), with approximately 2:1 child/adult ratio. There is a wide and shifting demographic of children of mixed ages, sizes, developmental stages, clinical profiles, and family backgrounds, all with individual and particular pedagogical requirements. Fewer are now arriving with language skills. There were a range of opinions about what had caused this change.

> P11 (LCA) - "Mainstream. They're more able. We're getting severely disabled children."
> Interviewer - "So mainstream can actually support these children better than they used to...?"
> P11 (LCA) - "We're finding we're getting less language. We're getting the more impaired children, the more challenging. That's the truth. We had more able kids (in the past), and they were doing GCSEs [General Certificate of Secondary Education]."

Acquiring language - or other - skills will take longer with these learners [Hornof 2008], with an accompanying requirement for more patience, more support, and more accommodation for setbacks.

> P08 (Teacher) - "Our children don't really acquire vocabulary through their environment. Most of it has to be taught. Everything has to be taught."
> Interviewer - "When you say through their environment...?"
> P08 (Teacher) - "Oh just absorbing things and picking things up in conversation. A lot of kids will not have that skill where they can listen to what you're saying and link it to what they already know."

Attempts are made to support and moderate any negative effects of developmental diversity by placing children in classes with approximately similar need, rather than, as traditionally, by chronological age - and therefore beyond the basic divisions of the three departments described earlier (primary, secondary, enhanced support area [autism spectrum disorder]). However this

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688 approach is sometimes further complicated by resourcing restrictions (see *The Battle for Resources*
689 below).

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693 > P11 (LCA) - "You do things very gradually, especially with autistic children. Well we don't group our classes like that as such... (w)e group our kids mainly by ability rather than by age because our kids are all at a different stage in development."

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695 Each child has an individual customised learning plan, but a common trait is for frequent setbacks in their learning to occur, and often unconnected with their situation at school:

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701 > P05 (Teacher) - "Out of five I have (three children) regressed so I need to move back a bit and replan... None of these things would be the fault of myself, the child or anything - just the environment can change so quickly here... a child here can regress, it can be health, it can be change of circumstances to a carer, from the parent - there are many things... I just want you to bear that in mind that these things do happen in the school more than any place else."

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709 It is common for pupils to come from challenging backgrounds, where support from home may prove inadequate. Some children attending the school are themselves the offspring of former pupils, who may struggle to provide optimum parental support despite their best intentions. This is important because children with CCN benefit from modelling and reinforcement, and consequently active engagement and the exchange of information between school and home - for example in the shape of day book diaries, and BIGmack switches (Fig. 2) - is often a pivotal element of the attempted pedagogical approach.

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716 One should avoid drawing conclusions about the intellectual abilities of children at the school based upon superficial assessments. Some of the older children, mostly in Secondary, appeared ostensibly to have neurotypical verbal skills:

> P12 (LCA) - "See people fall into that trap. Because kids are very good verbally they think they must be very good cognitively and it's not necessarily the case. Some kids could yap [away] but ask them a question about what you've just said and boof! They can't answer... Good at this doesn't mean good at that."

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722 The preponderance of older children in the school able to demonstrate verbal acuity seems at least partially linked to the recent demographic pivot towards attending mainstream schools for more able children (identified above by P11), rather than being entirely the fruits of current pedagogical practices. In contrast to when these older children commenced their education, fewer young children with the potential to speak may now be attending the school.

Conversely:

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729 > P02 (SLT) - "And I think some of our kids might not be verbal but actually how do we find out what they're understanding - so just because the child doesn't speak doesn't mean, they might not be as cognitively challenged as they actually appear. I'd say they've either no interest in speaking with someone or they haven't got a way. We have these assessments like Derbyshire [Derbyshire-Language-Scheme [n. d.]] but it's looking at other ways to assess them because some of our kids would not sit for them."

730 *5.1.2 Sub-Theme: The Battle for Resources.* A key message from many participants in the study
731 related to pressure exerted on their work by the scarcity of resources, be they human, temporal,
732 material or - intrinsic to these first three - economic. This factor is not unique to SE, but its effects
733 on ease of access to expensive AAC technology and its support may be particularly acute. Anecdotal
734 evidence from participation in the classroom echoed and supports the interviewee's comments
735 below:

> P05 (Teacher) - "I don't know how much these things cost but I'd love to see iPads within the rooms, I don't see tablets, I don't see things the children will need in life. So there are ways that things can change in here, without being too difficult but it's a cost - and I understand that, it's all about cost. My children need money, and they need time."

In an attempt to offset these restrictions, both individual staff members and parents will occasionally make significant personal contributions towards meeting pedagogical goals:

> P05 (Teacher) - "Then wait for the next bit, get all the velcro, put that there so we can stick that on and it is laborious to the ridiculous. That is what every child coming in here has to move from a photograph into symbols and then we go from symbols into words. Simple steps. And then you get moaned at because you use too much velcro... Then you buy it yourself. 'Cause you can't do anything without your velcro, you need it!"

Numerous participants note the need for more access to high-tech AAC:

> P07 (Teacher) - "Ideally we could probably use a more GoTalk system, em, unfortunately they're not available really."
>
> Interviewer - "So are resources an issue then?"
>
> P11 (LCA) - "For iPads? For these kinds of things? Huge issue!"

But - again to underline complexity in the real world - it is not necessarily the case that throwing money at the problem would be a panacea, and opinions are occasionally divided here:

> Interviewer - "Are resources an issue?"
> P04 (Teacher) - "Always. In every school. Even really well-funded schools. Technology changes so quickly that we can't keep up. We'll spend months and months fundraising for something [only for it to become obsolete]."
>
> P01 (SLT) - "So sometimes high-tech does not help communication... I can have a hard time convincing parents of this because high-tech is seen as sexy and bits of paper are not... it's about what's best for the child. But it's difficult to convince parents of that."

The issue raised by P01 is looked at in more detail in *AT Interventions Require Expertise* below.

Achieving pedagogical goals is undoubtedly more difficult - and the lives of those delivering and receiving services more stressful - when working and balancing significant resource constraints. Participants alluded to a first come, first served distribution mechanism:

> P05 (Teacher) - "Some classes have two computers, some have got one, some have whiteboards some don't."

A better-coordinated control and distribution of resources could ease some of these pressures, and ensure a more equitable division of assets.

5.1.3 Sub-Theme: Partner Relationships and Attitudes. The differences in attitudes of the respective stakeholders could be quite stark; and the tangible impacts of these factors - positive and negative - on achieving pedagogical goals are significant. An extreme example that demonstrates a poor level of awareness of inclusivity in society even today:

> P10 (Parent) - "Yeah, my gran was wondering why I hadn't put (P10's disabled child) in a home... ."

Earlier, we highlighted the potential ramifications for emerging communicators with CCN who have challenging backgrounds, which can have significant implications:

> P06 (Teacher) - "[S]ome families who might not be as literate...you know if you're not sure about writing, or if you can't read everything we're putting in... ."
>
> Interviewer - "So in terms of AAC, which approaches if any, are you aware of being used in [the school]?"
> P09 (Parent) - "I wasn't aware of any of them before the SLT had obviously noticed how [my child] was able to use them, I never pushed for it - because I had never even heard of them before."

P09 had two children attending the school with CCN, and in this case was referring to the younger one who - after a successful trial and subsequent quest for funding - had been offered a speech generating device. Both children had already been using low-tech aided communication for a number of years. At home P09 also indicated prior satisfaction with the status quo, redolent of early research in this area [Murphy et al. 1996].

Contrast this against the following:

> P10 (Parent) - "Yeah. Like I'll turn up to training day and the SLT will be there and there are no other parents."
> Interviewer - "How would you interpret that?"
> P10 (Parent) - "I think I've just got a drive and I want what's best for my kid. And I'm not saying that any other parent doesn't! I just think I'm the type of person that sits and researches and if I feel that there's gonna be some benefit then I like to give it a go or discuss it or find out if that is an opportunity for [my child] and take it from there."

This would seem to make a compelling argument in favour of increased efforts to raise awareness, and encourage, wherever possible, more engagement with family members - a position strongly supported within the literature [Johnson et al. 2006].

The dichotomy - or contrasting levels of engagement - demonstrated by the two parents P09 and P10 might cause the observer to assume that the more engaged of the two would be welcomed by the professional educators who encountered her. This was largely true, yet occasionally there was scepticism, rightly or wrongly, in evidence about the level of optimism and ability P10 displayed.

Tension could also exist between teaching staff and LCAs. Unquestionably there was a great deal of respect between the two groups, who must both work closely together towards delivering pedagogical outcomes. Regarding, and in recognition of, this issue:

> P05 (Teacher) - "I go straight in there and say... pleased to meet you, I know you know the class and I'm depending on you for the first couple of weeks. Thereafter I'll take control but I'm really looking forward to working with you, I've heard lots of nice things about you, I know you're a great team *CLAPS HANDS* Straight in there! I'm the teacher but I want you here on my side."

SLTs are the healthcare professionals working most closely with the pedagogy-focused teaching and support staff, and also with the parents themselves. They are gatekeepers to AAC and allied assistive technologies that might be deployed in assessing and intervening in cognitive-communicative impairments presenting by the children at the school. They also have a responsibility for training staff and parents in their recommended solutions. As such they have a uniquely influential role for the focus of this study.

> Interviewer - "So you go and do what I do, you're ...sitting there observing and..."
> P01 (SLT) - "Yeah, in conjunction, in partnership, I'm trying to make language acquisition functional, real life in real time. And not isolated and segregated and separate."

Straddling the fence between the assistive technology, the therapy, the parents, and other staff appears to be uncomfortable at times. Like most of the adult stakeholders who participated in the

study, they are passionate about their role and appear committed to enabling their colleagues to reach their pedagogical targets with the children. However there are indicators that the role is not an easy one - being responsive to the child's, their parents', and their teacher's needs; yet with their agency perhaps only extending as far as an advisory role can:

> P01 (SLT) - "Sometimes it cannot be fixed! You know and if a parent hears 'Oh all you needed to have done is X and it would have been fine', how does it make that parent feel? You know they have tried their level best for years, they've read to their child, loved their child, sat with their child... and we've got to be careful that we... you see in newspapers you know 'This is the fix' and the parents will be banging your door down to get this fix..."

It would, however, be a mistake to consider all of the practitioners of a certain role as sharing equivalence. Like the children, and the parents discussed above, they naturally display intra-individual and indeed role specific variability (specialisms in the latter case):

> P02 (SLT) - "I'm a bit rubbish at the more high-tech things... ."

This is likely a modest appraisal, and contrasts with P02's later member-check response that she was moderately comfortable with high-tech AAC, but is illustrative that individual team members have correspondingly individual strengths and weaknesses, and that this sensibly may dictate their respective contributions. For the best potential outcomes, all participants need to assent and understand their roles and relative capacities, and work together to meet agreed pedagogical goals. Yet in a domain with this level of complexity, there are many potential pitfalls in doing so, and a great need for cross-disciplinary coordination.

5.1.4 Sub-Theme: Assessing Outcomes. For any researcher developing a technical tool for this population, an important step might be to make a baseline measurement, perform an intervention, and then measure again to determine any tangible effect. However, the level of development that many of the children in the school present appears to make such evaluations less of a priority:

> P06 (Teacher) - "I couldn't put my hand up and say this is this vocabulary size and this is this vocabulary size. Somebody like (Child A) who is very early communication level, you wouldn't be looking particularly at vocabulary... I suppose (Child B) with her eyegaze you could look at her device and count the number of words that are on it, couldn't you? But actually how many of them does she use meaningfully - that's a different question. From the point of progression, and this is interesting with the communication books - that would be a concrete thing to actually say last year we had five pages in the book and we're using them well, this year we've now got ten pages that they are now using well - and that would be a tangible way of measuring progress."

Resonating with prior research, participants talked about the inadequacies of standard assessment tools for measuring outcomes in their students:

> P03 (SLT) - "The hard bit for us here, a lot of the pupils here if you're doing standardised assessments, they don't fit in with the standardisation - they won't fit with this population."

Complications in this area are not simply down to the learning capacity of a particular child, but also reflect the barriers of any physical impairments. So regarding the Derbyshire Language Scheme:

> P01 (SLT) - "You need vision and you need hearing and you need motor skills to do that, though we can adapt it a little bit. If somebody's not got vision but they've got decent

> motor skills and can scan, then you might be able to do it that way (*demonstrates something not captured*)."

It is clear that approaches to assessment are adaptive and need to be framed within the context of the individual child in question.

5.2 Main Theme: Assistive Technology Interventions Require Expertise

It is very important to match the optimum AT/AAC solution to the specific requirements of the individual concerned. Failure to do so effectively can have far-reaching implications both in terms of resources (ill-matched devices often resulting in abandonment [Johnson et al. 2006; Murphy et al. 1996]) and the long-term prospects for the young person with CCN. Unfortunately, a hallmark of this complex technology remains the challenging level of expertise often required to operate it, which also places significant demands on the competencies of any adult stakeholder involved in a support programme.

5.2.1 Sub-Theme: High Tech Benefits Being Missed. The literature highlights the potential benefits represented by high-tech AAC, but also documents the twin issues of low adoption and high abandonment. In our study, there were six active users from a population of approx 180 pupils with CCN. This amounts to only 3.3 percent of the total. This concurs with prior research, but on a scale that the researchers did not anticipate. Against a backdrop of massively increased app development, awareness and availability - a scenario which might intuitively be anticipated to increase device uptake - we believe these numbers underline a crisis in service delivery supporting children with communication disabilities in SE. To describe this level of uptake as "low" or "poor" is to understate a situation that demands to be addressed. The relative scale of deficiency may not have been appreciated without the embedded element of our approach. The data were generated by our researcher's presence and participation in classes within the school, rather than via interview. Practitioners were not generally aware of this school-wide low adoption statistic and it did not appear to be a significant issue for them. Lack of acknowledgement of such metrics may indicate that at the time of the study there was no coordinated strategy, or no recognition of a need, to increase high-tech AAC uptake to leverage its potential benefits for fitting candidate pupils; or it may be symptomatic of a pragmatic acceptance within the school that the support infrastructure for such upscaling is simply not in place.

Some adult stakeholders with a longstanding relationship with the school (P09 above) remain unaware of the existence of high-tech AAC, let alone the potential benefits that such devices may represent. But teachers such as P05 and P07, and LCAs (e.g. P11) animatedly discussed their wish for more technology in the classroom (in Section 5.1.2). Clearly some staff would champion far more high-tech AAC in the classroom.

In those cases where the technology had been provided, some serious issues were observed:

> Study field notes: "iPad size and weight is an issue (full size model), small child cannot hold [the device] with one hand and operate it, too bulky - needs to be seated (why not iPad mini? Casing with handles? iPhone? Child observed struggling to carry the device around, what about some sort of velcro support strapping that allows the device to hang from shoulder/be dropped?)".

The child in question was being offered a very inconvenient and uncomfortable relationship with his "voice" that was clearly incompatible with a user-centred approach.

In interviews, teachers also reported failure (abandonment) in their efforts to integrate high-tech AAC into their supporting pedagogical approach:

> P06 (Teacher) - "I have a pupil who used to use GoTalk app on an iPad... it's not been hugely successful - partly because he thinks his iPad means playing games and it hasn't worked hugely successfully as a communication device so we're actually going to look down a different route for a change."

P06 was abandoning high-tech AAC to return to a paper-based communication book support solution for the young person in question. There is a disconnect apparent between this teacher's experiences and the successes and potential benefits of high-tech AAC as documented in the literature of evidence-based practice [Caron et al. 2016; Holyfield et al. 2018; Sennott et al. 2016]. The extremely limited number of children with CCN using high-tech AAC to communicate in the school was a revelation warranting further, urgent, investigation.

5.2.2 Sub-Theme: Training is Paramount. To develop competency in operating any complex technology, a system of adequate training should be provided as a support. However, comments from interviewees, and observations recorded in the study field notes suggest that some adult stakeholders are struggling to develop the necessary skills as afforded by current policies and practices.

> Field notes: "P09 (Parent) received brief familiarisation training (Assistiveware Proloquo2Go) of around an hour from SLT; wants Makaton training to fill gaps (e.g. when (Child Y) in shower or out and about): Problem is (Child Y) has some motor skill impairment and struggles with Makaton. Their teacher received similar level of training. LCAs receive no such training".

The training in question was intended to furnish the adults with the knowledge to operate the device, and maintain and update it for the benefit of the child both at home and in the classroom. Significantly, there appears to be little time or focus on the particular requirements for modelling and encouraging interaction which is consistently recommended [Schlosser and Raghavendra 2004; Sennott et al. 2016].

Where training had been provided it was reported that it can lack the necessary depth or context. One teacher recalled attending PECS training to support secondary department children, then moving classes to the enhanced support area - where PECS is much more intensive - with no supplementary training forthcoming, and found the experience very difficult:

> P04 (Teacher) - "Most of the time I laugh rather than cry".

P04 may have been tongue in cheek with that remark, but she was implicitly referring to potentially serious deficits in staff training provision, as demonstrated by the tangible impact on an emerging communicator described in the following exchange:

> P13 (LCA) - "They don't use Makaton when they leave school!"
> Interviewer - "No?"
> P13 (LCA) - "One (child) came here from a mainstream school, used BSL (British Sign Language), had to learn Makaton. And I think when they go to college it's BSL."
> Interviewer - "My understanding is that Makaton is easier to learn."
> P13 (LCA) - "Yes but the big world out there... it's all BSL."
> Interviewer - "So is there anyone in here that does BSL?"
> P13 (LCA) - "I don't think there's anyone."

This particular example - apparently wrought by a lack of trained staff - may have implications with regards to meeting the requirements of the UN Convention on the Rights of Persons with Disabilities [UN 2006].

LCAs reported no access to training with high-tech AAC - although training for low-tech and unaided is provided and, indeed, the LCAs appear to be a mainstay and source of mentoring and

expertise in this regard. They describe learning in situ as being commonplace, and often to the benefit of the population as a whole:

> P12 (LCA) - "You learn on the job here, and you learn as an adult from the others around you. It's just something you learn over time, how to talk to our children, and how to extract information from them... You have to learn from other people. It doesn't matter what it says in that book because wee Jimmy in the corner's never read that book... I've learnt from some of the best LCAs and teachers that this place has ever had."

One observation, however, exposed a flaw in restricting LCA training in high-tech, whether as a strategy or due to budgetary constraints. The practitioners were ill-prepared to assist a child using eyegaze (eye tracking) technology when the device developed an access malfunction, and all appeared unaware of the calibration procedure, rendering their problem-solving efforts completely ineffective.

There can be strength in ad hoc training practices, at least as far as unaided or low-tech AAC is concerned. But the complexity of high-tech systems, their maintenance requirements and diverse access methods, pose a challenge to current training and support models in SE.

5.2.3 Sub-Theme: Supporting Technology-Mediated Communication. This sub-theme considers the ways participants described or were observed supporting communication in their classrooms. Due to the paucity of high-tech adoption observed, some of the examples relate to low-tech or unaided AAC, but insights are relevant.

There is evidence that training children to use their high-tech device may be more seamless than that of the adults. In this example, a parent describes the joy her child with autism spectrum disorder experiences upon receiving a funded speech generating device that he had previously trialled for six weeks:

> P09 (Parent) - "Yes and now that he's got it back he just flips through the menu to get to what he needs, it's come back, it must be like someone taking something so much from you that you need! Yeah, he's really good on it - you have to go in and see him on it!"

This is a good example of the success of early intervention (triangulating work by researchers such as Janice Light [Light 1997]), in this case for a child with autism spectrum disorder who values the precision and predictability of computer-based interactions.

> P13 (LCA) - "Well kids have got technology as soon as they are born, they see mum and dad on it, they know what to do. If it was there and available to them to use, it probably would be a good thing, yeah."

Supporting communication - technology-mediated or otherwise - requires knowledge, skill, and flexibility. Participants described what appears to be a culture of make do and mend, adaptive, borne perhaps of resource constraints and the motivation to meet the contrasting needs of their heterogeneous audience with ingenuity and improvisation:

> Interviewer - "And you're calling that...?"
> P06 (Teacher) - "A communication folder or book I suppose. And we're away to set it up with [the SLT], we were gonna do one for each child."
> Interviewer - "So you're launching a new strategy almost?"
> P06 (Teacher) - "Well, kind of... ."

> P04 (Teacher) - "So we were making a polar bear one day - and I knew the sign for bear but not polar bear. And we discovered that there wasn't one so we kind of made one up - and just went with ice bear."

P04 refers to a common occurrence apparently, so much so that the Makaton sign language programme common within SE had been wittily nicknamed "Makie-Up-A-Ton".

All of the children who used high-tech AAC had low-tech or unaided alternatives available, in other words a multiple-modality approach, to their planned intervention strategies.

> P02 (SLT) - "So some teachers have that as a backup for more high-tech because you can't rely on technology all the time *laughs*".

Where adverse conditions hold sway, innovation can still engender improvements to support for technology-mediated communication that are cost effective - yet such improvisation is unlikely to represent a secure pathway towards organisational best practice.

6 DISCUSSION

There is an ongoing squeeze on public finances around the world, exacerbated by demographic trends increasing pressure on disability services; and rapid advances in assistive technologies - exemplified by more affordable touchscreen tablets and apps. These factors demanded a fresh look at how well matched current systems and policies are to meeting the evolving needs of people with communication disabilities. The narrative, however, is a complicated one, with many moving parts and protagonists. The literature indicated that early intervention was an important strategy for enhancing outcomes for young emerging communicators [Sevcik et al. 2004] - helping them cross that bridge to independence that can make a material difference to their lives, and the lives of those around them. Some of the issues we encountered in our research are well known - low adoption and high abandonment of AAC technologies, for example, have been identified in numerous studies. In the course of our research we found that most, if not all, prior work had been restricted to discrete surveys or interview methodologies. By embedding a researcher in the classrooms and corridors of SE, we set out to accumulate a richer understanding of the school ecosystem within which educators, and children with CCN, operate. Having originally intended the user-centred development of a novel high-tech AAC device, our ensuing immersion in an SE environment convinced us that there were more urgent issues to address encompassing a wider, systemic perspective. These centred on severe limitations in the uptake of devices, and how the focal community interacted with those devices that were in place.

We now consider the original aims of this study, and the implications of our results.

6.1 Identifying Facilitators and Barriers (see Aim 1, Section 3.2)

We identified a mix of five factors (see Table 2 below, accompanied by examples from within the *Results* section) that appeared to act as facilitators toward achieving successful outcomes in supporting language acquisition in children with CCN in SE. Some of these were intrinsic, some were extrinsic - and, significantly, expandable with enhanced access to support or appropriate resources.

Similarly, eight potential barriers to the achievement of good outcomes were also observed (described in detail in Table 3 below, again with examples).

We believe that this mix of issues are significant factors, both in the critically low uptake and high abandonment of devices, and in the opportunities afforded for improvement.

These insights validate prior research gathered using less immersive methodologies but in terms of barriers, they also suggest a greater scale of deficit, or missed opportunities, in the sector.

Table 2. Key Facilitators

Facilitators	Description	Examples
Advancing EBPs	Where observed, the uptake of evidence-based practices within the community was typically beneficial.	*Section 5.1.3 Sub-Theme: Partner Relationships and Attitudes notes the benefits of EBPs as portrayed by one SLT during the Study.*
Population of Digital Natives	Some of the children who make up the population of potential AAC users have a particular affinity for computer-based interactions.	*P13's anecdote in Section 5.2.3: Supporting Technology-Mediated Communication.*
Increased Availability of Technical Solutions	Enhanced access opportunities to technology through apps and mass produced (lower cost) hardware solutions.	*Section 5.2.1: High Tech Benefits Being Missed notes the increased availability of mass market high-tech solutions, and this factor is echoed by repeated references to Apple's iPad as a platform being adopted within the partner school.*
Implementation of Multi-modality Interventions	Access was enhanced for all pupils through a mixture of modalities being adopted.	*Section 5.2.3: Supporting Technology-Mediated Communication notes the strength of Makaton signing as an unaided alternative modality common within the partner school.*
Motivated Community of Stakeholders	The team around the child, parents/carers, and the broader school community typically displayed a commitment and motivation toward achieving the best outcomes possible for the children they worked with.	*Throughout the Results section we see examples of adult stakeholders doing their best to support pupils, perhaps best exemplified by teachers using personal funds to purchase resources - Section 5.1.2: The Battle for Resources.*

Table 3. Key Barriers

Barriers	Description	Examples
Complex Technologies	The complexity of high-tech AAC technologies, and the accompanying pedagogical requirement for frequent adaptations tailored to individual learners' needs was identified as a burden in a community of non-technical educators and other adult stakeholders.	*The main theme Assistive Technology Interventions Require Expertise provides numerous examples, often revolving around operational issues e.g. eye gaze calibration (Section 5.2.2).*
Coordination Deficiencies	In this continually evolving technological milieu, insufficient cross-disciplinary coordination emerged as a complicating factor, causing confusion among practitioners	*Consider the lack of clarity over roles and responsibilities referred to in Section 5.1: Achieving Pedagogical Goals with AAC Users is Complicated.*
Persistent Training Deficits	Insufficient training opportunities for staff and other adult stakeholders.	*Section 5.2.2: Training is Paramount provides examples but further evidence of this barrier is available throughout the Results section.*
Restricted Availability of Professional Expertise	A paucity of professional expertise and, as a consequence, low uptake of EBP in the field was indicated.	*Section 5.2.2 also provides a cogent example of the impact the lack of available expertise can have in the exchange with P13 concerning British Sign Language.*
Pace of Technological Change	The speed of technological advance, and restricted horizon scanning mean some devices becoming obsolete before they can be used, and emerging technical tools may be overlooked.	*Section 5.1.2: The Battle for Resources has an illustrative example of P04 discussing this topic.*
Societal Challenges	We gathered evidence of the negative impact circumstances and attitudes within the wider community may have on the progress of learners with CCN.	*Section 5.1.3: Partner Relationships and Attitudes presents examples of this significant barrier.*
Resource Restrictions	Resource scarcity, and an ad hoc approach to distribution may have a potentially tangible impact on outcomes.	*Section 5.1.2: The Battle for Resources considers this issue in detail.*
Vulnerability of Users	Co-existing with the digital native facilitator identified in Table 2, the increasingly sensitive nature of the target population within SE, impacted by societal trends, also represents a challenge to the organisation of support made available to these learners.	*Section 5.1.1: Target Population is Diverse and Challenging provides good evidence of the barrier for children that their vulnerability represents.*

Individually such barriers are debilitating, but in combination they may create an impact that is much more damaging than their individual parts.

As indicated in our Introduction and Section 3, on commencing this study an ethnographic approach seemed both a useful and important contribution on the basis that:

(1) It did not appear to have been attempted before.
(2) The immersive element seemed well-matched to collecting data from such a sensitive user group.

The approach was intended as a first, context gathering, stage of a planned UCD process. Yet what is perhaps most revealing about the results of the exploration summarised in the tables above is that traditional user-centred aspects of technology design do not dominate. Instead, what we repeatedly see is evidence of the value and influence of the community within which these devices must operate; and the underpinning criticality of ensuring that an holistic approach giving equal status

and consideration to this singular environment is adhered to. The efficacy of any AAC intervention or solution, in other words, appears inextricably bound in the symbiotic relationships between hardware, software, community partners, policies and individual user attributes - a sociotechnical system [Carayon 2006].

6.2 Technology Procurement and Implementation (see Aim 2, Section 3.2)

In an environment where resources are sparse, those making decisions about procurement, delivery and support need to strive for the most effective solutions possible. The reasons for failure of strategies or abandonment of devices must be understood, and efforts made to ensure high-tech AAC is matched appropriately to individual users, and suitably supported. During the study, sharply contrasting views were observed or expressed on the support and distribution of high-tech AAC. Practitioners and parents alike navigate this complex topic quite idiosyncratically, based upon personal experiences, respective roles and understanding. High-tech is clearly not always best but questions remain over how well-informed and supported respective protagonists in pivotal roles are - and the impact on resource allocation and coherent service delivery between disciplines also plays a significant role.

While best practice suggests a sensitive and responsive matching of AAC to any candidate user's needs [Scherer and Craddock 2002], we observed a number of shortcomings over the course of our study. For example, we noted weaknesses in the system of procurement (assessment of AAC solutions and features matching) that echoed the literature, such as the challenge of "gatekeeper" practitioners maintaining topical knowledge of the latest tech [Lund et al. 2017]. Stretched SLTs were not in a position to undertake horizon scanning - and nor did adequate emphasis appear placed upon this vital activity - to identify the most apposite high-tech solutions. Identifying candidates for high-tech AAC support also appeared ad hoc, possibly depending upon a particularly engaged teacher or parent initiating an assessment.

In implementation (adoption and use) we observed devices being delivered into the hands of children in classes where their teachers had minimal or no training in best practice to support a high-tech AAC user [Light and McNaughton 2013]. This training deficit is particularly important because - supported by the literature [Baker et al. 2011] - aided-language stimulation, and engineering opportunities for children who use high-tech AAC to communicate using their devices, are essential to promote language acquisition. A suitably-trained teacher could make the difference between success and failure in the brief window of opportunity that is available for trialling a device with a candidate child.

AAC services must be responsive to the fact that developing skills to master these devices requires a range of physical and cognitive competencies [Light and McNaughton 2014]. Such skills may take years to acquire, resulting in an inevitable educational focus on managing access rather than using technology to achieve pedagogical goals. While there is little doubt that AAC technology improves the quality of life for individuals with severe disabilities, our evidence shows that when someone has a severe communication disability, there are too few people in education sufficiently familiar with the technology to support them in their learning [Bercow 2008; Government [n. d.]].

During our collaboration with the school, we noted the rarity of high-tech AAC adoption. One barrier, noted above, was resource scarcity; but there were also incidents of device abandonment (e.g. P06 and the GoTalk app in Section 5.2.1), ineffective (occasionally non-existent) support of both aided and unaided AAC (e.g. P13's anecdote about British Sign Language support in Section 5.2.2), and ergonomically inappropriate device allocation (e.g. small child matched with full size iPad seriously impacting upon usability in Section 5.2.1). These phenomena do not occur in a vacuum. Extensive knowledge and expertise is required to curate these complex technologies, and while it may be unreasonable to expect flawless service delivery this study highlights the many

interconnections which demand a coordinated solution. We believe that the embedded element of our study helped to reveal the rich intricacies of this environment and their implications relating to this aim.

The usability of current AAC devices may be improved - e.g. the complexities, highlighted in Sections 1 and 2.2, mitigated - by careful application of UCD principles (described in Section 2.5), enhancing meaningful engagement with end users. However, before we even look at these design issues for individual tools, it appears essential that other factors - see 6.1 above, e.g. the nurturing of knowledge and EBP expertise in the environment - are addressed first if we are to improve levels of adoption and promote enduring use of these potentially life-changing technologies. Our work documents that a receptive community is there, but one currently lacking the direction, resources and practical expertise to address the challenges of effective implementation in the field.

6.3 Conclusion

This research, applying immersive UCD techniques to determine context of use, actually reveals that current organisational systems within SE are not adequately geared towards the adoption and meaningful support of high-tech AAC devices. We highlight a crucial gap between the skills of the current team around the child and their ability to harness the true potential of these technologies. A potential solution to this problem is upgrading the access for educators to more focused and comprehensive training, or to third-party sources of expertise. Greater emphasis needs to be placed upon bridging this gap by integrating richer, more sustained support for AAC users and practitioners alike. The organisational complexity of orchestrating teaching for children with CCN is clear; and the accompanying need for pedagogical and technical expertise as an integral, enduring presence.

More broadly, from a human-centred computing perspective, what also emerges from our application of UCD principles is evidence that designing effective solutions for this domain cannot begin, and end, with the technology alone - something that, as technologists, we may have been prone to overlook. Instead, we identify an attendant requirement for the design and seamless integration of effective, user-centred support i.e. the development of novel systemic support mechanisms enabling young people with CCN and their advocates to undertake the challenging tasks demanded of them using these empowering, though often complex, technical tools.

6.3.1 Future Directions for Research and Practice. We further propose that the systemic missing link in this sociotechnical environment may be found in the role of the Assistive Technologist - a trained professional who can innovate advanced technology solutions which cross disciplinary boundaries of computing, engineering, psychology, education, social and healthcare. Guidelines for the training of Assistive Technologists have been developed e.g. Natspec's (further education-focused) DART Project in the UK [Maudslay 2015] but to date there has been no formal attempt to understand or define their role in the SE classroom.

An Assistive Technologist could be a skilled mediator within the learning environment, working closely with teachers and other staff, as well as supporting children, in the use of these technologies. Such a role could contribute towards eroding many of the barriers identified in Section 6.1, optimising access to the technology, and engineering tailored support for Light's four competencies. For example, taking "ownership" of the tech could mitigate complexity, and assist coordination and horizon scanning; their expertise could provide a source of ad hoc or formal training for other staff members - which in turn would raise awareness of, and promote, EBPs. Assessing and supporting higher numbers of high-tech AAC users would be more feasible with a dedicated expert on hand and the low uptake/high abandonment challenges the sector faces could therefore be reduced. Extended access to modelling could elevate support for children with language comprehension deficits, as well as improving expressive communication where more focus has traditionally been

placed [Allen et al. 2017]. Such cross-disciplinary expertise in situ would be an enabler of the holistic approach [Savignon 1983] to AAC intervention and assessment that is needed but appears largely unattainable with current organisational paradigms.

Significantly, in the context of promoting technology-mediated communication as a part of the UCD continuum, the presence of such a practitioner could serve as a bridge between external developers and users, and act as a major contributor toward developing an effective, user-centred support environment: One where educators can focus upon pedagogy - that is boosting students' current abilities, and future potential - rather than upon "access to technology" as appears often currently to be the case. Testing this hypothesis will be our major focus for extending this research into the future.

6.4 Limitations of the Study

The data collection and analysis for this article - e.g. the coding and theme generation - was undertaken by one individual (the first author). This imparted consistency to the approach but removed the perspective of others, which may be an important mechanism for identifying latent, or implicit, codes [Braun and Clarke 2006]. This may have impacted upon the richness of the extrapolated data.

As a small scale study, the diversity of views available was curtailed - most notable is the dearth of formal male interviewees, and the ethnicity of adult participants was also uniform. Gender and cultural differences therefore may not be well represented. The study was restricted to one school although itinerant SLTs and other staff allowed insights from further afield.

6.5 Acknowledgments

The authors would like to thank the partner school, and all the participants for welcoming us into their world and sharing their thoughts and experiences. We would also like to thank Alan Newell, Norman Alm, Garreth Tigwell and Mike Crabb for their invaluable feedback, and of course our anonymous reviewers. This work is funded by an EPSRC DTP grant.

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