



Metatla, O., & Cullen, C. (2018). “Bursting the Assistance Bubble”:
Designing Inclusive Technology with Children with Mixed Visual Abilities.
In *2018 CHI Conference on Human Factors in Computing Systems: Proceedings of CHI 2018, April 21-26, 2018, Montreal, QC, Canada* [346]
Association for Computing Machinery (ACM).
<https://doi.org/10.1145/3173574.3173920>

Peer reviewed version

License (if available):
Other

Link to published version (if available):
[10.1145/3173574.3173920](https://doi.org/10.1145/3173574.3173920)

[Link to publication record in Explore Bristol Research](#)
PDF-document

This is the accepted author manuscript (AAM). The final published version (version of record) is available online via ACM at <https://doi.org/10.1145/3173574.3173920> . Please refer to any applicable terms of use of the publisher.

University of Bristol - Explore Bristol Research

General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:
<http://www.bristol.ac.uk/pure/about/ebr-terms>

“Bursting the Assistance Bubble”: Designing Inclusive Technology with Children with Mixed Visual Abilities

Oussama Metatla
University of Bristol
Bristol, UK
o.metatla@bristol.ac.uk

Clare Cullen
University of Bristol
Bristol, UK
c.cullen@bristol.ac.uk

ABSTRACT

Children living with visual impairments (VIs) are increasingly educated in mainstream rather than special schools. But knowledge about the challenges they face in inclusive schooling environments and how to design technology to overcome them remains scarce. We report findings from a field study involving interviews and observations of educators and children with/without VIs in mainstream schools, in which we identified the “teaching assistant bubble” as a potential barrier to group learning, social play and independent mobility. We present co-design activities blending elements of future workshops, multisensory crafting, fictional inquiry and bodysorting, demonstrating that children with and without VIs can jointly lead design processes and explore design spaces reflective of mixed visual abilities and shared experiences. We extend previous research by characterising challenges and opportunities for improving inclusive education of children with VIs in mainstream schools, in terms of balancing assistance and independence, and reflect on the process and outcomes of co-designing with mixed-ability groups in this context.

ACM Classification Keywords

H.5.2 User Interfaces: Prototyping, User-centered design; K.3.1 Computer Uses in Education: Collaborative learning; K.4.2 Computers and Society: Social issues - Assistive technologies for persons with disabilities

Author Keywords

Inclusion, Education, Co-Design, Children, Mixed Abilities

INTRODUCTION

There are over 25,000 children and young people with visual impairments (VIs) in the UK [57], and 7 out of every 10 of them are today educated in mainstream rather than special schools [59]. This usually takes the form of one or two pupils in a class of up to thirty sighted peers [53] (e.g. Figure 1). Including children with special educational needs (SENs) in mainstream schools is a growing trend across a number of countries, often backed by policies that have been in place for



Figure 1. A blind pupil with a teaching assistant in a mainstream class

a number of years now [74]. However, recent studies show that the participation of children with SENs in mainstream classrooms is still not optimal and that sound knowledge about effective practices in this domain is lacking [30, 64, 74, 79]. In the case of children with VIs, educators often resort to modifying curriculum resources to make them accessible, using tools such as Braille, tactile diagrams, screen readers, and screen enlargement software [2]. But these tools are designed to be used by pupils with VIs alone and not by their sighted peers, and can therefore lead to learning in isolation and reduced opportunities for peer interaction and engagement [4].

A twofold underlying issue emerges in this context; first, there is an increasing integration of technology in the modern classroom, e.g. in the form of electronic whiteboards and mobile computers [5, 45]; second, current technological support for children with VIs in mixed classrooms emphasises accessibility over inclusion, focusing on a child’s disability and not on the variety of abilities present in a social context of learning involving pupils, educators and technology. An alternative and perhaps complimentary approach is to augment learning environments with technologies that take into consideration the mixture of abilities and processes surrounding group and individual learning. But this requires furthering our understanding of inclusive learning environments and devising appropriate approaches for designing technology that can enhance them. We propose that such approaches should include co-designing with educators and both children with and without VIs.

Involving stakeholders in general and children in particular in the process of designing technology is now well established, and a number of methods have been developed to facilitate participation (e.g. [18, 52, 75]). Many researchers are also actively seeking to involve children with SENs in the design of technology across a number of domains including education

(e.g. [44, 78]). However, relatively little research has examined co-designing with children who are blind or live with VIs in a process that also involves their sighted peers [6].

We address the question of how technology can intervene in meaningful ways to improve inclusion in education environments, making two main contributions to this body of work. First, by characterising barriers to inclusion of children with VIs in mainstream schools, and offering extra insight into the role of the teaching assistants in balancing dependence and inclusion for these children. We also identify areas that lend themselves to technological intervention. Second, by demonstrating how engaging children and educators through inclusive co-design methods enable joint production of radically new conceptions of inclusive technology. Crucially, we frame both contributions in a shifting emphasis away from accessibility and towards inclusion in practice and design for inclusive technology in this context.

BACKGROUND

Inclusion and Special Educational Needs

Inclusion is a central topic in contemporary educational discourse. It refers to the practice of providing a learning environment that allows pupils to experience and embrace diversity, and to schools employing teaching approaches that enable learners to participate fully in a mainstream setting regardless of their needs [70]. The Index for Inclusion [7] is an example of a framework that describes what an inclusive school looks like in practice, enabling schools to draw upon the knowledge and views of staff and pupils about barriers to learning and participation. In this respect, educational support staff are crucial in ensuring the recognition and appropriate responses to the needs of all learners [1].

Inclusive practices have been grounded in both legislative and policy decisions throughout their relatively short history, but it is important not to overlook practical challenges on the ground. Pupils identified as having SEN continue to have difficulties participating fully in mainstream education [8], and teachers across a number of countries do not always report having the training, time and resources for the implementation of inclusion. Findings from 68 surveys of teacher attitudes toward inclusion between 1958 and 2011, which included 18,926 respondents from the US, indicated a consistent attitude towards inclusion: While a majority supported the general idea of inclusion, only a minority supported full time inclusion, and much smaller numbers agreed that they had sufficient resources to carry out inclusive practices effectively [64]. Similar results were reported in the UK and Northern Ireland [30].

In order to support this move towards more inclusive classrooms, there has been a huge increase in the number of teaching assistants (TAs) working in mainstream schools, both internationally and in the UK [21, 66]. Data from the Department for Education's School Workforce Census shows that the number of TAs employed in state-funded schools in England has increased by nearly 50,000 since 2010 alone [24]. With such a huge influx of support staff in UK schools, adequate training and assistance should be in place to ensure that TAs are able to deliver effective interventions. However, evidence from

recent reviews suggests that TAs rarely receive the necessary support, and that this can have negative effects on academic progress for students with additional support needs [21, 27]. The present work extends this body of work in terms of method and participants, combining in-depth interviews with class observations to characterise challenges and opportunities related to the provision of inclusive education.

Educational Assistive Technology for Pupils With VIs

Children with VIs have complex needs that require appropriate provisions [2]. They have limited access to the curriculum via the visual medium, and accessing information via alternative mediums such as Braille, is often time-consuming or even impossible [31]. A child with a severe VI is also likely to require additional support in developing social skills [60]. A number of researchers have developed novel assistive technologies (ATs) that address these sorts of issues. For instance, Hayden *et al.* [33] developed a portable note-taker to provide blind students with better access to classroom presentations, Murphy *et al.* [54] investigated the use of non-speech and speech sounds to improve access to mathematical formulae, and McDonald *et al.* [46] used 3D printing to produce rapid prototyping tactile tools. Despite progress, however, uptake of novel ATs in educational settings continues to be limited [9, 40, 79], and text-to-speech devices, and screen enlargement software continue to be the dominant ATs used by pupils with VIs [46]. We suggest that involving educators and pupils in the design of inclusive educational technology can improve uptake by ensuring designs are informed by and adequately embedded within ongoing practices and provisions.

Co-Designing With Children With SENs

Participatory design (PD) is a common approach for involving end users in the process of designing technology, and a number of methods have been developed to facilitate engagement with different populations (e.g. [13, 41]). There is growing interest in exploring ways to co-design with and for people living with VIs [10, 43, 49, 51, 62]. For example, Magnusson *et al.* [42] used PD workshops to develop support for sensory motor rehabilitation of children with VIs, and McElligott *et al.* [47] co-designed toys with children with VIs. Research has also demonstrated that PD approaches to designing technology for children with certain SENs, such as autism, is valued for creating meaningful technology as well as for enriching and empowering participants experiences [25]. Many researchers are now actively seeking to involve children with SEN in the design of new educational and assistive technologies (e.g. [44, 78]). However, relatively little research has examined co-designing with children who are blind or live with VIs in a process that also includes sighted peers [6, 72]. In this paper, we build on prior work that highlighted the need to adapt methods to the children and their environment [6, 25, 36] by exploring how to engage educators and both children with and without VIs to design inclusive technology.

FIELD STUDY: IDENTIFYING CHALLENGES

We aimed to identify challenges facing educators and children with VIs in mainstream settings in order to identify areas that lend themselves to technological intervention. We partnered

Table 1. Children and teenagers with VIs we observed(*)/interviewed(†)

Name	Gender	Age	Description of visual impairment
Noah *†	Male	14	Degenerative VI leading to total blindness
Rosie *	Female	9	CVI with low light perception
Cian *†	Male	12	Blind from birth
Kevin *	Male	16	Low vision from birth
Tom *	Male	8	Low vision from birth and learning delay
Samy *	Male	7	Blind from birth

with three SEN Support Services and three mainstream schools in the UK. SEN Support Services are local government services who work primarily in schools to provide support and advice about the needs of children and young people with SENs. Our partners work across 14 boroughs with approximately 600 children and employ Qualified Teachers for Visual Impairments (QTVIs), who in turn work closely with SEN Coordinators (SENCos), Teaching Assistants (TAs) and teachers in schools. The SEN services helped us engage with three mainstream schools hosting children with varying ages and VIs (Table 1). 25 educators and six children with VIs took part in the field study, including nine QTVIs, three SENCos, seven TAs and six teachers with experience ranging from eight to 20 years in their corresponding practice. Each QTVI currently works with 20 to 30 children with a variety of VIs, and each TA works with up to two children with VIs¹.

Procedure, Data Collection, and Analysis

We met with QTVIs at their work sites, and with school staff and with Noah and Cian at the schools' premises at a time convenient to them. It was not possible to interview all of the children due to time constraints. We conducted semi-structured interviews with flexibility to adjust questioning based on responses [65]. We structured questions around focussing on inclusive provisions in practice, and challenges faced by children and educators. Interviews lasted between one and two hours for staff and 30 minutes for pupils. We also conducted intermittent observations of 10 teaching sessions involving all six pupils with VIs and spanning English, mathematics, crafts, and design technology (Key Stages 1-2, Year 2, Primary), history (KS2, Year 4, Primary), and business, science, drama and ICT (KS3, Year 9, Secondary) and computer science (KS4, Year 10, Secondary). Consent forms were obtained from all participants and pupils' parents. All pupils also gave verbal assent at the onset of observations and interviews. We used a thematic analysis [11] to analyse interview transcripts following a grounded approach, which enabled us to build themes up as we went through the collected data. Two researchers iteratively identified codes and common themes that emerged across five interview transcripts, which were then refined and used by one researcher to code the remaining transcripts and observation videos. We also organised follow-up meetings with educators and the two pupils we interviewed to present them with our constructions of the data.

Findings

The following themes emerged from the data: *Classroom Arrangements*; *Incidental Learning*; *Group Learning Pace*

¹At the wish of participants and parents, we use pseudonyms for all pupils and quote educators as: support staff=QT#; SEN Coordinators=SC#; Teaching Assistants=TA#; Teachers=TC#.

and *Language; Materials, Tools and Maker Culture; Social Interaction and Play*; and *Mobility*. These were related to an overarching theme of the “*Teaching Assistance Bubble*”, which was prevalent across the data:

Teaching Assistance Bubble

In all schools we visited, pupils with VIs have a dedicated TA who sits with them through all their classes. This role was sometimes filled by a QTVI or split amongst multiple TAs each dedicated to a subset of classes. The “*bubble*”, “*lesson-within-a-lesson*”, or the “*separate class*” were reoccurring discussion points in the data, referring to the close interactions that develop between a pupil and their TAs. Most interviewees (N=21) described this close interaction in implicit and/or explicit terms as leading to the formation of what effectively amounts to a separate lesson that has its own material, scope and pace, and that could gradually lead to detachment from the main activities taking place in a given lesson: “*Cian sits with the TA only, which is necessary at times, but can lead to isolation from the whole classroom*” (QT2); “*some teachers have Noah on a separate table with me, and he almost has a lesson within a lesson [...] I mean have him in a different room, it's almost the same thing cause we're just in our own little bubble*” (TA6) (e.g. Figures 1). The TA bubble then became a metaphor that characterised the learning experiences of the children we observed as reflected in the following themes.

Classroom Arrangements

The decision as to where a child with a VI should sit in the classroom is often driven by technical as well as accessibility needs and considerations for the impact of noise. Explaining seating choices following one of our observations, a QTVI pointed out: “*we had to sit there for access to sockets and wifi*” before further reflecting that; “*but you don't want the child to be cornered all the time, he might think I don't want to go there I want to be with my mates*” (QT1). There were instances in the data showing that adverse effects of classroom arrangements could be either mitigated or exacerbated by teaching and assistance activities. For instance, we observed one teacher running an activity that allowed children to choose where to sit: “*that was quite nice because different children could come sit next to Tom*” (TC1), while in another instance, a TA described a group activity where pupils: “*needed to get to the sheets stuck on the wall [...] I just took pictures, took them back to where Noah was sitting and just read it to him, but then I guess he was not fully participating because of this arrangement*” (TA6). In this case, class arrangements, the choice of activity, and the TA's attempt to overcome potential mobility issues, made it difficult to balance accessibility and inclusion, leading to the TA becoming a mediator for the pupil.

Incidental Learning

Classrooms are typically dense with visual displays and artefacts related to ongoing learning activities: “*think about the richness of resources that we use with the sighted children these days, we have beautiful pictures, interactive whiteboards and displays around the classrooms, all these things that we think are necessary for the sighted children*” (TA9). While we observed teachers refer to such displays during a number of teaching sessions, their stimulation persists across lessons,

which means that a sighted child could still be engaged by such displays outside the particular lesson they were relevant for. Being completely inaccessible to children with VIs, these resources of incidental learning become a further source of isolation from potential shared learning experiences. For instance, we observed a TA quickly bring out a counting artefact in a mathematics class while the teacher engaged the sighted children in counting using wall displays.

Group Learning Pace and Language

Pace and ambiguous language were highlighted as two further factors that hinder effective engagement of pupils with VIs in group learning activities. Differences in how learning materials are accessed and delivered, e.g. through a screen-reader and whiteboards, leads to necessary exchange with TAs to bridge gaps, and some interviewees (N=8) attributed these sort of disconnects to the introduction of more technology in the classroom, as QT5 explained: *“more and more of [technology] now relies on the teacher making a verbal input that assumes either a shared visual resource or a shared previous visual experience and therefore the language used is incomplete”*. This issue is compounded by the pace of delivery, which gradually increases as pupils progress through the schooling system: *“teachers are encouraged to keep the pace up otherwise you get into trouble, and that doesn’t always suit our children because they need a bit more time”* (SC1). The use of incomplete, ambiguous and visual language increases exchange with the TAs, some of whom described active strategies to avoid falling into “the bubble” when supplying clarifications: *“if I’m explaining what’s going on, Samy usually starts to engage in a conversation with you, which is great, but you get lost a bit and he loses thread of what [the teacher]’s talking about, so I try not to say too much”* (TA2). Noah also pointed to the issue of keeping up with multiple discussion threads, having to pay attention to the teacher, his TA, and to concentrate on his screen-reader over an earpiece: *“it gets a bit too much a lot of the times, so I usually focus on one or two of them and drop the other, and that’s usually Miss [TA6] and my PC”*.

Materials, Tools and Maker Culture

The materials and tools used for accessing the curriculum amplify the TAs’ mediation role. An obvious example is Braille transcription. All teachers we interviewed did not read Braille for instance: *“like today, Samy’s done some lovely writing with his Braille, but I can’t read it unless his TA transcribes it or he reads it to me”* (TC1). The same was true for sighted peers. Interviewees also pointed out that tools and materials can take too much space that could otherwise allow for group formations (N=6) leaving a pupil with a VI sitting only with their TA: *“Cian often needs double the space to house all the various bits he uses and nobody can sit besides him”* (TA4). This is exacerbated by the fact that adapted materials and tools are seldom designed to be used by or shared with sighted peers. On the other hand, there was an evident and prevalent maker culture among our participants. TAs and QTVIs are directly responsible for adapting learning materials for the children: *“we’re always changing things, seeing what works and what doesn’t, and we just adapt, that’s part of our job really”* (TA2). This maker culture seemed to be nurtured by two recurring factors: 1) the difficulty of

reusing materials: *“that’s the trouble, we’ve got Kevin in year 11 at the moment, and it will be another couple of years before we’re going to have another year 11, by then the curriculum is changed”* (QT6); 2) the heterogeneity of needs of children with VIs: *“adaptation of the material is very individual, for Rosie, the colour red is very important, so I colour code the numbers so she can see them”* (TA1).

Social Interaction and Play

Interviewees emphasised the importance that children with VIs feel part of a social group and develop social skills that allow them to maintain social engagements. Some of schools we attended deliberately engineered opportunities for social encounters: *“we have a buddy system here, different children who would work with Rosie each day, so she knows she has someone to play with”* (SC1). However, the TA bubble appeared again in this context as a potential factor that can reduce opportunities for social interaction. Interviewees (N=7) described how they find themselves in situations where they have to balance adult supervision with the occurrence of healthy social interactions: *“children in classrooms do an awful lot of looking out of the windows, kicking each other under the table, sniggering and giggling and all that, as a TA, I can’t really be there as an adult and be seen to just ignore it”* (TA3). This means that “non-curricular” social interaction is naturally reduced around the presence of a TA, and hence children with VIs miss out on: *“a lot of learning that goes on with that, everything becomes mediated through adult behaviour, which actually isn’t what they should be experiencing”* (QT4). Discussions about games are a typical example of informal chats that go on amongst peers. But this is rarely a shared experience because of the gap that exists between accessible games and typical games available to sighted children: *“kids talk about computer games they’re playing, but our children completely miss out on that whole bit of social world”* (QT7).

Mobility

Interviewees pointed out that mobility issues are more likely to arise when teachers plan activities that involve moving around the classroom in ways that deviate from routine mobility, e.g.: *“a question is placed in each corner and they have to walk around from poster to poster and answer the questions”* (SC2). We observed a teacher orchestrating the same kind of activity but ensuring there is reduced mobility demands on Noah by assigning him a stationary role in his group. But the tendency of pupils with VIs to stick to familiar routes and navigation strategies came up as posing more concerns for their mobility outside the classroom (N=13): *“we were taking him over bits of the school that he doesn’t learn in, and he didn’t even know that those bits existed, he had no concept of the upper plateau, there is a huge field up there”* (SC2). When probed about the utility of accessing areas outside routine routes, the SENCo highlighted a link between physical space and the sense of safety and security: *“it’s a larger space of security, he feels very safe in school and actually if we expand that space beyond the corridors he uses then he’s got a bigger space of safety that he belongs in, and I think the sense of safety cannot be underestimated for those with a visually impairment”* (SC2). Mobility here highlights a hidden dimension of inclusion that explicitly moves beyond traditional views on accessibility.

Discussions implying the TA bubble were also present in this context, particularly with regards to difficulties finding friends outside the classrooms. In one instance, a TA relayed a real ordeal for a child with a VI who could no longer find his friend: *“we realised he was hitting quite a low patch and when we looked into it it was because he could no longer find his friend [...] what had actually happened was that his friend had a new rucksack and he was looking for the wrong colour, it was such a tiny thing but it was making a huge difference”* (QT4). To avoid this kind of issue, some TAs (N=4) described that, while they deliberately avoid being too present, they ensure they are not too far from the child they support as they moved around the school.

Summary of Findings and Design Implications

The findings highlight a clear need to move beyond traditional accessibility concerns. Designing inclusive technology in educational contexts should aim to target a variety of sensory modalities to promote opportunities for joint attention and shared experiences between pupils with and without VIs; to scaffold the prevalent maker culture among educators; and to improve and promote independent mobility. There was consensus amongst the educators we interviewed that a fuller inclusive experience of children with VIs should involve: *“bursting [the TA] bubble or to at least expand it so that more people could come in”* (TA6). Collating discussion points about this “assistance bubble” allowed us to identify a number of recurring factors that contribute to its formation, including: **Space disconnects:** e.g. *“a TA needs to talk to the pupil about what’s going on, so teachers often then put them at the back of the class so they’re not disturbing others”* (QT5). **Language disconnects:** e.g. *“it starts with that, the teacher hasn’t explained what’s on the board, the TA then gets busy with ‘he is pointing to this and that’, then the pupil stops listening to the teacher even when the teacher is talking, they don’t think the teacher is talking to them, they’re actually conditioned not to listen”* (QT9). **Material disconnects:** e.g. *“it is the TAs who have to adapt [the material] it would be wonderful if somehow that material was suitable for everybody”* (SC3). Addressing factors that contribute to the formation of the TA bubble could therefore be promising areas for technological interventions.

CO-DESIGNING WITH MIXED VISUAL ABILITIES

Following the field study, we organised a series of workshops with children with and without VIs as well as their educators to explore how to design technology that could address some of the challenges we identified. We established a set of priority areas in follow-up meetings with staff and children at each school, who chose their focus based on children’s abilities, preferences and ongoing educational and social development priorities. We provided parents, heads of schools, and teachers with information about the workshops, and obtained consent and assent from all participants involved. The primary goal of these workshops was to gather design requirements. We therefore blended techniques known to facilitate this process, including low-tech prototyping (aka the Bag of Stuff technique [20]), elements of fictional inquiry [35] and bodystorming [17]. Here, we report on our work with one of the schools who chose to focus on joint storytelling and mobility and outline our adaptations of design methods in their contexts below.

Table 2. Examples of materials we used in our Multisensory Bag of Stuff

Sensory modality	Example materials
Vision / Touch	Fabric, cotton, feathers, cardboard, foam sheets, play doh, strings, rubber bands, polystyrene shapes, legos
Hearing	Recording pegs, recording cards, dictaphones
Smell / Taste	Candle scents, scented pens, food flavouring cinnamon bars
Other materials	Scissors, Glue, Glitter, Tape, Coloured tape, Blu Tack

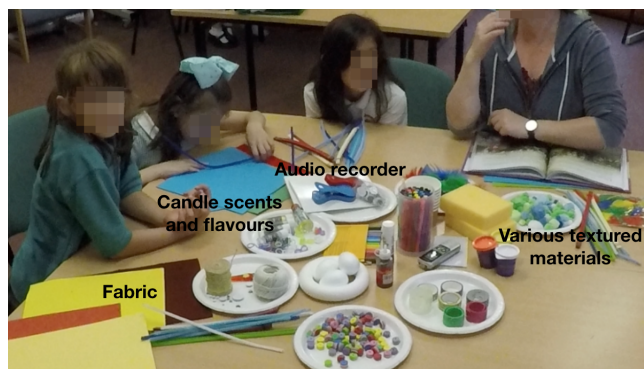


Figure 2. Our Bag of Multisensory Stuff, example materials labelled.

Workshop 1: Joint Storytelling

Children are assigned regular reading materials throughout the school year. TAs then adapt story books by transcribing them in Braille and sometimes adding tactile artefacts: *“I use tactile graphics to help [Samy] memorise the story, to sequence and to add interest”* (TA2). These adaptations rely primarily on the input of the TA and are only used by children with VIs. They are thus representatives of potential material and language disconnects that could lead to the formation of the TA bubble.

Session 1: Multisensory Ideas for Joint Storytelling

We first aimed to explore how soliciting several sensory modalities could make storytelling more inclusive and fun for both children with and without VIs. Following a pre-workshop planning meeting with the educators, we decided to do this by combining two activities already familiar to the children; reading a story and crafting. We worked with 13 participants in this primary school, including Samy, Rosie and Tom, six sighted buddies (age 7-9, 4 female), three TAs and one SENCo.

Methods, Structure and Procedure — The workshop took place in one of the classrooms at the school and mimicked a typical crafting lesson, as we had observed. It was organised in three parts; an introduction (10mins), crafting (50mins), and a show and tell (15mins). In the introduction we presented the storybooks and crafting materials, using a variant of the Bag of Stuff technique, which was adapted to incorporate multisensory stuff (Table 2), were chosen to provide different affordances in different modalities in-line with the children’s interests; e.g. pronounced visual appearance, unusual tactile experience, audio recording, flavours and scents. In the crafting part, participants were divided into three groups, each including three children and one TA. Each group was given a storybook and was instructed to think about how they could be made more fun to read using the multisensory craft materials,



Figure 3. Top: Example multisensory crafts. Bottom: Blindfolded sighted children and a child with a VI exploring each other's crafts.

with the SENCo and researcher facilitating discussion about the designs. At the end of the session the children gathered around to present their crafts. We also asked the sighted children if they wished to wear blindfolds and explore what the other groups had crafted (Figure 3). The aim was to engender awareness, empathy and reflection. All children volunteered to wear blindfolds, and the activity was scaffolded by the SENCo who had used the technique with the participating children before. The decision to use blindfolds was reached in consultation with the SENCo and TAs, who we involved as equal partners in planning the design activities.

Outcomes

Tom and Samy's groups read *Sharing a Shell* and *What the Ladybird Heard* and decided that the stories would be more fun if they could feel them and hear the characters. They created tangible representations of the characters and recorded sounds that occurred during the stories, such as footsteps, or sounds made by the characters; e.g. a cat's "meow", a duck's "quack". They also sprayed their crafts with representative scents, e.g. a Cornish scent for a shell. Rosie's group read *Little Red Riding Hood* and decided to craft one artefact to represent each scene of the book. The TA then suggested arranging them in a sequence on a poster to create a map of the story (Figure 3). They also recorded story lines at different points of the map and used representative scents and flavours to augment the artefacts, e.g. vanilla and cherry scents to represent flowers and cakes in the character's basket.

During the show and tell part, the SENCo and TAs used scaffolding techniques to support the children in articulating their responses to the experience. The blindfolded sighted children found the scents helpful and enjoyable to use: "*it made it more exciting and helped me know what it was*". Other sighted children found the blindfolded experience more difficult: "*it was a bit hard to name the things from the way I felt them, I wasn't quite sure what it was because I couldn't see them*". Others identified the need to use different textures to help them dif-

ferentiate between items. Some of the children were explicit in expressing empathy: "*I liked it because you get to find out how different people live and my friends who can't see very well*". Rosie, who has low light perception, and Tom who has low vision, also tried to explore the artefacts through a blindfold. Overall, all children were able to use the bag of multisensory stuff to build on the stories they read. The crafting and show and tell made the process more engaging, and got the children to reflect about how their peers experienced their crafts. However, the educators indicated that the form and amount of the "multisensory stuff" was not ideal for the children with VIs, who found it difficult to keep track of where different types of material were located.

Session 2: A Tool for Joint Story Maps

We then aimed to explore more concrete ideas about potential future technology that allows children with and without VIs to engage with one another through storytelling. Here we report on our work with Rosie's group, focusing on the idea of an inclusive tool for creating story maps. The group included Rosie, her TA and two sighted buddies (female, age 8 and 9).

Methods, Structure and Procedure – The session took place on a different day and was divided into three parts; an introduction (10mins); an imaginative discussion (20 minutes); and crafting (30 minutes). Taking inspiration from the Future Workshop technique [73], we asked participants to travel forward in time to a school in the year 2117. Taking an imaginary tour through its premises, participants imagined what they would encounter, and thought about what tools or devices they might use in the future to create story maps. In the final part of the session, we engaged participants in a discussion on the design of novel tools for joint storytelling, and a hands-on activity to capture these ideas. We gave children "inventor hats" for this part of the workshop and brought in the Bag of Multisensory Stuff to help with crafting ideas. Throughout all of the activities the TA contributed ideas and helped moderate the discussions.

Outcomes

In the imaginary tour, children described pencil boxes that move autonomously in the classroom and "*write for you*", and materials that rearrange themselves at the end of lessons. They imagined "*lots and lots of robots that just play*", and objects such as chairs with sensors that "*move out of the way before you walk into them*". Other ideas included flying books that "*pop out ideas when they sense that you are stuck on something*", which then developed into story books that allow readers to be inside the story themselves. In the future storytelling workshop, the children imagined characters that "*speak and growl when you touch them or when they feel hungry or when you say something to them*", and respond to hand gestures, and tools that allowed children to add more parts to the stories rather than be confined to the original narrative.

A Programmable Joint Story Mapping Tool – With our inventor hats on, participants and the researcher explored the design of a tool for joint story mapping. The discussion focused on how parts of stories could be recorded and added onto a story map. Drawing on their recent coding experience with Bee-Bots, the children suggested having "character bots" which they could program. The TA then suggested using a

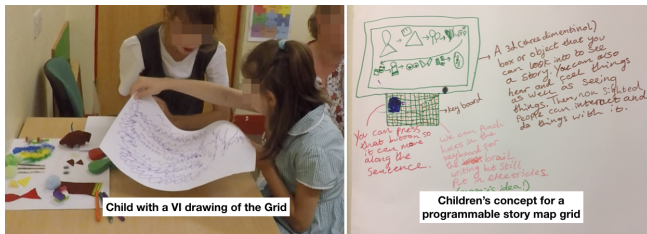


Figure 4. (Left) Child with a VI drawing of a grid. (Right) Children’s conception of a programmable joint story mapping tool.



Figure 5. Bodystorming across school premises.

grid structure that would allow them to code and keep track of characters’ movements. In addition, the children also wanted to program each square on the grid for “what it should say or smell like when the story got to that point”. The final consensus was for a “a three dimentinol [sic] box that you can look into to see a story. You can also hear and feel things as well as seeing things. Then, non sighted people can interact and do things with it [...] you can press a button so it move along the sentence [...] we can punch holes in the [pop out] keyboard for the brail writing but still put in electricles [sic]” (Figure 4).

Workshop 2: Independent Mobility and Exploration

We found that children with VIs tended to stick to familiar routes, and to move less independently during play time compared to their sighted peers; that they were often accompanied by their TAs, albeit from a small distance; and that this sometimes constrains social encounters. We aimed to explore the design of novel technology that could help increase independent mobility and exploration inside school premises. We worked with 10 participants: three sighted children (age 7-9, 2 female), Rosie, Samy and Tom, three TAs and one SENCo.

Methods, Structure and Procedure – The workshop took place across the school’s premises and was divided into two main parts; a requirements gathering activity using a variant of bodystorming [17], and a low-tech prototyping activity using a modified version of our Bag of Multisensory Stuff. For this version, a *Box of Multisensory Stuff* was introduced, in which the materials were organised in a compartmentalised box (Figure 6) to make it easier for the children with VIs to keep track of where the materials were located. Both parts of the workshop were linked by a narrative inspired by fictional inquiry [35], developed in consultation with the educators, involving an alien landing in the school that went wrong.

Outcomes

Bodystorming – Table 3 summarises the outcomes of the bodystorming activity. A quick thematic analysis of the notes



Figure 6. (Top) Modified Box of Multisensory Stuff (contrast to Figure 2). (Bottom) Children’s conceptions of independent mobility technology.

taken during the session showed that participants identified 3 to 4 types of information that should facilitate independent navigation; *Fixed* and *Dynamic* items, *People*, and *Environment*. For instance, inside the classroom, “fixed” items included tables and whiteboards; “dynamic” items were items that changed depending on which lesson is taking place, “people” included children and TAs, and “environment” included knowing where the exit door is located. Audio was the predominant modality for displaying most of this information. Two kinds of mappings were suggested: sounds should correspond to the type and content of an item; e.g. a knock for table and doors; and sounds should get faster and louder as the alien gets closer to the items they represent. The TAs thought that in busy areas, there may be too much information to convey at once, and so information should be conveyed in either a simple or a complex mode, allowing one to focus on the whole soundscape of the playground or zoom in on particular items. The second predominant modality was tactile, mainly in the form of vibration, but also as tactile floor markers with textures corresponding to different locations, e.g. a rough texture next to the playground door. The participants also thought that vibration should get stronger as the alien gets closer to items. Olfactory display was also suggested as a means for marking locations, e.g. a smell should be displayed as the alien passes by a room to reflect its content, e.g. the smell of old books when passing by the reading room.

Multisensory Crafting – Participants designed mobility technology that combines wearables in the form of bracelets and badges, walkie-talkies, and augmenting various parts of the school with sensors and interactive buttons. Samy’s group designed a bracelet that displays audio as the alien encounters items and people of interest. They represented this by placing different numbers of sensors on audio recording cards, and recording the accompanying sounds that should be displayed when each sensor is triggered. They also designed an accompanying bracelet with the corresponding number of sensors on each side (Figure 6 (a)). Tom’s group also designed bracelets, their version included multisensory feedback of vibration, lights and smells, in response to items encountered in the environment; they wrote “on the bracetl when you get near something a smell comes from the bracetl also buttons on the

Table 3. Outcomes of bodystorming workshop

Area	What stuff to be wary of	How to display it	Mapping
Classroom	<i>Fixed:</i> tables, chairs, drawers	<i>Audio:</i> knock, squeak, Pshhhh, creek, slam	Everything sounds faster and louder when Coco (the alien) gets closer to it
	<i>Dynamic:</i> PE kit, floor cushions, things on tables	<i>Audio:</i> Jingle, rain maker sound	
	<i>Environment:</i> Which direction to the door	<i>Audio:</i> Speak direction	
	<i>People:</i> Other children, teacher, TAs	<i>Audio:</i> Say "Hello" or "Bye" in different languages	
Corridor	<i>Dynamic:</i> Sports bags, box of instruments	<i>Audio:</i> Spoken labels	Sounds, smells and touch should correspond to the type and content in each room
	<i>Fixed:</i> access points; Main door, other doors, fire door, what room is it, where does it lead to	<i>Audio:</i> Spoken labels that tell Coco what to do E.g. "open door" <i>Olfactory:</i> Smells outside the door like old books <i>Tactile:</i> Markers on the floor	
	<i>Environment:</i> Height of corridors	<i>Audio:</i> Clicks like Samy's echolocation	Everything sound faster and louder as Coco gets closer to it
	<i>People:</i> Friends, teachers	<i>Audio:</i> Say "Hello" or "Bye" in different languages	
Playground	<i>Fixed:</i> Table tennis, chairs, stools, shelter	<i>Audio:</i> Spoken labels	Simple and advanced signals Different sounds for each friends Stronger vibrations near objects
	<i>Environment:</i> Branches, trees, falling rocks, stones Uneven floor, paint lines	<i>Audio:</i> e.g. sound of trees <i>Tactile:</i> Vibration like a pager	
	<i>People:</i> Friends, other children	<i>Audio:</i> Tap feet, beeps, walkie talkie,	

bracket mite vibrate or light up [sic]". Rosie's group decided to design vibrating wristbands that respond to sensors placed on items of interest around the school. They also designed olfactory buttons and a walkie-talkie device that can be worn as a badge and emits auditory guiding beacons. Throughout the design sessions, Rosie's low light perception and sensitivity to the colour red informed her choices, from the book she and her group worked on during the storytelling workshops, to the means for capturing design ideas of the programmable joint story map, and even the colour of her "inventor hat". We also discovered that Samy had an obsession with recording equipment, and this influenced the choice of materials we provided as part of our box of multisensory stuff. Samy's fascination with recording sounds also served as an entry point for engaging with him during design work, and his enthusiasm was manifest in his group's conceptions of the wearable navigation bracelet, in which he contributed recordings of sounds that should be played in response to encounters with sensors blended into the school environment (see Figure 6). While Rosie and Samy had no concern exploring multiple design concepts at the same time, Tom's learning delay meant that his group focused on characters with limited sets of multisensory materials. The decision to use alien dolls was also important to him, mimicking other lessons where we observed similar dolls used to capture his interest and concentration.

DISCUSSION

Through using a combined ethnographic and PD approach we have contributed new findings to the current landscape of inclusive education, reassessing the challenges facing visually impaired learners and their educators in mainstream schools. Our findings support earlier work on the role of TAs as the main academic and social support for children with SEN, but we extend this view to consider the TAs as 'makers' and 'hackers', which can potentially open up a new design space for inclusive technology. We also examined how co-design with both mixed visual abilities and mixed stakeholder groups can lead to more inclusive and meaningful designs for future educational technologies, which may improve the chances for successful adoption in mainstream settings.

Challenges to Inclusive Schooling Environments

Findings from the field study provided rich insights confirming that inclusion involves multifaceted and complex factors that

go beyond access to curriculum and physical integration in the learning environment [8, 30, 64]. Examples of technology that explicitly support collaborative learning between children with and without VIs were lacking in our data despite educators' emphasis on the importance of peer engagement and the availability of devices that could potentially support such activities, e.g. interactive whiteboards and tablet computers [5, 45]. We postulate that creating accessible artefacts specific to children with VIs may be a contributing factor to this issue because of the implicit emphasis this places on accessibility over inclusion. Indeed, there was a prevalent DIY culture among the educators we interviewed, particularly the TAs, which we believe could be scaffolded by developing maker toolkits for rapid and adaptable tinkering that allow them to exploit the variety of experiences and materials already familiar to the TAs, children and teachers to explore and facilitate shared experiences between pupils with different sensory abilities. Developing multisensory tinkering toolkits can be a means for engaging children in the production of their own learning material, which could not only lead to their empowerment [34, 16] but also address the reoccurring issues we identified with reusing support materials across the heterogeneity of VI needs. By supporting activities that readily fit within current teaching and learning practices, such toolkits could also help avoid the issue of technology uptake [9, 79].

Lack of shared experiences and barriers to social engagement with peers were also prevalent in our data. While a lot of social aptitude may depend on a child's personality, research has shown that children with VIs find it harder to engage with their peers [8, 37], which our findings confirm. We have seen how some schools invested efforts in the engineering of social engagement strategies, such as deploying a buddy system throughout the school and introducing a friend's bench to make it easier for children with VIs to find their friends in the playground. This type of peer-mediated interaction and assistance has been shown to be effective in facilitating inclusion for students with disabilities, through encouraging greater autonomy and self-determination [58, 67, 71]. An opportunity to contribute to these efforts is therefore to introduce technology that improves and promotes the independence of children with VIs to seek and explore their own environment in pursuit of social encounters. For example, to find their friends themselves in the playground and to explore additional physical

spaces outside their regular routes, which can expand their sense of security and safety.

Based on these insights, we suggest that enhancing inclusive schooling environments with technology should aim to target a variety of sensory modalities to promote opportunities for joint attention and shared experiences between pupils with and without VIs; to scaffold the prevalent maker culture among educators; and to improve and promote independent mobility for children with VIs. These challenging areas highlight a clear need to move beyond traditional accessibility concerns, and are consistent with recent developments in this domain (e.g. [14, 26, 34, 79]). However, our analysis extends existing work in one crucial aspect; by emphasising the potential adverse effects that over-reliance on teaching assistance could have on any technology that would be developed to target these potential areas of intervention. The close interaction between TAs and children with VIs is crucial to their learning in inclusive classrooms and is a characteristic feature of their learning experience in mainstream settings [37, 39]. But a number of factors in the environments we explored showed how such structures could morph into “an assistance bubble”, one that has its own material, scope and pace, that could isolate the pupil from the rest of the classroom. This “bubble” has likely developed as the role of the TA has evolved from a primarily ancillary, administrative role, to a more central and instructional one [3, 71], in which the TA often functions as a “metaphorical bandaid” [27] for both the academic and social needs of visually impaired learners.

TA-student partnership has been shown to have many positive benefits for students with SEN and disabilities [61], but such constant and close proximity to a dedicated adult can also have negative impacts on learning and academic progress [38, 76], as well as social relationships and the ability to cultivate and maintain peer networks [12, 61, 71]. Additionally, TAs’ “hovering” behaviour has been shown to have a detrimental effect on the students’ sense of autonomy and self-competence [28, 77], compounding learning and social dependencies which could further marginalise the student. Designers should therefore actively avoid designing technology that consolidate the undesirable effects associated with such support structures. The technologies we encountered, whether in the form of visually dense tools that push teachers and peers to use ambiguous and incomplete language, or DIY artefacts that make the curriculum accessible to children with VIs but not their sighted peers, make it difficult to balance assistance and independence.

Inclusive Co-design with Mixed Visual Abilities

This research builds upon earlier work exploring collaborative learning with children of mixed-visual abilities [48, 63, 72], and extends it by using PD methods and involving mixed stakeholder groups in the design. In this paper, we suggest that involving educators and both children with and without VIs in the design of inclusive technology for schooling environments is an important step in the move beyond accessibility and towards inclusion. A recent survey of methods and techniques that have been used to involve children with SENs in the design of technology highlighted the scarcity of methods for engaging both children with and without VIs [6]. In this

paper, we open up the co-design space to groups of children with mixed visual abilities, which has only previously been explored with adults [10]. Prior research on co-design with children with VIs has used personas [15], 3D prototyping [16, 29] malleable digital prototypes [49] and wearable/mobile devices [42], but has only involved visually impaired, and not sighted children. Accounts of our design process and outcomes therefore extend existing work with descriptions that could serve as additional starting points for eliciting insights and guidance for research and design in this area. We chose to blend methods shown to be effective for early definition and exploration of design requirements [17, 20, 35] and adapted them based on the following considerations: *adaptations from familiar environment and content*; *leveraging participants abilities*; *building empathy*; and *sharing roles in developing relationships*. These considerations emerged from both the field study and follow-up meetings with participants.

Adaptations from Environment and Content –

We adapted methods to the school environment by running workshops inside school premises following typical lesson structures that the children were familiar with. Working inside the school was important for the adequate application of the bodystorming, but this also helped make participants comfortable as we gradually moved with them from a familiar activity (e.g. a reading session) onto a design space engendering new forms of creative and imaginative activities (e.g. to conceptualising new joint storytelling technology through a futures workshop). We also incorporated content from the curriculum into the design activities. For example, the books chosen as the objects of the first workshop were drawn from actual assigned reading materials, and themes of the fictional narratives were based on concepts introduced in prior lessons.

Leveraging Participants Abilities – We leveraged the detailed knowledge we developed about the specific needs of each child with a VI, for example Rosie’s low light perception and Samy’s fascination with audio recording. This builds on prior work that emphasises the need to adapt methods [6, 25, 36] and contributes to refining frameworks developed for the context of designing with and for children who live with a disability, e.g. Guha’s inclusive model of Druin’s Co-operative Inquiry [19, 32]. An example of this is restructuring the Bag of Stuff into a ‘Box’ of *Multisensory Stuff* based on educators feedback, which gave children with VIs more freedom and independence in exploring materials during joint crafting activities. These frames served as a means for guiding the re-interpretations of the design methods we chose to employ.

Building Empathy – We aimed to engender empathy between child participants by using blindfolding, bodystorming and a fictional narrative that included physical characters, which we introduced in the initial parts of each workshop as a means for preparing all participants for conceptual design. For example, giving participants access to multisensory artefacts to critique improved both understanding of the design domain and the issues encountered by their peers. Children made empathic references to those experiences when documenting design decisions, highlighting considerations for peers’ abilities (e.g. Figure 4).

Whilst the children were largely positive about the blindfolding experience and it was successful in fostering empathy here, it is advised that this technique is used sensitively and only with appropriate guidance. Research on disability simulation shows that in some cases it can lead to more negative views of disability through representing it as an inferior, or diminished experience, rather than as part of a broader, lived experience [23, 55, 68]. However, it has also been shown that with appropriate scaffolding and support, simulations can actually improve attitudes about disability when used as a positive learning activity [69]. In our case, the simulation was carried out by the SENCo who gave appropriate guidance to the children throughout. Rather than a main focus on the design process, it was used as a supplementary activity to engender empathy and reflection. It was intended to help participants to jointly evaluate and reflect on the designs generated in the workshop, and served as a tool to help the children assess the extent to which the use of multisensory materials in the storymaps was successful. Although our use of blindness simulation was the result of planning workshops with school educators, we recognise that there is limited research on the effects of disability simulation, and we would advise that researchers consider the use of this technique carefully.

Sharing Roles, Exploring Relationships – Involving specialist educators at these early stages of design proved valuable. In addition to contributing ideas, the TAs and SENCo assisted in planning workshop activities and in moderating group discussion, a role they shared with the researcher. They also played a further crucial role. As mentioned above, it is important not to regard visually impaired users as a homogenous population as differences in cause of blindness, age of onset, and degree of light perception translate into a variety of needs that could have significant impact on design decisions. However, it is important that this information is unpacked sensitively and effectively when engaging with children with VIs. The close relationship the TAs have with the children in this case was a valuable resource for ensuring explorations of visual impairment conditions was present during the design activities, but incorporated in a sensitive and positive manner. Further examination is required to understand and characterise the various roles and relationships that unfolded during co-designing with mixed-ability groups. For instance, both sighted and children with VIs played the role of assistants, guiding their peers on how best to explore materials and navigate space (e.g. Fig 5).

Conceptions of Inclusive Technology for Mainstream

We suspect that the phenomenon of the assistance bubble extends beyond visual impairments to other SENs, but further investigations will be necessary to examine this in more detail and to distinguish any specific characteristics related to the particular SEN in question. In the case of visual impairments we suggested that addressing the factors that contribute to the formation of the TA bubble, which we characterised in terms *space, language* and *material disconnects*, could be a promising avenue for technological intervention. For example, by designing tools that nudge teachers and peers towards regulating pace and avoiding dyadic referencing to bridge language disconnects, and to introduce shared multisensory displays to bridge spatial and material disconnects.

The prototypes developed as part of the first cycle in our project show examples of what technology children with and without VIs and their educators are interested in creating to address some of the challenges they face in mainstream education. Their conceptions have common properties insofar as they all focused on 1) sharing experiences and 2) augmenting the school environment, and 3) working with multisensory feedback, combining visual display with auditory, tactile and olfactory feedback. In the programmable joint story mapping, these properties afford accessibility of coding by embedding grid structures to organise multisensory representations of scenes, while at the same time spark and nurture interaction between children with and without VIs. Mobility technology had wearable components to interact with the environment through embedded sensors that trigger multisensory feedback, affording serendipity and discovery. We thus argue that our methods supported children with and without VIs to jointly lead design processes and to effectively engage with educators and researcher to conceptualise designs that reflect considerations for mixed visual abilities with potentials to bridge the disconnects in their learning experiences. Our findings open up new spaces for general systematic study and application of multisensory experiences in HCI [56] and principles of cross-modal correspondences to improve engagement in learning [22, 50]. We aim to develop the next iteration of these prototypes and an evaluation strategy for assessing the experiences the children and educators will have with their technologies. In addition to joint storytelling and independent mobility, we are also currently pursuing this line of development to design and research ambient multisensory displays inside and outside classrooms and multisensory tinkering DIY toolkits for TAs.

CONCLUSION

We interviewed and observed educators and children living with visual impairments in mainstream schools in order to identify challenges facing inclusion and areas that lend themselves to effective technological intervention. Our field study presents rich descriptions of how existing educational and social support structures could lead to “*teaching assistance bubbles*” with undesirable effects on group learning, social play and independent mobility. As schools move towards more technology in the classroom, technological support for children with special educational needs should move beyond accessibility concerns to consider effective support for inclusive interactions. We suggested areas where technology could more usefully intervene to promote inclusion by characterising the subtle balance between accessibility and independence in terms of bridging *space, language, and material* disconnects. Our adaptations of co-designing methods for children with mixed visual abilities demonstrate the effectiveness of opening up novel design spaces and producing conceptual designs for technology that can accommodate and augment the varied abilities present in inclusive schooling environments.

ACKNOWLEDGEMENT

We would to thank all participating schools and support services, educators, children and parents, and acknowledge the support of EPSRC Fellowship Grant EP/N00616X/2 Cross-modal Interactive Tools for Inclusive Learning project.

REFERENCES

1. Mel Ainscow, Tony Booth, and Alan Dyson. 2006. Inclusion and the standards agenda: negotiating policy pressures in England. *Int. J. Inclusive Education* 10, 4-5 (2006), 295–308.
2. Christine Arter. 2013. *Children with visual impairment in mainstream settings*. Routledge.
3. Stephen Bach, Ian Kessler, and Paul Heron. 2004. Support Roles and Changing Jobs Boundaries in the Public Services : The Case of Teaching Assistants in British Primary Schools. In *Proceedings of the 22nd Annual International Labour Press Conference*. 5–7.
4. Julie A Bardin and Sandra Lewis. 2008. A survey of the academic engagement of students with visual impairments in general education classes. *Journal of Visual Impairment & Blindness* 102, 8 (2008), 472.
5. Helen Beetham and Rhona Sharpe. 2013. *Rethinking pedagogy for a digital age: Designing for 21st century learning*. routledge.
6. Laura Benton and Hilary Johnson. 2015. Widening participation in technology design: A review of the involvement of children with special educational needs and disabilities. *International Journal of Child-Computer Interaction* 3 (2015), 23–40.
7. Tony Booth, Mel Ainscow, Kristine Black-Hawkins, Mark Vaughan, and Linda Shaw. 2002. Index for inclusion. *Bristol: Centre for Studies on Inclusive Education* (2002).
8. Goele Bossaert, Hilde Colpin, Sip Jan Pijl, and Katja Petry. 2013. Truly included? A literature study focusing on the social dimension of inclusion in education. *Int. J. Inclusive Education* 17, 1 (2013), 60–79.
9. Emily C Bouck. 2016. A National Snapshot of Assistive Technology for Students With Disabilities. *J. Special Education Technology* 31, 1 (2016), 4–13.
10. Stacy M Branham and Shaun K Kane. 2015. Collaborative accessibility: How blind and sighted companions co-create accessible home spaces. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, 2373–2382.
11. Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101.
12. Stephen M. Broer, Mary Beth Doyle, and Michael F. Giangreco. 2005. Perspectives of Students With Intellectual Disabilities About Their Experiences With Paraprofessional Support. *Exceptional Children* 71, 4 (2005), 415–430.
13. Deana Brown, Victoria Ayo, and Rebecca E Grinter. 2014. Reflection through design: immigrant women’s self-reflection on managing health and wellness. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1605–1614.
14. Emeline Brulé, Gilles Bailly, Anke Brock, Frédéric Valentin, Grégoire Denis, and Christophe Jouffrais. 2016. MapSense: multi-sensory interactive maps for children living with visual impairments. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 445–457.
15. Emeline Brulé and Christophe Jouffrais. 2016. Representing Children Living with Visual Impairments in the Design Process: A Case Study with Personae. In *Proceedings of the 8th Cambridge Workshop on Universal Access and Assistive Technology*. CWUAAT, 23–32.
16. Erin Buehler, Shaun K. Kane, and Amy Hurst. 2014. ABC and 3D: Opportunities and Obstacles to 3D Printing in Special Education Environments. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility*. ACM, 107–114.
17. Colin Burns, Eric Dishman, William Verplank, and Bud Lassiter. 1994. Actors, Hairdos & Videotape—Informance Design. In *Conference Companion on Human Factors in Computing Systems (CHI '94)*. ACM, New York, NY, USA, 119–120. DOI : <http://dx.doi.org/10.1145/259963.260102>
18. Christian Dindler, Eva Eriksson, Ole Sejer Iversen, Andreas Lykke-Olesen, and Martin Ludvigsen. 2005. Mission from Mars: a method for exploring user requirements for children in a narrative space. In *Proceedings of the 2005 conference on Interaction design and children*. ACM, 40–47.
19. Allison Druin. 1999. Cooperative Inquiry: Developing New Technologies for Children with Children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '99)*. ACM, New York, NY, USA, 592–599.
20. Jerry Alan Fails, Mona Leigh Guha, Allison Druin, and others. 2013. Methods and techniques for involving children in the design of new technology for children. *Foundations and Trends® in Human-Computer Interaction* 6, 2 (2013), 85–166.
21. Peter Farrell, Alison Alborz, Andy Howes, and Diana Pearson. 2010. The impact of teaching assistants on improving pupils’ academic achievement in mainstream schools: A review of the literature. *Educational Review* 62, 4 (2010), 435–448.
22. Daniel J. Finnegan, Eamonn O’Neill, and Michael J. Proulx. 2016. Compensating for Distance Compression in Audiovisual Virtual Environments Using Incongruence. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, 200–212.
23. Ashley Flower, Matthew K. Burns, and Nicole A. Bottsford - Miller. 2007. Meta-analysis of disability simulation research. *Remedial and Special Education* 28, 2 (2007), 72–79.

24. Department for Education. 2016. School Workforce in England: November 2016. (2016).
25. Christopher Frauenberger, Julia Makhaeva, and Katharina Spiel. 2017. Blending Methods: Developing Participatory Design Sessions for Autistic Children. In *Proceedings of the 2017 Conference on Interaction Design and Children*. ACM, 39–49.
26. Euan Freeman, Graham Wilson, Stephen Brewster, Gabriel Baud-Bovy, Charlotte Magnusson, and Hector Caltenco. 2017. Audible Beacons and Wearables in Schools: Helping Young Visually Impaired Children Play and Move Independently. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 4146–4157.
27. Michael F. Giangreco. 2013. Teacher assistant supports in inclusive schools: Research, practices and alternatives. *Australasian Journal of Special Education* 37, 2 (2013), 93–106.
28. Michael F Giangreco, Susan W Edelman, Tracy Evans Luiselli, and Stephanie Z C MacFarland. 1997. Helping or hovering?: Effects of instructional assistance proximity on students with disabilities. *Exceptional Children* 64, 1 (1997), 7–18.
29. Stéphanie Giraud, Philippe Truillet, Véronique Gaildrat, and Christophe Jouffrais. 2017. ?DIY? Prototyping of Teaching Materials for Visually Impaired Children: Usage and Satisfaction of Professionals. In *International Conference on Universal Access in Human-Computer Interaction*. Springer, 515–524.
30. Colette Gray. 2009. A qualitatively different experience: Mainstreaming pupils with a visual impairment in Northern Ireland. *Euro. J. Special Needs Education* 24, 2 (2009), 169–182.
31. J Greaney, M Tobin, and E Hill. 1999. Braille Version of the Neale Analysis of Reading Abilities. *RNIB* (1999).
32. Mona Leigh Guha, Allison Druin, and Jerry Alan Fails. 2008. Designing with and for Children with Special Needs: An Inclusionary Model. In *Proceedings of the 7th International Conference on Interaction Design and Children (IDC '08)*. ACM, New York, NY, USA, 61–64.
33. David S Hayden, Liqing Zhou, Michael J Astrauskas, and John A Black Jr. 2010. Note-taker 2.0: the next step toward enabling students who are legally blind to take notes in class. In *Proc. 12th int. ACM SIGACCESS conf.* ACM, 131–138.
34. Amy Hurst and Jasmine Tobias. 2011. Empowering individuals with do-it-yourself assistive technology. In *Proc. 13th int. ACM SIGACCESS conf.* ACM, 11–18.
35. Ole Sejer Iversen and Christian Dindler. 2008. Pursuing Aesthetic Inquiry in Participatory Design. In *Participatory Design Conference*. The Trustees of Indiana University, 138–145.
36. Eija Kärnä, Jussi Nuutinen, Kaisa Pihlainen-Bednarik, and Virpi Vellonen. 2010. Designing technologies with children with special needs: Children in the Centre (CiC) framework. In *Proceedings of the 9th International Conference on Interaction Design and Children*. ACM, 218–221.
37. Coral Kemp and Mark Carter. 2002. The social skills and social status of mainstreamed students with intellectual disabilities. *Educational Psychology* 22, 4 (2002), 391–411.
38. B. Lamb. 2009. Lamb Inquiry: Special Needs and Parental Confidence. *DCSF Publications* (2009).
39. Suk-Hyang Lee, Michael L Wehmeyer, Jane H Soukup, and Susan B Palmer. 2010. Impact of curriculum modifications on access to the general education curriculum for students with disabilities. *Exceptional Children* 76, 2 (2010), 213–233.
40. Yeunjoo Lee and Luis A Vega. 2005. Perceived knowledge, attitudes, and challenges of AT use in special education. *J. Special Education Technology* 20, 2 (2005), 60.
41. Stephen Lindsay, Daniel Jackson, Guy Schofield, and Patrick Olivier. 2012. Engaging older people using participatory design. In *Proceedings of the SIGCHI conference on human factors in computing systems*. ACM, 1199–1208.
42. Charlotte Magnusson, Héctor Caltenco, Sara Finocchietti, Giulia Cappagli, Graham Wilson, and Monica Gori. 2015. What do you like? early design explorations of sound and haptic preferences. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*. ACM, 766–773.
43. Charlotte Magnusson, Per-Olof Hedvall, and Héctor Caltenco. 2018. Co-designing together with Persons with Visual Impairments. In *Mobility of Visually Impaired People*. Springer, 411–434.
44. Laura Malinverni, Joan Mora-Guiard, Vanesa Padillo, MariaAngeles Mairena, Amaia Hervás, and Narcis Pares. 2014. Participatory design strategies to enhance the creative contribution of children with special needs. In *Proceedings of the 2014 conference on Interaction design and children*. ACM, 85–94.
45. Anne-Marie Mann, Uta Hinrichs, Janet C Read, and Aaron Quigley. 2016. Facilitator, Functionary, Friend or Foe?: Studying the Role of iPads within Learning Activities Across a School Year. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 1833–1845.
46. Samantha McDonald, Joshua Dutterer, Ali Abdolrahmani, Shaun K Kane, and Amy Hurst. 2014. Tactile aids for visually impaired graphical design education. In *Proc. 16th int. ACM SIGACCESS conf.* ACM, 275–276.

47. Joanne McElligott and Lieselotte Van Leeuwen. 2004. Designing sound tools and toys for blind and visually impaired children. In *Proceedings of the 2004 conference on Interaction design and children: building a community*. ACM, 65–72.
48. Oussama Metatla. 2017. Uncovering Challenges and Opportunities of Including Children with Visual Impairments in Mainstream Schools. *Proc BSC-HCI'17* (2017).
49. Oussama Metatla, Nick Bryan-Kinns, Tony Stockman, and Fiore Martin. 2015. Designing with and for people living with visual impairments: audio-tactile mock-ups, audio diaries and participatory prototyping. *CoDesign* 11, 1 (2015), 35–48.
50. Oussama Metatla, Nuno N. Correia, Fiore Martin, Nick Bryan-Kinns, and Tony Stockman. 2016a. Tap the ShapeTones: Exploring the Effects of Crossmodal Congruence in an Audio-Visual Interface. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 1055–1066.
51. Oussama Metatla, Fiore Martin, Adam Parkinson, Nick Bryan-Kinns, Tony Stockman, and Atau Tanaka. 2016b. Audio-haptic interfaces for digital audio workstations. *Journal on Multimodal User Interfaces* 10, 3 (01 Sep 2016), 247–258.
52. Neema Moraveji, Jason Li, Jiarong Ding, Patrick O’Kelley, and Suze Woolf. 2007. Comicboarding: using comics as proxies for participatory design with children. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, 1371–1374.
53. Marian Morris and Paula Smith. 2008. Educational provision for blind and partially sighted children and young people in England: 2007. *National Foundation for Educational Research (NFER) for RNIB* (2008).
54. Emma Murphy, Enda Bates, and Dónal Fitzpatrick. 2010. Designing auditory cues to enhance spoken mathematics for visually impaired users. In *Proc. 12th int. ACM SIGACCESS conf.* ACM, 75–82.
55. Michelle R. Nario-Redmond, Dobromir Gospodinov, and Angela Cobb. 2017. Crip for a day: The unintended negative consequences of disability simulations. *Rehabilitation Psychology* 62, 3 (2017), 324–333.
56. M. Obrist, E. Gatti, E. Maggioni, C. T. Vi, and C. Velasco. 2017. Multisensory Experiences in HCI. *IEEE MultiMedia* 24, 2 (2017), 9–13.
57. ONS. 2015. National Population Projections for 2015, 2012-based projections release. *Office for National Statistics* (2015).
58. Wendy R. Locke and Lynn S. Fuchs. 1995. Effects of Peer-Mediated Reading Instruction on the On-Task Behavior and Social Interaction of Children with Behavior Disorders. *Journal of Emotional and Behavioral Disorders* 3 (04 1995), 92–99.
59. RNIB. 2013. Key statistics on the prevalence and population of children and young people with vision impairment. (2013).
60. Joao Roe. 2008. Social inclusion: meeting the socio-emotional needs of children with vision needs. *British J. Visual Impairment* 26, 2 (2008), 147–158.
61. Helen Saddler. 2014. Researching the influence of teaching assistants on the learning of pupils identified with special educational needs in mainstream primary schools: Exploring social inclusion. *Journal of Research in Special Educational Needs* 14, 3 (2014), 145–152.
62. Nuzhah Gooda Sahib, Tony Stockman, Anastasios Tombros, and Oussama Metatla. 2013. Participatory design with blind users: a scenario-based approach. In *IFIP Conference on Human-Computer Interaction*. Springer, 685–701.
63. Eva-Lotta Sallnas, Jonas Moll, and Kerstin Severinson-Eklundh. 2007. Group work about geometrical concepts among blind and sighted pupils using haptic interfaces. In *EuroHaptics Conference, 2007 and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems. World Haptics 2007. Second Joint*. IEEE, 330–335.
64. TE Scruggs, MA Mastropieri, and P Leins. 2011. Teacher attitudes towards inclusion: A synthesis of survey, comparative, and qualitative research, 1958–2010. In *Ann. meeting of the Council for Exceptional Children, Washington, DC*.
65. Irving Seidman. 2013. *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. Teachers college press.
66. U Sharma and SJ Salend. 2016. Teaching Assistants in Inclusive Classrooms: A Systematic Analysis of the International Research. *Australian Journal of Teacher Education* 41, 8 (2016), 118–134.
67. Smita Shukla, Craig H Kennedy, and Lisa Sharon. 1999. Intermediate School Students with Severe Disabilities: Supporting Their Social Participation in General Education Classrooms. *Journal of Positive Behavior Interventions* 1, 3 (1999), 130–140.
68. Arielle M. Silverman, Jason D. Gwinn, and Leaf Van Boven. 2015. Stumbling in Their Shoes: Disability Simulations Reduce Judged Capabilities of Disabled People. *Social Psychological and Personality Science* 6, 4 (2015), 464–471.
69. Arielle M. Silverman, Jennifer S. Pitonyak, Ian K. Nelson, Patricia N. Matsuda, Deborah Kartin, and Ivan R. Molton. 2017. Instilling positive beliefs about disabilities: pilot testing a novel experiential learning activity for rehabilitation students. *Disability and Rehabilitation* 0 (2017), 1–6.
70. Miriam D Skjærten. 2001. Towards inclusion and enrichment. *Education Special Needs Education: An Introduction*. Oslo: Unipub Forlag (2001).

71. L Tews and J Lupart. 2008. Students With Disabilities' Perspectives of the Role and Impact of Paraprofessionals in Inclusive Education Settings. *Journal of Policy and Practice in Intellectual Disabilities* 5, 1 (2008), 39–46.
72. Anja Thieme, Cecily Morrison, Nicolas Villar, Martin Grayson, and Siân Lindley. 2017. Enabling Collaboration in Learning Computer Programming Inclusive of Children with Vision Impairments. In *Proceedings of the 2017 Conference on Designing Interactive Systems*. ACM, 739–752.
73. Giasemi N Vavoula and Mike Sharples. 2007. Future technology workshop: A collaborative method for the design of new learning technologies and activities. *International Journal of Computer-Supported Collaborative Learning* 2, 4 (2007), 393–419.
74. Giacomo Vivanti, Ed Duncan, Geraldine Dawson, and Sally J Rogers. 2017. Facilitating Learning Through Peer Interactions and Social Participation. In *Implementing the Group-Based Early Start Denver Model for Preschoolers with Autism*. Springer, 87–99.
75. Greg Walsh, Alison Druin, Mona Leigh Guha, Elizabeth Foss, Evan Golub, Leshell Hatley, Elizabeth Bonsignore, and Sonia Franckel. 2010. Layered elaboration: a new technique for co-design with children. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1237–1240.
76. Rob Webster, Peter Blatchford, Paul Bassett, Penelope Brown, Clare Martin, and Anthony Russell. 2010. Double standards and first principles: Framing teaching assistant support for pupils with special educational needs. *European Journal of Special Needs Education* 25, 4 (2010), 319–336.
77. Ben Whitburn. 2013. The dissection of paraprofessional support in inclusive education: 'You're in mainstream with a chaperone'. *Australasian Journal of Special Education* 37, 2 (2013), 147–161.
78. Ru Zarin and Daniel Fallman. 2011. Through the troll forest: exploring tabletop interaction design for children with special cognitive needs. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 3319–3322.
79. Li Zhou, Amy T Parker, Derrick W Smith, and Nora Griffin-Shirley. 2011. Assistive technology for students with visual impairments: Challenges and needs in teachers' preparation programs and practice. *J. Visual Impairment & Blindness* 105, 4 (2011), 197.