Informing Design for Tangible Interaction: a Case for Children with Learning Difficulties

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ABSTRACT
The advent of new technologies is expanding the possibilities for a richer, multi-sensory interaction to support children with learning difficulties in schools. However, little research has yet investigated how such innovative interaction can enhance the learning experience of these children. Effectively informing research and design of innovative educational, technological resources for children with learning difficulties requires relevant field study. Findings from a qualitative classroom study indicate the potential of tangible technologies to enhance these children’s experiences by providing a variety of modes of representation, and opportunities for collaboration, physical engagement and hands-on exploration. They also provide an effective foundation for investigating how tangible interaction can help to structure exploratory learning: a recommended but problematic approach for these children.

Categories and Subject Descriptors
K.3.1 [Computers and Education]: Computer Uses in Education.

General Terms
Human Factors, Design

Keywords
Learning Difficulties, ICT, Tangible Technologies.

INTRODUCTION
Children with learning difficulties perform significantly below average, due to a permanent condition acquired from birth or early childhood. In the UK, they represent the largest group of children with special educational needs (SEN) [14]. Many have no known organic cause for their difficulties and no accurate description of cognitive functioning [11]. Recommended teaching strategies for these pupils include [4, 13, 14]: a visual, auditory and kinaesthetic approach, with the aid of resource materials, practical, concrete examples to illustrate explanations, and organising cooperative learning groups. Traditional ICT resources are claimed to facilitate these children’s access to the curriculum and support some of these strategies. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

However, most resources developed so far are desktop applications that do not promote physical engagement, and are based on behavioural learning theories [3], with drill and practice activities. The advent of new technologies, like virtual reality environments and tangibles, is broadening the possibilities for supporting learning strategies for children with SEN and increasing the focus on exploration rather than drill and practice, as advocated by constructivist theories [10]. Such change is reinforcing the need for understanding better in which ways innovative interaction can improve learning of children with SEN. This paper reports findings from an empirical study that collected data from teachers and school environments about the needs of children with learning difficulties in the classroom, and associated pedagogical practices, to inform the research and design of innovative technological educational resources.

LEARNING DIFFICULTIES
Even with differentiated methods, children with learning difficulties hardly achieve at expected curriculum levels. Reasoning for problem solving is less effective and cognitive development is slower [11]. They can suffer from low academic self-concept [1] and exhibit unacceptable behaviour as a way of avoiding failure [4]. Defining the group of general learning difficulties is problematic and some authors prefer not to distinguish between subgroups whose cut-offs are unclear [7]. Although not all children with general learning difficulties share the same profile, there are common characteristics [1, 4, 13]: tendency to be distractible and off-task; difficulty in understanding instructions and remembering what has been taught; reliance on external cues and opinions of others, and reluctance to use own judgement. Similarly, there are strategies recommended for facilitating learning for these children: multi-sensory approaches; cooperative learning groups; and giving concrete examples [4, 13, 14]. In particular, there is an increasing agreement on the value of ICT resources for supporting learning of SEN children.

ICT AND SPECIAL EDUCATIONAL NEEDS
Since the 1980’s, PC’s have been used to support the education of children with learning difficulties in the UK, as a means of enabling SEN children to access the curriculum [15], and of creating a sense of achievement and self-esteem. Many tutor or computer-assisted instruction software programs, based on cause-effect activities and drill and practice, have been developed so far. They
represent a longstanding type of educational technology, mostly based on behavioural learning theories [3]. Generally speaking, computers have mostly been used for research, writing, editing, and presentation of work [9], but there is still little stimulation of sensory engagement and collaborative learning, creativity and flexible thinking [6]. Recently, the progress of technology has allowed the development of exploratory learning environments, in which pupils have more control over their learning as they interact with the interface [3]. In such environments, increasingly popular in education, exploration replaces drill and practice, as advocated by constructivist theories of learning. There has been a renewed interest in hands-on approaches for special education, allowing children to learn via active exploration with concrete materials that facilitate knowledge construction and problem-solving [1].

By embedding digital data in physical objects, tangible technologies are aligned with constructivist and embodied cognition theories, building on the alleged benefits of educational manipulatives, and hands-on experimentation. With tangible technologies, educational designers can go beyond screen-based applications for PCs, and create systems more diffused in the physical environment [2]. Although several tangible learning systems have been developed to date, there is still not sufficient empirical research on tangibles for learning [6], and very little work on the use of tangibles for general learning difficulties. Nascent research has primarily focused on specific learning difficulties such as autism [6] and attention disorders [8].

**EMPIRICAL WORK**

A qualitative field study was carried out to inform design of innovative educational, technological resources and associated activities for children with learning difficulties. The study aimed to understand better the characteristics of children with learning difficulties and the specific problems they face in school. An open-ended methodological approach was taken to elicit a broad picture of ‘everyday learning’ in schools for children with learning difficulties, and within this picture identify relevant themes to inform design of technologies for such population. The rationale for such open-ended exploration lies in the fact that undertaking empirical work specifically focused on the use of technological resources would have narrowed the findings down to existing artefacts and current pedagogical strategies, possibly leaving out themes unknown to the researcher, but relevant for the aim of the study. The empirical work consisted therefore of semi-structured interviews and unstructured observations, with themes emerging from data collection and analysis.

**Data Collection and Analysis**

Ten semi-structured interviews with teachers who have experience with SEN were undertaken and audio-recorded. Interviews were informal and lasted 30 minutes on average. The researcher had a list of guiding questions, but remained flexible to elicit the teachers’ own account and opinions. Teachers were asked what the main needs and difficulties of children with special educational needs are; what strategies they use for helping/dealing with these children; whether children work in groups and collaborate with one another; and whether and how they use concrete materials and technological resources. The last question aimed to elicit the benefits of different learning resources, in order to inform the design of innovative artefacts that could bring these benefits together. More specifically, tangible interfaces have the potential of providing the advantages of both concrete manipulatives and interactivity of technology.

Seven hours of unstructured, direct classroom observations were performed. Observations were mostly non-participant, although in some cases the researcher was invited by the teacher to take part in the activities or give opinions. Data was collected through note-taking, and observations mainly focused on: children’s behaviour, kinds of questions they asked, level of participation in classroom activities; group work; social interaction; ways teacher addressed the children; and materials used during the lesson. Classroom observations complemented interviews by providing additional information and insights rising from the researcher’s direct contact with the children.

Five main categories emerged from the qualitative analysis of interviews and observations, namely: children’s needs and difficulties; children’s positive characteristics, ways of addressing children’s difficulties; teacher’s difficulties when dealing with the children; and requirements for educational resources.

Consistent with the literature [4, 13, 14], the main learning difficulties elicited during field work were: lack of attention and concentration on tasks, difficulties in understanding and recalling instructions and remembering what has been taught and said; over-reliance on opinions and behaviours of others; difficulty in recognising and retaining relevant information; difficulty in understanding and retaining abstract concepts; low self-esteem, negative outlook on learning and fear of making mistakes. However, the study also elicited positive characteristics of the children, not usually mentioned in the literature, namely: being familiar with cooperating and working in groups; pride in being assigned roles and responsibilities and in sharing their good work; feeling smart with their achievements; and refusal to be treated as if they were young children. Collectively, these characteristics and children’s difficulties, linked to the elicited teachers’ strategies to overcome learning barriers, can be used to inform design of educational resources and activities for children with learning difficulties, and to guide effective research strategies.

**DESIGN GUIDELINES**

Findings from interviews and observations suggest the potential of tangible technologies for supporting children with difficulties, to help them understand, communicate, express themselves, interact with others and work more independently. Despite the teachers’ belief that technology is a way of stimulating pupils through different senses in a
dynamic way, they also point to a lack of adequate educational resources for children with special needs, which need to be safe and robust, and provide other forms of interaction beyond text-based. Common current uses of ICT in schools, such as information search on the web and preparation of slides’ presentations, were considered difficult and in many cases inaccessible for children with learning difficulties. The few possibilities offered by traditional ICT resources were also mentioned; teachers highlighted the need for providing more challenges than simply drag-and-drop and copy-and-paste activities. One of the teachers declared: “The difficult part is to find something that they can access, because most websites have a lot of writing. They find it difficult. So it is more or less getting them to download pictures or copy and paste pictures, so it’s quite basic.” From the data analysis, design guidelines were formulated for the development of educational resources and learning activities for children with learning difficulties, and are presented next.

Design of Educational Resources

Kinaesthetic approach: using the body is important and especially motivating for children with learning difficulties. Resources should provide opportunities for physical engagement, i.e. doing, touching, manipulating, moving.

Modes of Representations: children with learning difficulties need concrete instances to help them understand abstract concepts. Resources should provide a variety of ways for presenting and producing knowledge, preferably focusing on oral interaction, with dynamic visualisations and a limited amount of text.

Collaboration: resources should also allow and encourage group work, so that peers can give support to one another, and there is opportunity to observe others and as well as for individual expression.

Scaffolding: children with learning difficulties can have fairly different profiles. Differentiation between levels of ability and types of needs is a challenge for teachers, and the resources should allow for different activities to account for a number of levels and needs and ensure everyone has opportunity to participate.

Design of Learning Activities

Clear and shared objectives: pupils should be aware of what is going to happen and reasons for doing activities should be clear. When possible, pupils should be involved in decisions, and be given roles and responsibilities.

Self-esteem and confidence: concessions must be made according to pupils’ difficulties and their limitations should be appreciated. Pupils should be stimulated and encouraged to do things themselves. Attention should be drawn away from their difficulties, mistakes should be given little importance, and good work should be praised.

Sense of achievement: challenges should be attainable to allow short-term success and feeling of progress.

Structured activities: need for clear and structured tasks, to avoid distraction and help focusing and progressing.

DISCUSSION

As relatively recent educational resources, ICT resources have brought the benefits of dynamic visualisations and interactivity to the classroom, along with self-paced learning activities. However, traditional desktop computers do not support physical engagement and concrete experiences - representations are mostly visual, and there is a great emphasis on text. In addition, personal computers are designed for individual interaction. Therefore, PCs cannot comply with several of the guidelines elicited in this research. Seeking to integrate the multi-sensorial human experience with the digital world, tangible interfaces provide a basis for embodied interactions, usually within a collaborative environment, complying with the guidelines elicited in this research.

Designing for Tangible Interaction

Engaging in tangible interaction usually means moving objects around, and spatial qualities regarding the positioning of objects and their relation to our body are fundamental [5]. This creates a multi-sensory experience, which not only offers a kinaesthetic interaction, allowing bodily engagement and manipulation of physical artefacts, but also provides a variety of modes of representation. Generally speaking, in tangible interaction, graphical representations and auditory and haptic feedback prevail over text, making them more accessible for children with learning difficulties. In addition, the possibility of sharing physical artefacts within an open and flexible environment invites collective interaction, promoting the kind of collaboration stated as beneficial in the guidelines. This is not easily achieved with PCs, which are designed for individual use. Tangibles also promote a rather exploratory interaction, which should be flexible enough to accommodate different levels of achievement, allowing all to participate according to their own ability. To sum up, tangibles comply with the four elicited guidelines for educational resources.

The guidelines for learning activities are mostly dependent on how the interaction is externally conducted and facilitated. It is nevertheless worth noting that tangible interaction enables hands-on activities [5] that can stimulate children to do things themselves, building their confidence and decreasing the over-reliance on others [1, 12]. On the other hand, however, tangibles usually encourage open-ended exploration rather than structured tasks, the latter being preferred by teachers for dealing with children with learning difficulties. Indeed, the literature states that these children usually need specific, well-defined tasks, and that open-ended questioning often results in whether cue-seeking or imitative answers, or no response [12]. Thus, constructing knowledge from hands-on activities is still not an easy process for students with learning difficulties and requires a lot of teacher’s effort and attention [12]. However, this research challenges this view by hypothesising that the type of (blended physical-digital) interaction offered by tangibles could bring new light to this debate. Tangible environments enhance the
learner interaction by augmenting physical artefacts with interactive, dynamic digital representations, thus enriching the learning activities and opening up new pedagogic possibilities. The feedback given to the learner by the system provides an underlying structure to the activities and some guidance throughout the interaction, helping to keep a focus but still allowing space for exploration. This suggests tangibles could help guiding pupils with learning difficulties through inquiry-based learning, providing a more scaffolded exploratory environment than with non-augmented materials.

Future Work
Findings presented in this paper provide an important foundation for future research on design of new technologies, particularly tangibles, for children with learning difficulties. A particular strand of future work will test the hypothesis presented above, investigating the specific ways in which tangible technologies can scaffold collaborative exploratory learning for children with learning difficulties. More specifically, the research will examine children’s level of engagement with the learning content through exploratory tangible interaction, and their ability to draw abstract conceptual conclusions from the concrete instances of the interface.

CONCLUSION
Although PC applications have their value and place, technology can provide richer sensory experiences through the interweaving of computation and physical materials. Findings reported in this paper show the need for more educational resources for children with learning difficulties to be developed, providing a variety of modes of representation, and opportunities for physical engagement and collaboration. This paper has discussed how tangibles can support recommended strategies and guidelines elicited in this work for teaching SEN pupils, but there is still little empirical research in the field. Findings presented here give an important contribution for establishing the relevance of further research on tangibles for children with SEN.

REFERENCES