Tangibles for Students with Intellectual Disabilities

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ABSTRACT
Students with intellectual disabilities tend to be reliant on other people's opinions and attitudes, and fear taking initiatives. Thus, they are reluctant to independently undertake activities of exploratory learning – a pedagogical approach recommended by constructivist theories. This research aims to investigate how different aspects of tangibles can better support more independent exploration for students with intellectual disabilities. In this paper we discuss three relevant themes that have emerged from ongoing analysis of empirical studies where children with intellectual disabilities experimented with four different tangible systems: the importance of both space and time dimensions of embodiment; the complexity of conveying concepts through audio representations; and the role of actions both as cognitive resources for thinking and expression.

Categories and Subject Descriptors
H5.2. Information interfaces and presentation: User interfaces. K.3.m Computers and education: Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Tangibles, intellectual disabilities, independent exploration.

1. INTRODUCTION
Special Educational Needs (SEN) is a term that embraces diverse difficulties that affect learning, which can be cognitive, behavioural, social, emotional, and physical. These categories are not clear-cut. For example, cognitive difficulties usually interfere in children's behaviour and social interaction. The present research has shown that in mainstream schools students with difficulties to learn are easily identified by the teachers and grouped under general labels like 'intellectual disabilities' or 'learning difficulties'. When included in regular classes, these students are usually grouped to receive extra support in dedicated classes. Although there is a strong worldwide tendency towards such context of inclusion, many children with intellectual disabilities still go to special schools. Again, in this context, classes are formed by heterogeneous groups with various kinds of disabilities. Many pupils have no known organic cause for their learning difficulties and there is no accurate description of their cognitive functioning [8]. However, despite peculiarities of each student, there are common general characteristics of such groups of pupils with intellectual disabilities, like: difficulties with attention and concentration, poor verbal memory, cue-seeking and imitative answers, poor logical reasoning and poor abstract thinking [3, 9]. These difficulties are also generally accompanied by immature social and emotional skills and a lack of confidence, typically leading to behavioural difficulties. This research is interested in working within the reality of heterogeneous school groups of students with intellectual disabilities, rather than focusing on a specific syndrome.

There are general teaching strategies recommended in the literature to deal with pupils with intellectual disabilities, like: using a VAK approach (visual, auditory, kinaesthetic) with the aid of resource materials to stimulate all the senses, and using practical, concrete, visual examples to illustrate ideas and conceptual explanations [3, 9]. Hands-on approaches fit very well with such strategies, providing concrete experiences and physical interaction. However, hands-on activities usually form the basis of exploratory forms of learning, where children are encouraged to undertake their own investigations to construct knowledge, with roots in the constructivist theory of learning [6]. Such lack of structure and instructions is problematic for children with intellectual disabilities, who may be easily distracted, not know what to look for, be reliant on instructions and guidance, and fear taking their own initiative. Thus, it demands a lot of teacher effort and attention, which is especially difficult in mainstream inclusive contexts, where the teacher has to deal with large groups of students with varied levels of ability.

For more than thirty years now, personal computers have been used to support the education of children with intellectual disabilities. At present, new technologies like tangibles are broadening the possibilities for supporting and expanding pedagogic strategies. Tangibles aim to build on the alleged benefits of educational manipulatives [5], embodied cognition and constructivist learning through the use of hands-on experimentation with embedded computer technologies [5]. By taking advantage of multiple senses and the multimodality of human interactions with the physical world, tangibles provide a rich multisensory experience allied to the dynamics and interactivity of digital technology [4], which is supposedly very appropriate for children with intellectual disabilities. Such theoretical evidence indicates, therefore, that tangibles could well support hands-on activities of exploration by providing some level of structure and guidance through interactivity and digital feedback.

Empirical research with tangibles and intellectual disabilities is still in its early stages, and there is a great need for understanding the specific ways in which tangible technologies can improve the quality of the learning experience for these children, and which aspects must be taken into consideration when designing tangibles for this population. This work is investigating which aspects of, and to what extent, the concrete, dynamic and interactive representations, provided by tangible technologies, can encourage students with intellectual disabilities to productively engage in independent exploratory hands-on learning. Recent empirical studies have been undertaken where students with intellectual disabilities explored four different tangible systems. A number of categories of interest related to independent exploration have emerged from ongoing analysis. In this paper, key topics related to such categories are proposed for reflection and discussion.

2. RESEARCH OUTLINE

Interviews with teachers and a series of classroom observations provided an understanding of the characteristics and needs of students with intellectual disabilities. This quick ethnography in schools indicated that there is a need for more educational resources suitable and accessible for children with difficulties, to help them understand, communicate, express themselves, interact with others and work more independently. A kinaesthetic approach is recommended by teachers, with resources and activities creating opportunities for physical engagement. Resources should create alternatives for presenting information and producing knowledge, preferably focusing on oral interaction, with dynamic visualisations and a limited amount of writing. Common current uses of ICT in schools, such as information search on the web and use or preparation of PowerPoint slide presentations, were considered difficult and in many cases inaccessible for children with learning difficulties.

Such findings reinforce the theoretical potential of tangible technologies for supporting children with difficulties. But, more importantly here, the ethnographic research also pointed to the over-reliance, lack of independence and lack of initiative that are characteristic of these children. Children with difficulties are usually given a clear task, with close and detailed guidance (a lot of teacher's talk, giving suggestions and instructions), to avoid them getting distracted and lost in the activity.

These findings informed the design and implementation of empirical studies, which comprised intervention sessions with students using four different tangible systems to investigate the degree to which the features of the environments support independent exploration for students with intellectual disabilities. Forty-six 9-15 years old (31 boys and 15 girls) with intellectual disabilities explored the following tangible systems (Figure 1):

- D-touch drum machine (d-touch.org): the user manipulates physical objects (tagged with markers) on a sheet of paper (the interactive area) where each row corresponds to a type of instrument. The aim is to produce a percussion composition, sounds being dependent positions of objects on the surface. A computational loop runs continuously reading each row of the interactive area (captured by a camera), and a sound is played for every object identified on that row.
- Sifteo cubes (sifteo.com): physical blocks (with screens) that communicate with each other and run a number of different applications when wirelessly connected to a computer. The user interacts with the games on the cubes by performing several actions like pressing, placing the cubes together, shaking, tilting, etc., depending on the application.
- A tangible interactive tabletop (www.lkl.ac.uk/research/ tangibles): designed to illustrate basic concepts of the physics of light, by providing an environment where children manipulate a torch and physical coloured blocks, all tagged with markers, on an interactive surface that shows digital effects to illustrate the interaction of light beams with the objects.
- An object augmented with LEDs and accelerometer (www.lkl.ac.uk/research/ tangibles): the accelerometer embedded in the object generates changes in LED colour according to orientation as well as movement, providing an interesting exploration of 'positioning' for the students.

Figure 1: Clockwise, from the top left: the drum machine, the Sifteo cubes, the object with accelerometer and the tabletop

The studies aimed to investigate student interaction with each of these systems in terms of their ability to explore ideas independently, and particularly how certain features of tangible systems might support such interaction.

Sessions were mostly open ended, to give students the opportunity to undertake independent exploration and enable analysis of how they explored the systems. Students were asked to experiment with the systems, and while exploration was taking place no interference from the facilitator was made. When students were reluctant to interact with the systems, or quickly disengaged, the facilitator suggested actions they could make, and asked the students to articulate what they thought was happening with the systems. When students asked questions the facilitator was free to interact with them, but in a way that encouraged students to discover things by themselves and verbalise their ideas.

3. TOPICS FOR DISCUSSION

Qualitative data analysis is useful for examining indications of independent exploration during student interaction with the systems, and identifying which features of the tangibles are playing which role. A number of important topics open for discussion around this are presented in this section.

3.1 Defining Independent Exploration

In this work, independent exploration is determined through instances identified in the students' interaction with the technology in terms of:

- Taking initiative (versus waiting for / following instructions)
- Expressing opinions
- Proposing and testing hypotheses / theories

Once the central concept of 'independent exploration' has been defined, other categories emerged from the preliminary data analysis as important aspects that relate to, support or facilitate students' engagement in independent exploration. Four key categories are presented in Figure 2: action-effect mapping, types of representations, actions, and meanings and metaphors.

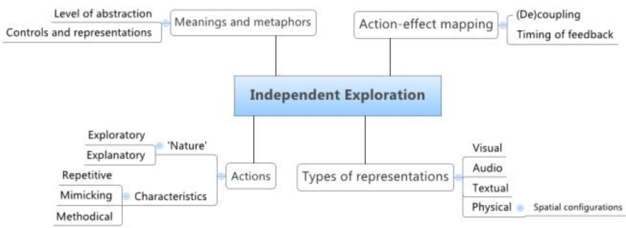

Figure 2: Key categories related to independent exploration

Within these categories, some interesting topics emerged that are presented next for discussion.

3.2 Time and Space Dimensions of Embodiment

Preliminary analysis has shown that the mapping between the student's action and the consequent digital effect produced by the system played a key role in supporting students' understanding of the system and allowing them to feel in control of it, and thus able to take 'conscious' actions of independent exploration. We discuss the action-effect mapping in the light of Fishkin's theory of embodiment in tangible interfaces [2]. According to Fishkin [2], tangible systems have different '*levels of embodiment'*, in a scale that goes from '*full*' (when the output and input devices are coincident), to '*distant*' (when the output is 'somewhere else'). The higher the level of embodiment, the 'more tangible' the system is, and the smaller the 'cognitive distance'. The effects of such physical (de)coupling were perceived in the studies. In the case of the Sifteo cubes, the sounds of the games playing on the cubes that the students manipulate are emitted by the speakers on the computer, which is located separately from the cubes themselves. This is what Fishkin calls '*environmental embodiment*'. This decoupling brought confusion for students' comprehension and attention, as they were doing something 'here' but the response was coming from 'there'. The students kept looking away from the cubes as the sounds played, losing their concentration on the system they were manipulating.

The interactive tabletop is an example of '*nearby embodiment*' (the digital effects are co-located with the physical objects, i.e. on the surface where the objects are placed), while the object with built-in accelerometer has '*full embodiment*'. We do not intend to discuss here if such scale makes a system more or less tangible, but clearly the two latter systems, with a closer physical coupling, presented more positive results in terms of students' focus of attention – and therefore facilitated their activity of exploration – than the systems with a more distant input-output coupling.

In addition to Fishkin's spatial attribute of embodiment, we suggest a time dimension to embodiment is also important for children with intellectual disabilities, particularly in terms of action-effect mapping. By time dimension, we mean the interval between the input action performed by the user and the response from the system. The D-touch drum machine and the Sifteo Loop Loop application are both systems that produce audio compositions where feedback is delayed. In both cases, feedback (audio) is only given within a timed loop, which does not depend on users actions but on internal programming of the system. With D-touch, this means that the result of one action with the blocks is only perceived the next time the computer program reads the position where the block is placed and identifies it. With the Sifteo cubes, it means that the sound will only be played next time the loop reads the side of the Mix cube to which the sound was added. This time delay between an action performed by the students and its result made it very hard for them to understand the systems, and learn how they could use, control and explore them. In contrast, the object augmented with an accelerometer provided immediate feedback to students' actions, by displaying changes in colour as the object was manipulated. This was a direct mapping that did not depend on any time delay for the system to be able to identify user input. Such findings indicate that time can place significant constraints on interaction and can be seen as another aspect of 'cognitive distance'.

3.3 Conveying Concepts through Audio

Systems discussed in this work make use of visual, audio and physical (objects) representations. The type of representation used impacted on students' engagement in exploration. Analysis suggests that audio representations are complex for the students to perceive and interpret. Previous studies with typically developing children have indicated the complexity of conveying concepts through sounds and associating sounds to visual representations [7]. The system used was the interactive tabletop that visually illustrates concepts of the physics of light. It was difficult to find a complementary audio representation to enrich the children's experience with the environment consistent with the concepts. Aspects like association of sounds with familiar life situations (e.g. a doorbell), and duration and continuity of sounds interfered in the design goal of the system and children's interpretation.

In the present studies with children with intellectual disabilities, apart from simple interaction feedback sounds for e.g. correct or incorrect input, 'game over' and the like, conveying actual concepts through audio did not show positive results for independent exploration. With both mainly audio-based systems (D-touch and Sifteo Loop Loop), students relied primarily on the auxiliary visual representations. Audio, being intangible and 'invisible', appeared to be harder for students to grasp. With the drum machine, some students did not perceive the sounds played after they had placed the blocks on the interactive area as consequence of their actions. When asked if anything had happened as a result of their actions, some of them immediately said 'no'. It is important to note that delayed feedback (as discussed earlier in the paper) also contributed for such lack of connection between action and effect, but it was clear that visual representations were more appealing for the students, perhaps due to the less transient nature than sound. With D-touch, their attention was naturally drawn to the image of the interactive area showing on the computer screen (which was not necessary for interaction, but only for setting up; the screen could have been turned off). Rather than listening to the sounds produced, students were more concentrated in observing the corresponding changes in the image as they placed the objects on the interactive area.

Sifteo Loop Loop has more complex visual representations, which support the choice and combination of sounds to compose the musical piece. The students were not able to associate these representations to the sounds produced. Instead, they associated the physical configurations of the cubes with the sounds (which is not part in the design of the system). This suggests that not only interpreting sounds is hard for these students, but also making associations between sounds and other representations.

3.4 The Role of Actions

Tangibility naturally invites physical exploration. Types of actions varied across the systems. Students explored freely with the object augmented with accelerometer, experimenting through a number of different actions. With the Sifteo cubes, on the other hand, students' actions were more constrained by the system, and required following instructions more than experimenting with their own ideas. The drum machine does not invite many types of actions – interaction simply consists of placing blocks on the interactive area. The configuration of blocks with markers and the mapping matrix was complex for the students and they did not know which actions to use on the objects.

It was noted that actions helped students think: watching their peer doing something was not enough, they had to do it themselves to understand and reflect. Sometimes students repeated exactly what their peer had done, as if they needed to do it to understand what they had seen previously. Some dispute for the objects took place in the pairs with the dominant child keeping hold of the objects and being the one performing the actions. This supports other work in different learning domains that highlights the importance of considering the role of action for children's reasoning when designing forms of input and control [1]. Based on theories of embodied cognition, Antle [1] suggests that, in order to better support the development of children's conceptual understanding of abstract concepts, such concepts should firstly have their meanings traced to physical actions, which should then be incorporated into the interaction design.

Actions were also used to give explanations. These students have difficulties putting their thoughts into words, in case they say something wrong, and they may have communication disabilities, so often resort to actions to explain what they mean, and demonstrate to someone else. Nearly all answers to researcher's questions were accompanied by demonstration with objects and minimal vocabulary (using words like "this", "that", "thing", "like that", "this way"), and in some cases answers consisted of action and gestures only. For example, after some interaction with the drum machine, when asked *"how could you make music play again?"*, some students would just take blocks, place them in the interactive area, and look back at the researcher expecting feedback. This showed they understood the question, but preferred to give an answer through action rather than in words.

4. CONCLUSIONS

Tangible technologies, which combine physicality with interactivity, are potentially beneficial for children with intellectual disabilities. However, tangibles can make use of different media and types of representations, different forms of interaction and coupling between input and output. These and other aspects may have significant impact for students' interaction, comprehension, and ability to explore the systems and learn from them. The present research investigates such aspects, and discusses themes around characteristics of tangibles and design choices for children with intellectual disabilities, with the aim of facilitating their engagement in activities of exploration.

In the context of this population, we have highlighted some key themes and related open questions. We suggest that timing of system feedback is of utmost importance for interaction and should be considered as another dimension of embodiment, beyond the physical coupling of input and output. A challenge posed here is: how to design clear enough action-effect mappings, with appropriate metaphors, that still leave space for curiosity and exploration? We also discuss the complexity of conveying concepts through sound and establishing conceptual links between audio and visual representations. How can audio representations be better designed to enrich the interaction in a meaningful way? Finally, we propose that physical actions help students in their understanding of the concepts illustrated by the systems, but also have a fundamental role in supporting students' explanations. How can concepts of embodied cognition be integrated into design to take advantage of actions for exploration and reflection? Discussing such topics may lead to specific guidelines for the design of tangibles for students with intellectual disabilities.

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