Early Years Learning with Digital Technologies: The Relationship Between Research and Design

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Abstract: The overall aim of this symposium is to focus on the relationship between research and design of technologies for early years learning. Presentations will centre around two studies, one concerned with understanding the role that digital technologies play in shaping interactions between parents and young children in the home and the other with understanding the role of digital manipulatives in early years learning of numeracy in school. It will be argued that whereas a common theme emerging from these studies is the importance of shared physical and social interaction within early years learning, digital technologies for this age group tend to be designed for individual use. Participants will be invited to offer explanations for this emphasis on individual learning and discussion will focus on alternative approaches to design that might take into account the intimacy of the interaction between young children and adults.

Background and Aims of Symposium

This symposium draws on the work of an ESRC[1] and Futurelab[2] funded network that aims to develop an understanding of early years learning with digital technologies. The work of the symposium will centre around two studies carried out by members of the network. The first study is concerned with understanding the role that digital technologies play in shaping interactions between parents and young children in the home and the second with understanding the role of digital manipulatives in early years learning of numeracy in school. These studies are concerned with different learning domains (literacy and numeracy), different age groups (under-fives and early primary) and different contexts for learning (the home and the classroom).

One common theme that emerges from the research reported in this symposium is the importance of shared physical and social interaction. Within the first study, the context is the intimacy of the interaction between children and parents – a key context for learning in the home. Within the second study, it is the close – even huddled - work between children and teachers around physical objects that support numeracy activities in early primary school. Another common theme that is emerging is the way in which informal learning in the home is influenced by considerations of schooling and learning in school is influenced by informal learning in the home. Study one shows that although interactions between children and adults in the home tend to focus on the here and now, directed towards practical activities, parents and care-givers also take time to think beyond the here and now, to notice relationships, to teach, providing an educational experience for children at home. Study two highlights the importance of informal interactions (i.e., non-prototypical teaching interactions) within the more formal classroom setting. In this respect both at home and in school the interactional dynamics of intimate shared moments between children and adults around shared artefacts is an important aspect of learning.

How then should we design intimate digital technologies that support sharing between young children and adults? Most designs of interactive technologies are, implicitly at least, aimed at supporting individual interactions with technology. They are designed for the individual child, interacting in a fairly solitary fashion with the software. It is interesting to probe why this should be the case. Does it relate to a view of learning in which one-to-one teacher/learner interaction is considered to be the most effective situation to be strived for, echoing the private tutors employed by the privileged, where the 'personal tutor' idea is replaced by the idea of a 'personal computer'? These kind of designs stand in contrast to the multiple and diverse and rapidly developing forms of technologies which support a different kind of use. Technologies for leisure and entertainment are shared, mobile, allow creativity, authorship, communication and physical interaction – for example digital video and still cameras, networked games consoles, digital audio players and recorders, and interface devices which respond to the user's body movements and allow a sense of immersion.

Whereas both studies point to the need to take into account the shared intimate interactions between children and adults when designing digital technologies for early years, each study was originally influenced by different theoretical considerations. Study one draws on sociocultural theories in which tools and artifacts within the environment are considered to be *integral* to learning and cognition. In contrast study two takes a more cognitive approach in which the artefact is theorized as *augmenting* learning and cognition. Through working within the network we have not only become aware of these differences but also to a certain extent there has been some convergence in approach.

Given this background the overall aim of this symposium is to focus on the following questions:

1. How might we most productively develop the relationship between the research and design fields in this area?
2. What are the key messages for designers (and commissioners) of digital technologies for early years learning – both from general principles and from the specific examples discussed here?
3. Where do sociocultural and cognitive perspectives meet with respect to young children's learning, and what is the emerging common ground?

The symposium will be organised around an introduction which sets out the aims and background to the symposium, presentations of study one and study two and discussion which focuses on the questions outlined above.

Study One: Digital technologies in the home

Introduction

This presentation draws on ongoing research that is concerned with understanding the role that interactive digital technologies play in shaping interactions between parents and young children in the home. Underpinning the research project is an approach to cognition in which artefacts are considered to contribute structure to the organisation of mental processes; we are able to *offload cognition* onto them (Hutchins, 1995; Pea, 1993). From this perspective, conventions of social relations, features and landmarks in the physical environment, and language itself are artefacts which are used to structure the complexity of the world.

The ways in which such artefacts are used relates to their material nature (or *affordances*) and at the same time are inseparable from our experience of other people's ways of using them;

> (the knowledge carried in artefacts) … may come to be exploited in activity by a new learner through a variety of genetic paths: through observations of use by other humans and attempts to imitate it, through playful discovery of its affordances in solitary activity, and through guided participation in its use by more knowledgeable others. (Pea, 1993, p.54)

Barbara Rogoff and colleagues have studied the informal social processes as they occur between adults and young children in families and communities, defining guided participation as *the process and system of involvement of individuals with others as they communicate and engage in shared activities* (Rogoff et al, 1993). Through active engagement with their children, and often in response to children's initiation, adults make arrangements for them to be involved in everyday activities, providing informal opportunities to learn. During shared activities, children and adults are actively involved in a collaborative process of *meaning making* with the objects, language, and social relations which are the artefacts of their culture.

The research to be presented in this part of the symposium is guided by questions relating to young children's use of interactive digital technologies in the home:

- What are the circumstances in which young children engage with others in the use of interactive digital technologies in the home?
- What kind of interactions take place between children and other family members as they use interactive digital technologies?
- How do a) the physical features of artefacts used and b) the family approach to learning guide, contribute to, constrain or discourage shared activity?

Families who are participating in the research study have been asked to make video recordings of occasions when their child (aged 3 +) uses interactive digital technologies with another person. Suggestions for possible occasions of interest are made during the course of an informal interview, whose purpose is also to collect information on other family members' use of interactive digital technologies in the home and on the family culture as it relates to learning, described as *philosophies-in-practice* (Matusov & Rogoff, 2002). Follow up interviews based around the material collected on the video tapes allow further exploration in accordance with the research questions.

Analysis of the data is based on Rogoff's qualitative pattern analysis (Rogoff et al, 1993), abstracting coding categories through close observation of activities. In relating interactions to the design features of the technologies being used and to the families *philosophies-in-practice*, the analysis refers to an existing body of research literature on family practices with young children that take place around another artefact, the storybook. This literature includes detailed studies of interactions between parents and children as they share books, studies which compare the approaches of families with different experiences of and beliefs about learning, and studies which relate the design of the book to interactions with children as it is read.

Family practices and story book reading

Research literature on family literacy provides us with a basis for the comparison of the nature of family practices with books and with interactive digital technologies, and a basis for thinking about the relationship between these practices and young children's learning, both informal and formal. Such a comparison immediately raises issues for consideration. Whereas family practices with books have a relatively long history and a clearly developed relationship with formal education, the history of family practices with interactive digital technologies is relatively short. To complicate matters, widespread use of digital technologies is destabilising certainties in formal education, including the definition of what it is to be literate.

Whereas it has been possible for research to describe cultural norms in the sharing of books with young children, norms which relate to ideas about the educational value of reading and which are informed by practices in educational settings, corresponding norms are unlikely to have been established in young children's use of interactive digital technologies in the home. However, studies of the use of books and other artefacts in family life help us to understand what makes a participative practice a rich learning experience, and how such practices can become norms, embedded within family routines.

For young children, sharing books is potentially a rich experience when co-readers know the child well and reading takes place at times when they are free to engage fully in the activity. Research studies document how, during shared reading, it is common for children to be active in initiating and contributing to conversations which relate elements from the book to their own experience. If a co-reader is familiar with the child and shares their knowledge of the people, events and other elements of daily life, they are better able to notice the relationships between the book and the child's life, and to share with the child in building meaning. Meanwhile it has been demonstrated that adults are more likely to respond to children's interests and engage with them in rich conversations which build meaning, explore concepts beyond the here and now, and involve explanations, at times of the day when they are not distracted by the need to fulfil tasks. Examples of this are at mealtimes (Snow, 1993; Cloran, 1999) and during story reading. Susan Nichols' study of parental involvement in the bedtime story suggests that story-reading at bedtime is maintained as a regular practice because it fulfils multiple functions, namely of settling the child and providing an opportunity for contact between children and parents who are out during the rest of the day, in addition to being underpinned by its relationship with formal education. (Nichols, 2000).

A perspective for thinking about design

The research literature on family practices with story books has motivated the framing of a perspective on the design of interactive digital technologies for young children, articulated here in the form of three questions:

- How might we think about young children's experiences at home in terms of preparing them for practices with interactive digital technologies in schools?
- How might interactive digital technologies be designed to encourage shared use between young children and others?
- How might sharing interactive digital technologies become established as a context in which children and adults engage in conversations about ideas and concepts beyond the here and now?

The symposium presentation offers an exploration of these questions, illustrated with findings from the research study. It will include a description of the variety of ways in which participating families use interactive digital technologies, and will foreground examples identified as being rich participative experiences.

Study Two: Digital technology to support numeracy in the early years classroom

Introduction

The notion that learning can be described in terms of progression from concrete to abstract representations (e.g., Piaget, 1965) is reflected in pedagogical practice by the use, followed by withdrawal, of physical learning materials (manipulatives) in early education. However, the effectiveness of manipulatives to support learning has been brought to question (Ball, 1992; Uttal, Scudder, & DeLoache, 1997). Understanding this area has now received renewed interest as a result of the technological advances that allow digital technology to be integrated almost seamlessly into physical objects (e.g. Marshall, Price, & Rogers, 2003).

This paper draws on arguments surrounding the author's current research investigating the potential for tangible (handheld) technologies to support early numerical development in the classroom. Initial studies have examined children's performance in numerical tasks using physical or pictorial representations and findings are intended to help inform the design of digitally augmented manipulatives to support learning in this domain.

Numerical development in early Mathematics

Children do not start school without any previous experience of number. Their interactions with the physical and social world have allowed them to construct an 'informal' numerical sense built upon innate capabilities such as enumerating small quantities visually (see Hughes, 1986). When children start school, they are generally familiar with the counting procedure but have a limited understanding of the meaning of number words and are inexperienced in applying their knowledge to more formal school mathematical problems. As children's number sense develops; they learn how a number represents a set rather than simply a position along a sequence, and then how numbers can be decomposed into smaller amounts. This developing knowledge allows children to apply more sophisticated and flexible strategies to solve numerical problems of greater complexity. However, despite our growing understanding of how children develop their numerical concepts (e.g., Nunes & Bryant, 1996), it is not yet clear how different representations foster this development. There are several ways that manipulatives may play a role.

How manipulatives might support numerical development

The categories: *Generating conceptual metaphors, Generating actions, Offloading concepts* and *Focusing attention* (Mix, in press) have been used to help describe the possible learning benefits of manipulatives. Although there is interesting overlap with the more widely recognized terms computational offloading, re-representation and graphical constraining (Scaife & Rogers, 1996), these refer more to problem solving using graphical representations rather than learning through physical representations.

Generating conceptual metaphors: Using features such as quantity, length or colour, manipulatives may provide conceptual metaphors for number concepts which may consequently be embodied by these perceptual experiences (Lackoff & Núñez, 2000). Unlike graphical representations, manipulatives can be directly manipulated and it has been hypothesised that these actions might foster new interpretations of the environment and consequently help individuals develop their ideas (Martin & Schwartz, 2005). This theory was supported through studies examining children's understanding of fraction problems. As Thompson (1994) states, "[children] are empowered when they recognize the multiplicity of viewpoints from which valid interpretations can be made for they are then alert to choose among them for the most appropriate to the current situation".

Generating actions: The actions generated by using manipulatives are metaphors for numerical operations. Collections can be added, subtracted, shared equally or broken apart in different ways. These actions are familiar to children from their informal experiences and may help them construct mathematical meaning by providing a way to develop concepts through the sensorimotoric encoding (Wilson, 2001). Indeed, the rising literature on embodied cognition (e.g., Lackoff & Núñez, 2000) and research into the importance of gestures in mathematical cognition (e.g., Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001) may prove highly relevant to arguments concerning physical interaction in learning.

Offloading cognition: Similarly to diagrammatic representations, physical representations have the benefit of organizing information by location (Larkin & Simon, 1987). However, information can be re-represented spatially using motor actions. Direct physical manipulation may prove cognitively advantageous over annotation, for example: through reduced demands on fine motor control, tactile feedback or proprioception therefore allowing incremental (and retractable) changes to be made more easily. Three dimensional spatial groupings may also be perceptually supportive allowing children to identify units and collections more efficiently using perceptual mechanisms such as subitizing: an innate capacity to enumerate small collections (Dehaene & Cohen, 1994). Consequently, manipulatives may facilitate exploration of various numerical concepts such as how taking from one group to add to another preserves the total (*compensation*) or how collections can be added in any order (*additive commutativity*).

Focusing attention: Manipulatives may help focus attention on key concepts by constraining not only what information is presented but also how this information can be altered. Accordingly, it has been suggested that the amount of extraneous features be minimized to reduce the chances that children are distracted from what is intended to be represented (Uttal et al., 1997).

Limitations of manipulatives

It is difficult to evaluate how transparent numerical concepts embodied in physical objects are to children who are still unfamiliar with these concepts. Manipulatives may be objects which children find interesting in their own right and which may distract, rather than focus children on numerical concepts (Uttal et al., 1997). In the case of graphical representations, it is possible to add supportive symbols and text (e.g. number lines); the possibility for doing this with manipulatives is limited. Speculatively, it is possible that this restriction encourages teacher to model more specific procedures using manipulatives for children to emulate; a practice that has been criticized (e.g., Gravemeijer, 1991; Thompson, 1994).

Augmenting manipulatives through technology

Increasing sophisticated features such as lights and sounds can now be integrated into smaller physical materials which are able to remotely communicate with each other and separate devices. These features can be used to emphasise important numerical concepts to children such as: what items they have tagged when counting, when collections have increased in size or the significance of collections of ten. It is important, however, that digital augmentation focuses attention on these ideas and does not simply aim to make the materials more appealing.

Arguably, the most exciting possibility afforded by tangible technology is to help map physical representations to verbal and written notations of number. Through communication between objects, devices can enumerate collections and provide these representations through integrated speakers or graphical displays. This affordance means that children can explore symbolic representations of number through physical interaction; such as how quantities can be decomposed in different ways (additive composition). However, it may prove beneficial to integrate costs such as delays between representations to encourage children to plan more before acting (see O'Hara & Payne, 1998).

Virtual (screen based) manipulatives (see Moyer, Bolyard, & Spikell, 2002) can already provide multiple external representations of number, however, indirect manipulation within a small 2D space may lose some of the cognitive benefits of physical manipulation and therefore be more limited in building on children's informal understandings. Virtual manipulatives do have other advantages, such as: providing structured activities, feedback and assessment. However, these features could also be extended to tangible devices through remote connection with computers thereby providing the flexibility for both unstructured and structured use.

Final comments

The arguments made in this paper will be discussed at the conference using findings from two studies examining children's interactions with different external representations when solving numerical problems. Children in both studies were asked to solve part whole problems using physical or pictorial representations. The findings help elucidate the role of physical manipulation as well as limitations of the materials. The research provides a platform to start considering how technology might address these limitations and moreover, build on the benefits of intimate interaction with these artefacts to support learning within this domain.

Discussion: The Relationship between Research and Design

Discussion within the symposium will be orchestrated by two co-applicants, one whose work focus in on the design of technologies for learning and the other whose work focus is on research in the area. Discussion will be organised around the questions set out in section 1, with an overall aim of provoking debate, teasing out differences and establishing common ground. The discussion will feed back into the work of the network on early years learning with digital technologies in order to develop guidelines for the development of digital technologies for this age group.

Endnotes

(1) See http://www.futurelab.org.uk
(2) Economic and Social Research Council, UK (www.esrcsocietytoday.ac.uk)

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