TECHNOLOGY ENHANCED LEARNING tel.ac.uk

Using technology to enhance learning in the early years

PRESS FOR PLAY

Contents

Play and learning

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Technology is often described as a 'tool' for learning. But education in the early years – which includes children up to the age of seven or eight – provides a wonderful opportunity to explore the ways in which technology can provide fun, pleasure and play as well as the more functional interactions implied by 'tool'.

There is widespread agreement that early years education should be child-centred and start from the child's individual needs and interests. Many professionals believe that the best educational experiences are based on play and that play leads to learning. Through play, children try out ideas, create scenarios, act out roles and develop rules for their imaginary worlds. These processes of play appear to contribute to children's social, emotional and cognitive development but good evidence for a link between play and specific learning outcomes is hard to find, partly because it's difficult to define what we mean by play.

Play is one way in which children learn, but not the only way. Imitating others, direct instruction and their own explorations and experiences also contribute to learning.

Learning about the world, how to do things, and how to do things better happens in the cognitive, social and emotional spheres of children's lives. Cognitive learning covers aspects sometimes described as intellectual or requiring mental action; it involves thinking, using language, categorising, sequencing, storing and retrieving information. It is evident when children begin to be able to sort objects by colour, size and function, or associate particular characteristics with objects or people. Learning in the social sphere is demonstrated when children start to negotiate shared roles and rules as they play together and when they acquire patterns of social behaviour that are appropriate for particular contexts, such as at the nursery, visiting a friend's house or shopping with parents. Emotional learning is seen when children become able to manage separation from their parents or can empathise with the feelings of others and predict and describe their own reactions.

While some see learning as basically the same as the development of intellectual processes, others see learning as more than this, including changes in the ways in which children participate in the world around them and how they learn to interact with people and objects with increased competence and independence. Unfortunately, this expanded way of thinking about learning is not always seen in products designed for young children.

How does technology enhance learning in the early years?

The three projects described here recognise that play can be a key contributor to learning in early years settings, and that technology needs to support children's imagination and creativity. But as we are looking at the ways in which technology can enhance learning in the early years, it is important to think about what this looks like even though it's difficult to separate learning from play.

We think of learning as an internal process that is unseen but made evident by changes in children's level of skill, confidence or knowledge. Our analysis of three- and four-year-old children's encounters with technologies at home and in their preschool settings suggests the following four dimensions of learning can be enhanced by technology.

Acquiring operational skills refers to understanding how to interact with various technologies and having the motor skills to achieve the desired outcome. The development of these skills dominates in early years settings, with a continued emphasis on actions like using the mouse or learning how to scroll. Although successful interaction with computers still depends upon children developing such skills, they are usually easily taught and do not really warrant the emphasis they receive.

All three of the projects described here have addressed this issue by developing or adapting technology to facilitate children's interactions. None of the examples uses a mouse or a keyboard or depends on written text to prompt interaction. Andy, the virtual agent, responds to children's gaze and touch; the maths activities and the SynergyNet support for the plan-do-review cycle use touch screens and gesture on tablet computers or multi-touch tables. The use of multi-touch screens and intelligent systems that adapt to children in response to their input reduces the burden of learning the operational skills of how to interact, freeing them up to focus on what's important. If we can get this right, it enables children to engage with the other, more important, dimensions of learning.

Extending knowledge and understanding of the world encompasses learning in areas such as mathematics, language, and knowledge about living things, typically gained through software, websites and some smart toys. As this learning develops, children can use their expanding knowledge to succeed in sequencing and sorting, to read, and to learn about topics and questions that fascinate them.

The maths activities described later are a good example of this as they use colour and shape to draw children's attention to number patterns. In the ECHOES project, children's interactions with Andy are used to develop their understanding of how people relate to each other by making contact in different ways. The SynergyNet application encourages children to share their knowledge and understanding of the world with others.

Developing dispositions to learn encompasses a range of emotional, social and cognitive features that make a difference to a child's capacity for learning. This includes increasing self-esteem and the confidence gained from success, developing an ability to work together, supporting independence and persistence in the face of initial difficulties, and beginning to develop some self-knowledge about how they learn.

The ECHOES project aims to develop children's affective responses – in other words, their emotions and feelings. As well as learning about social relations, ECHOES also provides a platform for children to learn self-control and patience. The SynergyNet project uses visual media to represent the process of learning, enabling children to look ahead in planning their learning as well as look back on what has been achieved. The tabletops make learning visible by displaying elements of the child's activities, so providing a shared resource for practitioners and children to discuss progress.

Understanding the role of technology in everyday life includes learning about the role of technology for a range of social and cultural purposes for both adults and children. These may include employment, study, and entertainment in family and community contexts. So far, we have found that the family home offered more opportunities to develop this dimension of learning although the use of digital cameras to communicate learning to others in the SynergyNet project is an opportunity for children to use a technology that will already be familiar to them from home.

Linking learning to the home

The projects described here are developing materials for use in the early years of school or preschool settings but it's important to recognise the role of the home and the family. By understanding more about how children experience technology in the home context, educators are more likely to be able to incorporate them into the cultural practices of the early years setting. This means developing existing mechanisms to support links between home and school so that discussions with parents routinely include children's experiences with home technologies. Staff can build on this information, shifting the current focus on skills towards a broader range of competencies and dispositions and recognising that children will start school with diverse experiences, involving not only computers but also a wide range of domestic leisure technologies and interactive toys.

Children aged three to five: learning and development

The early years are characterised by change: not only developmental changes in terms of physical and intellectual growth but also what children like to do, where they go, and who they spend time with. As children grow up so fast, we have focused here on the years between three and five, although the term 'early years' usually extends beyond this.

Children are not just adults-in-training or mini versions of bigger children. So when we're designing technologies for children in the early years it's important to do some basic research on what's suitable. Here are some guidelines on what typically developing children who are three to five years old can usually do with technologies, bearing in mind that there is an enormous spectrum of dispositions, skills and competences even within a single year of a child's life. Some children can surprise adults by doing or understanding a lot more than this; others may be more reluctant.

The list below describes development in four separate dimensions, but growing up encompasses all of these and any child's use of technology will be influenced by interactions between their physical, cognitive, linguistic, and social and emotional development.

Physical

As children develop the ability to produce precise movements (fine motor skills) they can use a mouse or track pad, swipe a touchscreen, scroll through pages on a website and depress the buttons on keyboards, remote controls and mobile phones. Using games consoles and other mobile devices becomes possible as they learn to coordinate movement in both hands at the same time. Children enjoy running, jumping and playing outside so mobile technologies that support or encourage activity may be particularly suitable.

Cognitive

Children learn to sort and match items, to arrange objects in order of size and to understand 'more' and 'less'. These changes in cognition mean they can also use categories such as shape and colour, so games that involve these skills should be suitable. Children become increasingly able to think about routines and sequences so they should be able to make choices from a basic menu and to understand and remember simple rules of a game.

Language and signs

As children start to understand the use of symbols they can identify 'stop', 'start' and 'fast forward' controls and the icons for their favourite games and websites. Some children are able to read or recognise simple instructions. By five, they can provide a narrative or commentary to accompany photos or video. Children of this age may not be able to read continuous text, so designers need to be creative about how to convey the information needed to promote interaction. For children in the early stages of learning to write, text-based input may also be inappropriate.

Social and emotional

Children of this age grow in independence, understand rules and become more able to control their behaviour. They are learning to take turns and cooperate with others, although they can still get frustrated when they don't get their way or can't achieve success at something. Children respond to animations and characters that appeal to their sense of humour.

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Developmentally appropriate?

Products are often marketed as being developmentally appropriate. On the face of it, this seems unarguable. Some technologies designed for adults can be inappropriate: desktop computers can be difficult for young children to use because, as a workplace technology, their physical construction and interface are designed for bigger, more knowledgeable users. However, it may be helpful to consider whether something is developmentally appropriate in terms of the hardware and content separately as there are different issues at stake. Young children may struggle with the physical features of certain technologies but be capable of interacting meaningfully with the content once they have been guided in how to access it.

Products specifically designed for young children and described as developmentally appropriate sometimes lack the elements that make technologies for older children or adults seem attractive. Children don't like to use products or websites that they think are for younger children – but they're happy to try things that their older siblings have. So getting a balance between what they want to do and what they can do is quite difficult.

As children can sometimes do more with technology than their parents or teachers might expect, limiting children to what is considered to be developmentally appropriate can mean reducing their potential for learning by restricting their creativity and curiosity. Though young children may still be developing their motor skills and are in the early stages of becoming literate, their interests are often much more wide-ranging and ambitious than the kinds of activities that many technologies designed for young children currently permit.

In terms of design, this means that an awareness of typical developmental pathways for young children is a prerequisite but we don't necessarily need to be constrained by this knowledge. Thorough investigations early in the design process will reveal more than a set of guidelines about what children 'can' or 'can't' do.

Echoes

Kaska Porayska-Pomsta, London Knowledge Lab

Technology as a companion for children: the case for AI in education

The ECHOES project has been exploring the ways in which Artificial Intelligence (AI) can provide ways of thinking about technology as a companion for learning and for playing with. A system that uses AI has the ability to 'see' its user (in this case, a child), to reason about its actions and to act on its observations and inferences. Such abilities are particularly valuable in technologies for young children as the system responds and adapts to the child rather than the child having to adapt to the system.

The ability for a computer system to 'see' its user is based on user modelling, an AI technique that involves automatic detection of the user's actions in order to make inferences about their characteristics. This information can then be processed so that the system responds appropriately while it is being used. This technique can be used to track a user's progress, as well as to assess a user's emotional states and preferences on a moment-by-moment basis.

User models rely on information that the system can detect and record about the user's actions. This information can include the messages typed by the user, or when and where they click the mouse. More recently it is likely to include physiological information such as the areas of the screen touched by the user, the direction of their gaze and their facial expressions. It can also include information from sophisticated sensors such as wrist bands that detect the temperature of the skin and the heart rate and EEG (electroencephalography) devices that record the brain's electrical activity through a net of sensors placed on a person's head. This means that what appears on the screen can be tailored for each user, providing immediate feedback and rewards.

How can this type of technology benefit children?

The ECHOES environment is designed for five- to seven-year-old children, both typically developing and children with Autism Spectrum Disorders. Its purpose is to enable children to explore and to practise skills related to joint attention, for example, the ways in which one person can make another person aware of an object or event by pointing or by gaze. These skills are crucial for social communication and interaction with others but are often missing in children with Autism.

A CHILD PLAYING WITH ANDY, THE ECHOES' AGENT

An on-screen semi-autonomous agent, called Andy, interacts with the child using the system and adapts its behaviour on a moment-by-moment basis based on what it knows about the child at any given point. The ECHOES system has access to information about the child's eye gaze (through two wide lens cameras), their facial expressions (such as smiling), as well as touch (through the touch screen). Based on this information, ECHOES can reason about the child's feelings in real-time. Andy interacts in such a way that the child is encouraged to make progress in the specific goals related to joint attention skills. For example, based on where the child is touching the screen, it's possible for the system to work out the child's ability to take turns and whether they can follow a pointing gesture or Andy's gaze. The frequency with which the child interacts with particular aspects of the environment or the accuracy of the child's responses may also be used by the system to infer the extent of the child's engagement.

Andy has been equipped with an underlying personality that affects the system's decisions about his actions – much as humans do, albeit in a simplified way. This means that it can emulate at least some human behaviours and can support believable interactions with children. Some children are keen to interact with Andy and love the opportunities for exploration, experimentation and rehearsals of behaviours and scenarios with immediate feedback, but without the real-world consequences. They enjoy the fact that the scenarios can be repeated endlessly and that Andy responds to their actions, giving them pleasure and a sense of control over the ECHOES environment. Comments by some teachers whose pupils used ECHOES suggest that many children become more verbal than they are in the classroom and some even initiate social interaction with Andy, although they usually would not want to interact with other children.

SynergyNet

Steve Higgins, Durham University

Educators get the most out of technology when it solves problems or challenges for them. Small, cheap digital cameras, for instance, are in widespread use in early years settings to document learning activities. The immediacy of a digital photograph or short video clip to stimulate recall and reflection makes it a powerful tool to support young children in reviewing their experiences and their learning.

Plan-do-review

Following consultations with early years educators we decided to build on these existing practices by developing technology to help teachers manage the plan-do-review process which is used to structure part of the day in many early years settings.

As it suggests, this is a three-stage cycle of supporting children's learning. The plan-do-review cycle encourages children's involvement in their own learning and establishes a pattern for later life. The focus is on child-initiated activities, so in the *planning* stage, children identify how they want to use the allotted time. This might involve decisions about whether they're going to use a particular area of the room or go outdoors, who they're going to collaborate with or whether it's something they want to do on their own, and which resources they want to use. This might be written down by an adult or agreed in discussion.

The next stage revolves around carrying out the plan – the *doing*. This could be building a boat from discarded cardboard, getting to the top of the climbing frame, making some music or going on the CBeebies website.

In the *review* stage, children discuss their activities with other children and adults, thinking about what worked, what needed more planning, and sharing successes and evaluating the problems. As a result, children can grow in confidence, take more responsibility for their own learning and reflect on their choices. The outcomes of one cycle feed into the next plan-do-review sequence.

— DIRECT TOUCH HAS INTUITIVE APPEAL FOR YOUNG CHILDREN —

The problem for practitioners is that it can be difficult to capture this process when children are not at the stage where they can record their choices and reflections in writing. Digital still or video cameras can be used effectively to create a record of what has happened which can also be used to support discussion about what the child has done or learned, but this still leaves the issue of how to make these recordings accessible and easy to share.

Solving the problem

Young children can easily use tablet computers, such as the iPad. The direct touch requires less co-ordination than a mouse and most gestures are intuitive (such as moving or enlarging objects). In the SynergyNet project we have been investigating the use of multi-touch surfaces that are like giant iPads. The size of tables, they support collaboration and interaction between learners and with the practitioner.

For younger learners, they can help bridge between the digital world and the direct experiences that are such an important part of early learning settings. A multi-touch table is also large enough for children with relatively undeveloped fine motor control so that they can easily move objects and select them by simply touching. We have prototyped ways of supporting the plan-do-review cycle which help children to plan and review their learning, while at the same time creating a record of these activities for the practitioner and a means to share learning with other children or parents.

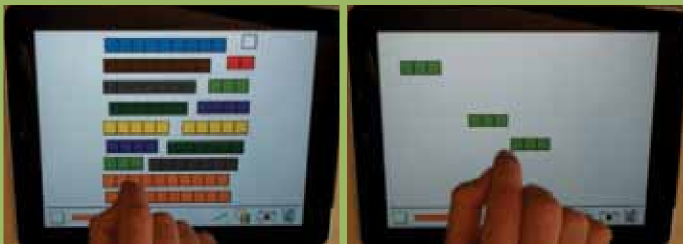
In one scenario a child *plans* what they are going to do that day by selecting activities on the table-top (such as making a model or painting a picture). During the *doing* phase they record this with a photograph which is uploaded to the table automatically from the camera. At the end of the task they can *review* what they have done, by recording a sound clip or indicating their enjoyment or success by touching a picture or icon on the table. This can also form the basis of a recorded discussion with an adult. The simple interface on the table could include the facility for the child to send a copy of this to a friend, or even as a multi-media message to a parent's mobile phone.

The key aim of such a design is to support discussion and guide interaction, using technology as a means to record and track learning, as well as a means to communicate it to others.

Supporting young children's number learning with new forms of interaction

Walk into almost any early years classroom and you would likely be surrounded by a wide range of physical materials, from blocks to tiles, used to help children learn different ideas such as Number. These type of materials have been used for over a century but it is still not clear exactly why moving objects with their hands helps young children to develop ideas in areas such as Maths.

CHILDREN CAN MOVE OBJECTS WITH THEIR FINGERS



Understanding the role of physical interaction in learning has gained in importance with the rising use of computers. Computers provide virtual objects that children can move on screen and offer new ways to support learning by providing activities, giving feedback or simply allowing children to save their work easily. However, children's interaction with these objects is made through a mouse or keyboard, and it's possible that this more indirect, constrained form of interaction is limiting for children in the early years who may lack dexterity.

New forms of interaction might address such concerns. Already we can see commercial gaming consoles where children can control objects on screen using handheld devices, or even just by moving their hands. There have also been developments in physical objects augmented with digital technology, known as 'tangibles', that allow children to explore digital effects through hands-on interaction.

We don't know how, or even if, these technologies benefit children. Different digital designs may initially fascinate and engage young learners, but these novelty effects are likely to diminish. We also have to consider possible limitations that initially seem counter-intuitive. Using a mouse may be more demanding for children, but could this encourage them to think about their actions before making them? Does constraining children's actions hinder their learning or help them practise efficient strategies for problem solving? In order to address some of these questions, we have been investigating how different forms of interaction shape the way young children (aged 4-8 years) solve mathematic problems. The aim is to evaluate the potential of new forms of technology, such as tangibles, to support early learning. Children were given a particular number problem to solve using different materials such as physical blocks, squares on paper, squares on a computer, or simply their fingers. By examining how children solved the problem using physical objects compared with other materials, we have been able to shed some light on the role of physical interaction in learning.

Children use a wide range of actions when manipulating physical objects to solve a number problem. They lift, grab, slide, touch, or cover objects to help them count or change the way objects are grouped and to explore different numerical relationships. We have taken what we learned from this to consider the potential of new forms of interaction with technology. Devices such as the iPad let children manipulate virtual objects using actions that are difficult to achieve with a mouse: they can move objects with their fingers on both hands and they can select and move single or multiple objects more easily. These devices may therefore build on some of the benefits of physical interaction we identified.

Digital technology also lets us design materials in ways that are not possible with traditional physical materials. As our research showed that children often missed number patterns when using physical objects, we considered ways to design virtual materials to draw children's attention to certain number patterns. We designed materials on iPads that change colour according to the number of objects grouped together. These colours may help children see certain number patterns. For example, the screenshots in Figures (left) show how some numbers (e.g. 9) may or may not separate into equal groups. We are also using these materials on the iPad to examine whether being able to use one or two hands makes a difference.

MOVING OBJECTS HELPS CHILDREN DEVELOP IDEAS

Designing technologies for young children

Finding out

Young children are not able to complete questionnaires or participate in a standard interview format - even getting them to focus for more than a few moments to talk about what they like can be difficult. This means that it's not easy to find out about children's preferences in terms of what they want devices to do, where they might want to use them, or surface characteristics such as shape and colour.

Here are starting points to highlight some of the key issues to keep in mind when designing technologies for young children. As it's important to get it right, it's worth following up some of the further reading suggestions or taking advice from people who have experience of working with children in this age range.

The best solution is generally to *observe children* at play and identify what seems appropriate for the design question, such as what they seem to enjoy and what seems easy to use. But observing children isn't easy – you need to know what it is that you want to observe and it is generally necessary to make special arrangements. Just observing some neighbours' or relatives' children is not likely to provide a representative cross-section of experiences.

Even young children can be involved as *participants in the design process*. They can be encouraged to draw and paint favourite things, to construct objects and to express opinions on prototypes. But they will generally engage with the process on their own terms and you might not achieve quite what you expected from an activity.

You can also try talking to *parents and education professionals* about their perceptions of children's favourites and their patterns of activity. As it is adults who make purchasing decisions, this can provide useful intelligence. Using adults as the only source of information won't provide all the insights that you need, though.

Preschool settings (nurseries, play groups, kindergartens) in the UK are not scaled-down versions of primary schools. They have a fundamentally different culture so the *location* in which the product will be used makes a difference – whether in preschool or primary school settings or at home. The principles of preschool practice are based on child-led activities in which children learn through play and exploration, supported by staff who monitor and facilitate rather than teach and direct. Observing children in the setting in which the technology will be used is therefore essential, especially as introducing technology usually changes the dynamics of a setting.

Children in the UK usually start school at the age of five and there is a transitional period in which their day becomes increasingly school-like in terms of activities, structure, the qualifications of staff and the curriculum. All of these factors vary across the different countries of the UK so it is important to do some background research.

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Some design principles

Content counts

Many products claim to be educational but the content is uninspiring and no better than you might find in an old-fashioned workbook. However glitzy, these are often based on mundane educational tasks disguised as entertainment. You will probably need to take advice from education professionals on the content and test it with children. Does the activity take too long? Are they able to complete it? Is the language appropriate? Is the feedback meaningful? Children are easily distracted and may give up if it seems hard or boring. Seek advice to check that it links to the curriculum if this is a requirement – and don't forget that the curriculum differs across the countries in the UK. The technology needs to enhance learning, in other words to offer an approach to learning or to open up an area for learning that was not previously possible with other resources. This is a tall order, but it's worth aspiring to.

Interactivity and interface

Operational problems may arise from a confusing or unrecognised interface design. Young children are not necessarily familiar with the interface conventions that we've got used to from workplace applications and not all icons will work for this age range – an old-fashioned microphone or movie camera is not necessarily going to indicate audio or video for a child who's never seen one.

If the screen is too cluttered it will be difficult for children to find controls for exit, volume, and moving from one page to another. Icons and buttons need to be large and clearly defined.

Tablet computers can solve some operational problems. The touch screen and gestural interface, the portability and easy share-ability offer new dimensions of control and interactivity, as do the multi-touch tables described earlier. Children's hands are small. Keep this in mind when spacing buttons and controls, particularly on mobile devices.

Designers find it hard to resist including examples of gratuitous interactivity – opportunities for interaction that are there because they can be rather than because they serve a purpose. Whether the main purpose of a given instance of interactivity is to provide some fun or test a new concept it's as well to check that you get the desired outcome rather than a child who is baffled. Sometimes, creating interactivity can get in the way of the educational potential and can actually be an impediment to a child's learning if they don't understand what they need to do or don't have the fine motor skills to do it.

Guided interaction

Young children need sensitive and responsive support when technology is introduced. They need the help of others who can recognise their existing understanding and skills and interact with them in ways that develop new competencies, or guided interaction. Adults (and sometimes peers or siblings) do this by modelling and demonstrating, explaining and instructing, monitoring and offering feedback, prompting exploration and asking 'what if' questions. While there's still a long way to go, some of these ways of providing support can also be provided by the design of the technology, through user modelling or interfaces that are appropriate for children of this age. In this case, it is the design that guides interaction rather than a human partner. Ideally, children's play and learning can benefit from both forms of guided interaction.

Solo or collaborative?

Most applications for children in this age range work best if a child can use them either alone or with others. At home, it's important that other members of the family can join in. They can become companions who share the experience and help when a child gets stuck. In a preschool setting, the application usually needs to work with more than one child at a time but it can also be important for a child to be able to use a product independently, to explore its potential and to make their own decisions. This is when the guided interaction offered by the design of the product is particularly important.

As new forms of technology are developed and it becomes easier to provide ways to design materials that children can touch, feel, move around and share we may begin to identify other areas of learning that can be supported. Concerns are sometimes raised about whether technology hinders the more playful, physical, and exploratory aspects of children's learning but this is more likely to be when it is limited to desktop computers with upright screens, a mouse and a keyboard. The projects described here represent the opening up of possibilities, enabling us to design new interfaces, look at how they guide interaction and how this, in turn, provides enjoyable experiences that contribute to children's learning.

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SynergyNet: Supporting Collaborative Learning in an Immersive Environment (ESRC/EPSRC RES-139-25-0400)

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