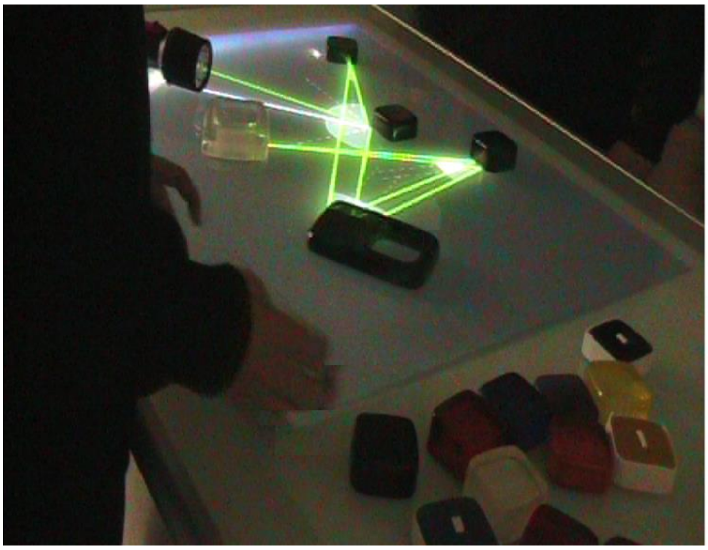
Research Briefing Nº 62

Designing ‘tangibles’ for learning: an empirical investigation

This project investigates how tangible technologies (‘tangibles’) affect the way learners (students) interact with and understand scientific ideas.



In human-computer interaction, ‘tangibles’ are physical objects or materials (e.g. building blocks, balls) embedded with sensor based technologies and linked to digital information in the form of images, sound or tactile feedback (e.g. vibrations). These technologies encourage hands-on learning, providing students with new ways of exploring and interacting with scientific information. This fosters a more active approach to learning than traditional computing. Also, ‘tangibles’ provide opportunities to expose students to scientific information not normally (or easily) available (visible) in the physical world for students to explore, such as the behaviour of light.

A LightTable, a purpose built ‘tangible’, was developed to explore how physical objects, reinforced with dynamic digital images to display invisible scientific phenomena, can support students’ understanding of science. The LightTable helped students explore the behaviour of light with objects of different colours, shapes and textures, i.e. how light is reflected, refracted or absorbed with these different kinds of objects.

A torch, developed with a specially designed digital white light beam, was placed on the table. When the students manipulated the digitally reinforced objects, either by placing them in the pathway of the light beam, taking them off the table, or altering their position, the light beam was interrupted or redirected. The students were able to easily see and experience the relationship between the digital light beam and the objects. This helped them to gain new knowledge about the properties of light.

Key words: tangibles; digital technologies; science learning; human-computer interaction; embodiment

Key findings

Findings are of interest to science educators, museum educators, digital designers and computer developers. Studies with 11-14 year olds have shown how tangible interfaces can promote exploratory

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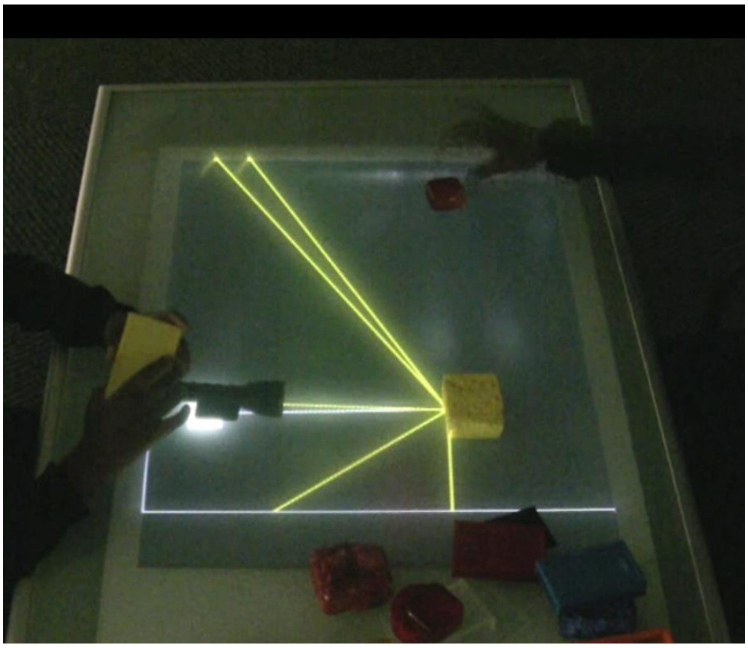
learning and collaborative working, helping students to learn. Findings are outlined under the following themes:

- **Collaborative learning:** 'tangibles' that are dynamically manipulated by students in real-time support collaborative hands-on interaction in various ways: when tangible objects are a common focus of attention for students, they are able to explore and work together to 'build' new knowledge; the physical characteristics of the objects contribute to balanced participation in the activity by all students; the capacity for students to move objects around simultaneously resulted in an over-lap between the students' activities. This allowed them to experience changes in light configuration at a quick and engaging speed. These fast interactions raised the students' interest in the behaviour of light, encouraged them to talk and explore together, and resulted in productive learning.



- **Engagement**: the dynamic nature of the 'tangible environment' (where the digital and physical work together), and the ability to simultaneously explore concepts together, helped the students to engage not only with the activity but also with the scientific concepts. The students were able to draw scientific conclusions from seeing the behaviour of the light in relation to the moving objects. Analysis showed that tangible environments also inspire students' interest in *how* the technology works. The students were motivated to understand the technology and the concepts they help explore.

- **Design of tangible interfaces**: Research suggests that the design of 'tangibles' is critical. The design needs to consider the way in which students interpret scientific phenomena. Students bring their prior experiences and 'knowledge' to scientific investigation. This means that although the tangibles may be designed to support learning in a particular area of science, the students may interpret what they see based on what they have already seen and feel they understand from prior experience in the real-world. For example, the students interpreted the light spectrum as a 'rainbow'. This suggested they were relying on a real-world experience rather than on what was being presented to them by the 'tangibles'. The same was true for the way in which students interpreted some of the tactile information presented by the objects. This shows that the design of 'tangibles' is not straightforward. Rather, designers must consider all perceptual properties of objects to make sure students interact with them in the most helpful ways to support new perspectives, ideas and ways of thinking about scientific facts.

What we did

This UK-based research, funded by the Engineering and Physical Sciences Research Council (EPSRC), took place from January 2008 to March 2010. The Institute of Education's **London Knowledge Lab (LKL)** collaborated with Birkbeck, to undertake the project which arose from previous studies that demonstrated gaps in our understanding of the technical possibilities made available by 'tangible technology environments' and their particular value for learning.

Based on a theoretical framework, a number of 'tangibles' were developed to support secondary students' science learning (e.g. the LightTable) and evaluated with students. The specific project objectives were to:

Understand the impact of different combinations of digital representations and tangible objects on students' learning interactions and interpretation of scientific concepts.

Design and develop and evaluate tangible environments to support such learning.

Provide design guidelines for tangible learning environments and associated digitally augmented (reinforced) objects in the form of various digital representations (e.g. visual, sound etc.)

How we did it

The theoretical framework provided the basis for us to systematically investigate how different ways of linking together physical objects, digital environments and information affect the way that learners interact with and understand scientific ideas. We developed a number of tangible artefacts to support students' science learning, including an interactive tabletop with associated digitally-embedded objects that students could use to explore scientific concepts. The design and development of the learning environment draws on academic research from a number of disciplines, including psychology, computer science, cognitive science and education, with input from teachers and domain experts.

Studies were undertaken with 43 students aged 11-14 years using the tangible table to learn about light behaviour, specifically reflection, refraction and absorption with objects of different colours, shape and texture. Analysis was based on a combination of observation, video and interview data from pairs of students interacting with the tabletop. The research was qualitative in nature, in order to gather an in-depth understanding of how and why certain behaviours and outcomes occur.

Further information

See the project website for a video showing an early prototype of the LightTable http://www.lkl.ac.uk/research/tangibles/Gallery/video/08_TableSept08_lrg.mov and selected publications:

Price, S. (2013). Tangibles: Technologies and interaction for learning. In Price, S., Jewitt, C. and Brown, B. (Eds.), *SAGE Handbook of Digital Technology Research*. London: Sage.

Price, S. and Pontual Falcao, T. (2011). Where the attention is: Discovery learning in novel tangible environments. *Interacting with Computers*, Volume 23, Issue 5, 499-512

Pontual Falcao, T. & Price, S (2010). Interfering and resolving: How tabletop interaction facilitates co-construction of argumentative knowledge. *International Journal of Computer-Supported Collaborative Learning* Springer NY, 23-29

Price, S. and Pontual Falcão, T. (2009). Designing for physical-digital correspondence in tangible learning environments. In *8th International Conference on Interaction Design and Students.* Como, Italy p.194-197

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The research is based at the London Knowledge Lab (LKL) – a collaboration between the Institute of Education and Birkbeck