# Tangible tabletop design and interaction for science learning

**Sara Price, George Roussos, Taciana Pontual Falcão, Jennifer G. Sheridan**
**London Knowledge Lab - Institute of Education, London - UK**

## Introduction

Wireless and sensor technologies enable objects and environments to be networked together in a number of different ways, and linked to various forms of digital representation, e.g. an image or animation on a screen display, a sound, or even a change in the object itself. Digitally enhancing physical objects in this way offers opportunities for novel representational formats in learning environments that enable learners to explore scientific phenomena in new ways.

To investigate the effect of different tangible design parameters on interaction, learning activities and cognition, we propose a framework centred around artefact–action–representation relationships, as a way of conceptualising physical–digital links from a learning perspective. The framework consists of the following parameters: (i) location, referring to the distance in space between physical and digital components of the system (i.e., co-located, discrete and embedded); (ii) dynamics, related to the flow of information throughout the interaction, including links between action, intention and feedback; and (iii) correspondence, depicting the metaphors involved in the representations of artefacts and actions upon them. In parallel, we also consider the modality of representation and how it impacts on different aspects of the interaction.

An interactive tabletop with tangible interaction devices was built as part of the *Designing Tangibles for Learning* project ([www.lkl.ac.uk/research/tangibles/](www.lkl.ac.uk/research/tangibles/)), and a number of empirical studies have been undertaken to investigate the effect of the tangible system, and different design parameters on interaction and learning. Drawing on the representation framework, findings to date suggest ways in which tabletop technologies affect collaboration, interpretation and knowledge construction.

## Interactive surface design

Object recognition is enabled in the system through Reactivision technology. For the studies an application was designed to support students learning about the behaviour of light and derived concepts of colour. Interaction is enabled using custom-made coloured blocks, a variety of off-the-shelf objects, and torches (Figure 1). The torches act as a light sources (causing a digital white light beam to be displayed when placed on the surface), and all other objects reflect, refract and / or absorb the digital light beams, according to their physical properties (shape, material and colour). Objects are detected by the system when placed on the surface, and correspondent digital effects are projected on the tabletop (when in co-located mode, as in Figure 2) or on a separate surface, e.g. a wall (when in the discrete mode, as in Figure 3). Multiple objects can be recognized simultaneously, thus enabling several participants to interact with the tabletop together.

*Figure 1: Interaction objects used with the tabletop*

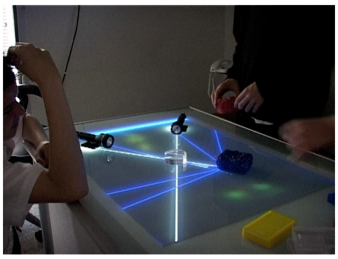

*Figure 2: The co-located mode*

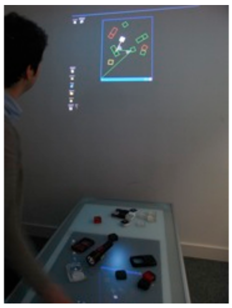

*Figure 3: The discrete mode*

## Empirical investigations and key findings

Studies with 43 students aged 11-15 years were undertaken. Children worked in groups of three for approximately 30 minutes. They were invited to explore the system and find out about how light behaves under different conditions. The aim was to observe the students as they engaged in collective and exploratory interaction rather than explicitly teach them the concepts. We outline the key findings below.

*Awareness*

The co-located design promoted a high level of awareness of others and of action–effect relationships. The co-located design provided a common and unique focus of attention. Everyone's actions and the consequent digital effects were visible to all participants on the shared surface, which facilitated collective exploration and collaborative knowledge construction. In contrast, with the discrete mode, the physically separated input / output coupling made the action–effect relationships less clear and awareness of others' actions, harder.

*Opportunity for reflection*

However, the discrete design promoted a slower interaction with more 'time' for thinking, while interaction in the co-located mode tended to be very quick, with children constantly changing configurations, and which frequently interfered with reflection. Although digital effects in the tabletop or screen display are affected by actions, as long as the objects are on the surface, the effects (if any) are permanently displayed, which allows children to stop, observe and think about what the system is showing. However, the need to specifically design learning activities that promote opportunities for reflection, particularly in co-located designs was noticed.

*Interference*

High levels of (accidental or intentional) interference, especially in the co-located mode (though occasionally disturbing individual reflection), were highly successful in provoking curiosity, drawing attention to relevant instances of the phenomena, engendering exploratory and inquiry activity, and promoting verbal negotiation and synchronization of actions. Overall this facilitated effective forms of collaborative interaction.

*Shared resources and representations*

The physical interaction devices themselves were shared through an implicit protocol of handing resources over, and the collective nature of arrangements produced on the tabletop favoured the co-construction of ideas. The physicality and availability of the devices contributed to balanced levels of participation. The digital representations were collective, i.e. everyone's input fed into the same, common digital representation, which contributed to collective knowledge building.

*Physical-digital metaphors*

Findings suggest that children's interpretation of scientific phenomena results from an interaction between different design choices for physical objects and associated representations, pre-conceptions and previous real-world experience. Although designs may have literal and symbolic correspondences, learners do not necessarily infer the same correspondence metaphor. Furthermore, boundaries between literal and symbolically representative were not always clear for children, and raised issues about and trade offs between using mixed models of real and virtual to create cognitive conflict, and undermining children's understanding.

*Engagement*

Moving beyond concepts of engagement as fun (commonly arising from studies with children interacting with novel technologies), four further kinds of engagement were identified during the studies that help explaining more clearly the value of engagement for supporting learning: namely, engagement with technology, activity, task and concept.

## Conclusion

Interaction with tangible tabletops involves a variety of physical objects and actions that create, shape and constrain different learning opportunities, with the potential to support hands-on, experiential learning, through links between artefacts, actions and digital representations. Such mappings, however, must be carefully designed, as the physical affordances evoke associations with real settings that influence learners' interpretation, conceptual generalisation and abstraction.

Overall, a multi-user shared surface with co-located interaction contributes to creating a highly collaborative environment leading to a productive process of collective exploration and knowledge construction, with balanced levels of participation, particularly through action. However, if on one hand, simultaneous interaction to build shared digital representations promotes such productive interference, on the other hand the resultant dynamic environment may not allow for enough opportunities for reflection. Thus, from a pedagogical perspective, the flexible design possibilities afforded by shared surfaces and tangible interaction should be constrained by the kinds of learning opportunities they promote, in consonance with the conceptual goals of the system and/or activity. This research contributes to understanding how such systems can be designed to effectively promote learning.