Extending concepts of engagement in tangible environments

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ABSTRACT
Engagement is often considered a principal advantage of tangible interfaces. It is most often linked to concepts of enjoyment and fun, which form a central part in motivation for learning. However, engagement per se does not guarantee learning. Based on studies using a tangible interface to support children learning about the behaviour of light, this paper specifies three further kinds of engagement. This highlights the need to extend the concept of engagement to explicitly include factors that enable us to identify more clearly how engagement maps to learning.

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Tangibles, learning, engagement, children.

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

INTRODUCTION

Engagement is usually considered one of the main advantages of tangible interfaces. Currently it is most often linked to concepts of enjoyment and fun, which are also considered key factors in promoting motivation. Much research demonstrates such levels of engagement in children interacting with tangible environments. In many cases, the toy-like nature of tangibles is claimed to promote engagement through their familiarity to children and derived emotional aspects. Children can play when interacting with technology-enhanced assembling kits (*Topobo* [6], *SystemBlocks* [10], *Programmable Beads* [8]), balls (*Bitball* [8]), paintbrushes (I/O Brush [9]) and so on. Generally, levels of engagement are measured in terms of fun and enjoyment, using various measurement scales, such as Read et al.'s [7] instantiations (positive, including: smiles, laughing, concentration signs, excitable bouncing and positive verbalizations; or negative, including: frowns, signs of boredom, and negative verbalizations). In terms of motivation, Malone and Lepper [2] developed a taxonomy around the concept of intrinsic motivation for learning, which involves challenge, curiosity, control and fantasy, plus the interpersonal aspects of cooperation, competition and recognition.

However, engagement or motivation per se do not guarantee learning [4]. Just as children may have 'fun' without being engaged with the concepts that they are expected to learn, similarly they might be challenged or curious, cooperate and / or compete, in situations which do not necessarily lead to learning. Although motivation is central to productive learning, we propose the need to move beyond concepts of 'engagement as fun' to identify what it means to be 'engaged' such that the engagement promotes effective learning.

Based on the studies performed, we identify three further kinds of engagement (with system, activity and concept), that are needed to underpin evaluation and analysis of learning environments, in order to explain more clearly the value of engagement for supporting learning.

THE TABLETOP ENVIRONMENT

As part of the *Designing Tangibles for Learning* project (www.lkl.ac.uk/research/tangibles/), we built an interactive tabletop (Figure 1) based on the ReacTIVision technology [1]. Interaction is performed through concrete objects (plastic blocks and torch) tagged with fiducials.

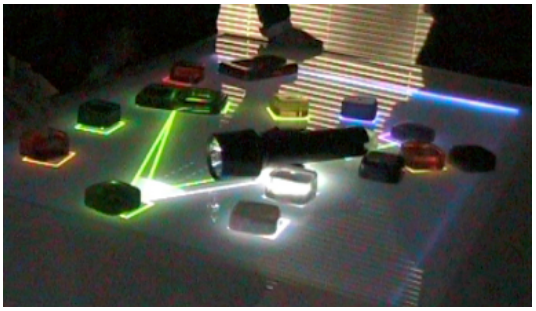

Figure 1. The tabletop environment running an application on physics of light

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We developed an application on the physics of light in which digital effects showing light reflection, absorption, transmission and refraction are triggered by the interaction between the torch and the blocks on the table's surface.

Studies

Initial studies were performed to evaluate the tangible environment in terms of usability, conceptual inferences arising from the interaction, attention, collaboration, engagement, locations and metaphorical mappings [5]. In this paper, we focus on the findings regarding different forms of engagement and their influence on the interaction and meaning-making.

Seven groups of 3 children aged between 11 and 12, from Year 7 classes of two schools in the outskirts of London (UK) took part in the studies. 11 were female and 10 were male, with groups consisting of a mixture of girls and boys. Some of them were aware of basic concepts such as light traveling in straight lines, shadows, and opaque and transparent objects.

Children were asked to freely explore the interface (by moving the objects on the tabletop) to find out about the behaviour of light. During the interaction, the facilitator would prompt the group with general questions like *"what's happening here?"* and *"why do you think this is happening?"*, to guide pupils through the exploration of the concepts towards making inferences and drawing conclusions.

ENGAGEMENT AND LEARNING

Findings from the studies suggest that there are three further aspects of engagement (beyond measures of fun and motivation) that are important to consider when analyzing the effectiveness of tangible interfaces for learning: engagement with the system; engagement with the activity; and engagement with the concept.

Engagement with the system

Nowadays, in developed countries, children have large access to and are familiar with information and communication technology (computers, video games, mobile phones, DVD players, interactive whiteboards, MP3 players and so on). Virtually all children (except one) participating in the studies presented here reported using computers and videogames everyday or at least every week.

When presented with a new, unfamiliar system, children tend to associate it with what they already know and try to produce explanations for how it functions. This engagement forms part of the interaction and occurs in parallel (and sometimes intertwined) with conceptual exploration. Throughout the interaction with the tabletop, children were very engaged in finding out how the system works and the reasons behind its behaviour. They asked questions like *"what are these bricks?"* and *"how do they make it come up there?"* in reference to the links between the tangible objects on the table and the linked representations. The children had conversations about or made comments on technical aspects of the environment, making inferences about the technology involved in the system (*"it's a computer, the table"*), and showed great excitement when they got to understand it. The children also asked questions about the use and purpose of the system and imagined other possible uses.

Engagement with the activity

It was apparent that a distinction could be made between engagement with an activity and engagement with the learning concept. In the studies presented here, the children interacted with the tabletop through exploratory activities, and all children concentrated and were engrossed in the activities during the whole session. An activity could consist of free exploration or be oriented by the facilitator's questions or suggestions, in order to induce exploration of some specific concept. In other words, the facilitator could either observe a free activity and take chances to ask *"what's happening there?"*, or suggest specific activities through inquiries like *"what happens with those objects that is different?"*.

However, being engaged in the activity does not necessarily imply learning. In exploratory activities, children are quite free to use the interface as they wish, without a rigid structure of tasks. Therefore, to obtain an effect such as light being reflected off several objects, children would sometimes try different arrangements quite randomly, without noticing objects had to be in the same colour. Although this is a typical form of exploration, the intention of the design is that pupils would eventually draw conclusions and perform activities in a less serendipitous and more intentional manner. However, the constant repetition of actions that would not lead to the sought result may be a sign of children engaging with the activity without engaging with the concept.

Another kind of evidence for this situation was identified through oral verbalization. For example, during activities, some pupils would refer to the light beams simply as *"lines"*, clearly using terms related to the digital representation rather than assimilating the metaphorical mappings of the design.

There were also situations in which children would not answer facilitator's questions. Although they would try using the system to find out the answers, they got distracted with performing different activities without concentrating on the concepts they should be trying to explore.

Therefore, evidence suggests that children can be totally involved in the activities without having to reflect upon the underlying concepts. In the studies performed, children could be playing and producing different effects without being curious about the system itself or the concepts.

Engagement with the concept

In learning environments, the main goal is to promote users' engagement with the concepts involved in the

interface design. In the studies performed, engagement with the concept was noticed in a variety of ways.

- *Spontaneous comments and explanations on the learning domain*: as an example, as soon as the tabletop environment showed light bouncing off an object, some children declared *"it's reflection!"*. After some time of interaction, they would start giving spontaneous explanations such as: *"if you put another colour in front of the line, it stops reflection"*. Yet in other situations, children would give justifications to facts somehow unexpected (i.e. which caused cognitive conflicts): *"oh, but it doesn't reflect off that because it's not white light"*. This showed children were making (correct) inferences from what they had already learned from the interface.
- *Explanations when solicited*: children would usually answer properly (even if not correct) facilitator's questions.
- *Instructions*: when asking peers to perform some action, children would sometimes use terms related to the concepts, e.g. asking peer to *"reflect the light into that"*.
- *Hypothesis*: children would ask themselves and their peers about hypothetical conceptual situations and resort to the interface to test them, e.g. *"can you still get it reflected if…?"; "if I put that there, does it reflect…?"*.
- *Conclusions:* children were able to draw (correct) conclusions from their interaction with the system, e.g. when seeing violet light being "blocked" by a green object, child exclaimed *"oh!"* and gave the correct explanation for the phenomena, in a typical a-ha moment.
- *Questions about the concepts*: when working collaboratively to try and achieve something, the children would discuss concepts that interfered in what they were trying to do. For example, when trying to get light reflected from several objects, one child noticed they needed similar colours and asked: *"is that the same colour?"*, getting an answer from someone who had not quite understood the concept yet: *"it doesn't matter"*. Children would also ask facilitator conceptual questions such as: *"do you get a different pattern if you have a different material?"*.
- *Associations with real life and metaphors*: after some time of interaction, children would start making associations with the real world, e.g. talking about mirrors and the moon, or using metaphors to explain the concepts like: *"light is like someone running – if someone gets in their way…"*.

DISCUSSION

This study suggests that distinctions can be made between a number of different kinds of engagement that take place during children's interaction with tangible learning environments. Each of these factors contributes to an effective learning process. Observation of interaction suggests that children cycle through these different forms of engagement throughout their interaction. This cyclical activity involved alternations between expressive and exploratory modes of interaction [3]. According to Marshall et al. (2003) [3], in exploratory situations, the learner explores a ready, prebuilt model, learning about the world from this interaction or using the model as a tool in a particular context. The exploration may lead to cognitive conflicts, when the learner's preconceptions do not match the system's model. In expressive situations, learners build their own representations using the system and make explicit their beliefs – which may also expose inconsistencies.

Studies showed two kinds of exploration going on in parallel throughout the interaction: exploring the system and exploring the concepts. These two approaches map straightforwardly to two forms of engagement previously described (with system and concept). When exploring the interface, children would sometimes wonder how things worked and why, ask questions, make inferences on technical aspects, examine and test the different objects, the fiducials, and sometimes try peeping under the table. Although system exploration / engagement was predominant in the beginning of the interaction, when children were getting familiar with the interface, it was still noticed throughout the activities, especially when children were surprised by unexpected effects from the system. For instance, after some time of interaction, one child noticed the torch was off, and could not understand how he could still get all effects on the table. His attention then became focused on examining the torch and trying to find out how it worked.

On the other hand, after reaching a good level of familiarity with the interface, and encouraged by the facilitator's questions (such as *"what's happening there? Why?"*) children would start exploring the concepts (i.e. they became able to engage more with the concepts). They would typically resort to the system to find answers for facilitator's questions, and also investigate phenomena they happened to produce by chance (*"wait, what was that thing?"*). Children also resorted to the interface to express themselves in a variety of contexts and moments, showing different forms of engagement throughout the interaction. Engagement with the system was clearly identified when children described or explained the interface itself (*"if you put it down, it…"*, telling peer that the fiducials had to be facing down).

Engagement with the concepts and activities were very intertwined when we think in terms of cycling through modes of interaction and engagement. Pupils would explain concepts based on what they could see happening in the interface (demonstrative pronouns like *"this"* and *"that"* were used very often, together with gestures like pointing); and use the system to express ideas (which also arose from the interaction themselves, in a clear process of knowledge production); and demonstrate or illustrate answers to facilitator's questions. In those situations, children showed signs of engagement with both concepts and activity.

Sometimes, children would seem to be engaged with activity only, for instance when talking about what they were doing and not necessarily relating to concepts; and when resorting to the system before verbalizing answers or ideas. This could either indicate children had not yet engaged with or grasped the concepts at that point or were not confident enough to risk giving opinions without checking the interface first (self-confirmation).

Although the fun aspect of learning is not to be neglected, when designing a tangible environment the ultimate goal is to be able to convey the concepts involved. Studies showed that situations involving challenge, curiosity, control, cooperation and competition [2] did not directly imply learning, as they could (also) arise from children's engagement with system or activity only. Engagement with the system is usually a consequence of novelty and tends to fade with time, when attention moves to *"what one can do with it"*. Therefore, signs and situations of engagement with activities and concepts should inform the design in iterative processes for developing learning environments. Although we believe exploratory activities are beneficial for knowledge production, the system should also be designed to try and ensure learners' engagement with concepts. This can either be *"forced"* by the interface in more task-oriented environments, or just supported by the system, i.e. a teacher or facilitator would be able to use the system to model appropriate activities.

In general, findings showed that children were keen to answer facilitator's questions, but seemed more excited and curious about how the system works. Although this may be due to the novelty of an unfamiliar piece of technology, it might also call attention to the need to arise curiosity about concepts (through some introduction from teachers, associations to real situations, i.e. context-based learning) and then provide a tool to explore them.

CONCLUSIONS

In conclusion, we propose a four-tiered analysis for understanding engagement in tangible learning environments, which may be extended more generally to technology-enhanced learning environments.

Fun and enjoyment: the belief that technology-enhanced learning environments, and especially tangibles, increase students' motivation through their playful nature is not new. However, other forms of engagement come into play that must be analysed.

Engagement with the system: tangibles (and technologies in general) carry an aspect of novelty, which promotes children's curiosity, exploration and excitement. As users become more familiar with the functioning of the interfaces, however, there is a tendency to move the focus of attention from the tool itself to its purpose and use.

Engagement with the activity: each environment will have a set of possible activities, which can be exploratory or more task-oriented. The goal of learning systems is to allow users to grasp concepts through performing activities. However, studies showed that children can be engaged in activities without reasoning upon the concepts.

Engagement with the concept: signs like use of terms from the learning domain, a-ha moments, demonstrations using the system and less random use of interface to find answers all suggest children are engaged with the underlying concepts.

Future steps include identifying, across different types of activities, patterns that promote engagement with concepts, whilst still keeping the fun of tangible environments.

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