ITERATIVE DESIGN OF TANGIBLE USER INTERFACES

Mark Stringer, Jennifer A. Rode, Eleanor F. Toye and Alan F. Blackwell
Computer Laboratory, University of Cambridge
Cambridge CB3 0FD, UK
+44 (0)1223 763500
{ms508, eft20, jar46, afb21} @cl.cam.ac.uk

ABSTRACT

In this paper we discuss the lessons learned creating a tangible user interface to teach argument to children. By gradually and iteratively introducing our technology we were able to isolate the effect of the physical affordances versus the technology components of our interface.

Keywords

Tangible user interfaces, RFID, prototypes, Children, iterative design, computer supported collaborative work.

1. INTRODUCTION

This paper presents an extensive interface design programme undertaken as part of the ongoing European Union-funded Webkit project. The aim of Webkit is to explore applications of tangible user interfaces (TUIs) to the World Wide Web, with particular focus on applications for school children. The project aims to develop novel TUIs and applications through a process of user-centred iterative design. Technical partners in the project had existing expertise in radio frequency identification (RFID) as the primary technology for implementing the TUI.

In seeking to apply iterative user-centred [5] and learner-centred [7] approaches in English schools we found it necessary to further focus and constrain our design activity. Most significantly, we were asked to ensure that classroom time allocated to our research would simultaneously enable children to achieve learning goals set forth in the English National Curriculum [2]. A secondary concern arose from previous criticism of HCI research in educational settings, which has suggested that the common emphasis on collaboration in HCI is gratuitous or unhelpful for educational purposes [3]. This was a challenge, as we had determined that TUIs were most likely to be beneficial for collaborative web usage [1]. In order to address these challenges, we focused on sections of the curriculum that require children to collaborate in researching and constructing persuasive arguments on discursive topics. Example subject areas include English and Citizenship.

A further constraint was that to ensure fulfilment of curriculum requirements, the prototypes that we tested in classrooms were not allowed to fail in such a way that they disrupted or derailed the lesson [6]. This had serious implications for the kind of prototypes that we were able to design and test. Therefore much of our work to date has been conducted using “low-tech” prototypes. As we will describe, this approach proved to have several advantages. Most importantly it allowed us rapidly to produce and trial a variety of prototypes. This gave us better understanding of desirable interactions before addressing the ability of RFID technology to augment and support them.

2. DESIGN ITERATIONS

2.1 Ethnography

Our research began with a programme of observation, involving minimal classroom intervention. The observer spent three weeks recording children’s normal school activities, and interviewing teachers in order to find which parts of the curriculum would benefit most from enhanced physical objects. We paid particular attention to objects that children already used, with a view to possible augmentation of these objects with RFID. We also observed school classes at the Science Museum in London where children interact with a wider variety of tangible educational materials, both technically sophisticated and low-tech, such as the large-scale “LaunchPad” activities.

2.2 Iteration #1: 3D Conceptual Prototypes

Our ethnography identified various physical objects that could be enhanced physically and electronically to structure and check logical arguments. We developed these through conceptual design workshops, constructing many exploratory 3D sketches (e.g. Figure 2a) from materials such as foam board and modeling clay. In each session, a video recording was made as designers demonstrated the sketches. The team then analysed its benefits and notational properties.

2.3 Iteration #2 Paper Prototype

In order to find out how children would approach the task of researching and constructing a persuasive argument from web resources, we ran a paper-only trial. Printouts of web pages are highly effective tangible representations, and can easily be augmented with RFID tags to provide augmented interaction. A small group of children supervised by a teacher were given a pile of page printouts relevant to a topic (Robin Hood and Mediaeval England). They were asked to construct an argument that would convince other people of their opinion on a question ("If you lived in Mediaeval England would you rather have been a peasant or one of Robin Hood's merry men?"). Three one-hour sessions were recorded on video by an observer in the classroom, and analysed later by the whole design team.

2.3.1 Argument Formation Cycle

On the basis of our observations, we developed a preliminary model of an Argument Formation Cycle (Figure 1). We observed that after a long initial period in which source pages are read, evaluated and selectively highlighted, relevant pieces of *evidence* are then grouped together. These groups are then named (e.g. Mediaeval Torture, Lifestyle of Merry Men) and claims or *statements* on each theme used to structure the argument. The final stage of argument formation is linearization: the argument structure turned into a linear form which can be delivered as a speech or an essay.

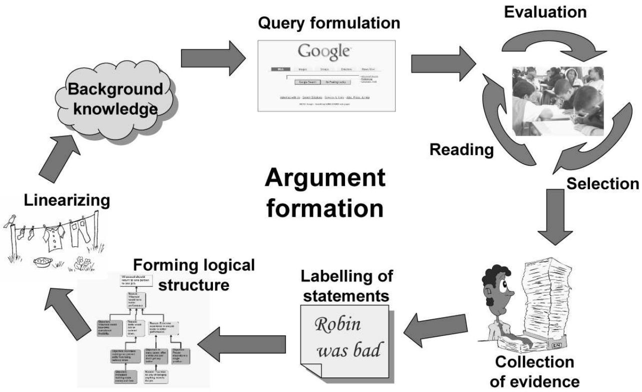

Figure 1. Argument Formation Cycle

The Argument Formation Cycle gave us a map of all areas of the process that we hoped to augment. This allowed us to target further prototypes at those activities where we thought TUIs would be most beneficial.

2.3.2 Rhetorical Rather than Logical Structure

The paper prototype trials led us to discard assumptions we had taken from prior research in Computer Supported Collaborative Argumentation (CSCA) [4]. We had expected that the TUI would significantly assist children to understand logical relations between points in an argument. But contrary to our expectations, children had no trouble understanding the logic or logical implications of any arguments or statements during discussion. However we did find that the children expressed confusion about the *rhetorical* structure of the argument. For example, they were not sure what they should do with material found during their research that did not support their side of the debate. This suggested that TUIs might be used to help students produce the rhetorical structure for a persuasive argument, rather than capturing logical structure as in CSCA systems.

2.4 Iteration #3 Evidence Collection

Our first trials of a 3D prototype focused on the selection, collection and labelling phases of the Argument Formation Cycle. We gave children small stands incorporating a whiteboard on which to write a statement, and a set of clips to attach collected evidence supporting that statement (Figure 2b). We intended that RFID tags in the documents would be recognised by an RFID reader in the stand, so that the logical relationship between statements and collections of documents would be recognised by the system.

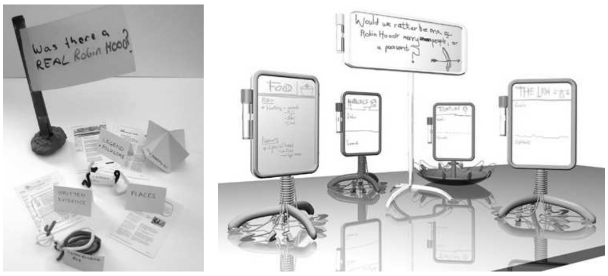

Figure 2. Iteration #1 and #3 selection prototypes

Initial evaluation used a low-tech version, with the stands as illustrated, but no RFID readers. We observed several problematic patterns of use:

- Children no longer collaborated as they had done with piles of paper in previous iterations. Instead, each child adopted one stand, collecting evidence just on that topic;
- Children transcribed evidence onto the whiteboard rather than attaching it to the clips. This further prohibited collaboration, and would make the proposed RFID operation ineffective.

2.4.1 Iteration #4: Evidence Collection Refinement

We addressed these issues in the next iteration with two subtle design changes. We drastically reduced the writing area on the board to discourage transcription. We also ensured there were fewer stands than children, which encouraged collaboration without removing the useful assignment of task roles to individuals in the group. These non-technical solutions were far cheaper to implement at this stage, before fully functional RFID prototypes had been developed. We then proceeded to investigate TUI support for the next phase of the argument formation cycle.

2.5 TUI's as an Aid to Rhetorical Training

Our trials suggested that the TUI should assist students in constructing rhetorical structure, rather than in analysing logical relations. In ancient times, students were taught the art of rhetoric using a series of exercises known as the *progymnasmata.* These exercises broke down the business of constructing an argument into a series of manageable steps that ensured that the student covered all the necessary ground and used his or research as effectively as possible. With the help of our teacher colleagues we updated three of these classical exercises:

- *Vituperation* – a speech opposing a person or idea;
- *Encomium* – a speech praising a person or idea;
- *Thesis* – a balanced argument dealing with points for and against an idea.

For each stage in the argument we produced an "Activity Square" – a large card stating what the student should do at that stage of the argument – e.g. "say something good about Robin Hood". Then we used statements produced in earlier stages of the Argument Formation Cycle as counters in a rhetorical board game. Children placed labels with these statements on suitable activity squares in order to structure their argument using evidence found in their research.

We continued iterative design of the TUI over five sets of trials, with varying form factors and degrees of computational enhancement (Figure 3).

Iter-ation	Statement Size & Shape	Activity Sq. Size	Tech-nology
5	2D (A4 paper)	A4	GUI
6	3D (A4 paper on boxes)	A2	GUI
7	3D (A4 paper on boxes)	A2	RFID
8	3D (Business card on stand)	A5	GUI
9	3D (Business card on box)	A5	

Figure 3. Differences between our prototypes.

2.5.1 Iteration #5 (2-D low tech, large scale)

Our analysis of previous trials found that argument structures are constructed from the collection of statements formulated by the children. Transcription of this material in order to create an argument structure is a time-consuming activity that does not directly contribute to the educational objectives. We therefore created a prototype in which the statements are recorded online and printed onto A4 sheets of paper. The activity squares were also printed on A4 paper (Figure 4a). We discovered this form factor resulted in exceptionally poor legibility, as statements and activity squares were hard to distinguish from a distance, and tended to be overlapped.

2.5.2 Iteration #6 (3-D medium tech, large scale)

Our next prototype improved visibility by attaching the A4 statements to large brightly coloured boxes. We also increased the size and contrast of the activity squares (Figure 4b). Whenever a child placed a statement on an activity square, a "Wizard of Oz" simulation updated a software visualisation of the complete argument structure that was projected onto the classroom wall. At the end of the session the final structure was printed out, so that children had a record of their work in progress that did not require transcription as in previous iterations.

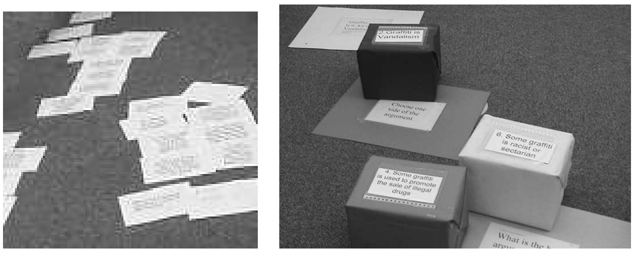

Figure 4. Iterations #5 & #6 (2d v/s 3d)

This large scale prototype was highly engaging, with children enthusiastically building towers of related statements on relevant activity squares. Unfortunately, the size of the individual boxes meant that statements higher in a tower would not be detected by an RFID reader. This was not a problem in our Wizard of Oz simulation, which was sufficient to show the advantage of digital visualisation of argument structure, but it would be a serious problem in a final high-tech implementation. A further problem with these towers was that the statements chosen first were typically most important, but were not visible when at the bottom of the pile. When children were asked to talk through the argument, they would start in reverse order of importance, with the box on the top of the pile. This was an unintended distortion of the rhetorical exercise itself.

2.5.3 Iteration #7 (3-D high tech, large scale)

In order to assess the implications of our design decisions for technological implementation, we moved at this point to building active prototypes that included RFID tags in the statement boxes, and RFID readers in the activity squares. The RFID technology used for this iteration did not support the "collision detection" method by which multiple ID tags can be detected by a single reader. This meant that two different statement boxes could not be placed on an activity square at the same time. We therefore redesigned the activity squares so that every square had a target, on which the children had to place each statement they wished to register. All statements had to be removed from targets before any student could register another statement. This enforced unnecessary turn-taking, and also meant that the physical arrangement of the tokens that had been registered did not reflect the recorded system status.

This change to accommodate a specific version of the RFID reading technology disrupted the running of the lesson, as did the performance of the prototype reader hardware: ID tags in the boxes were only identified about 50% of the time. For the first time since we began trials in schools the thing that we had wished most to avoid happened – a problem with our prototype resulted in the lesson "stalling" and the children losing interest in the activity we had created.

The benefits of our multiple low-tech iterations became clear at this stage. We had developed and evaluated a wide range of TUI options that allowed us to explore desirable interactions in the educational context with relatively little distraction from the limitations of electronic prototyping cycles. Iterations of electronic hardware require far longer to design and build, so that problems such as the detection of multiple ID tags, while technically feasible, significantly disrupt research progress.

2.5.4 Iterations #8 & #9 (2-D & 3-D md. tech, sm. scale)

The large size of our early prototypes also proved to be an important issue in a real school where storage space is at a premium, and where clearing large floor spaces for a single lesson may not be desirable. In further prototypes we therefore examined possible table-top embodiments. At the time of writing, we have conducted some further classroom evaluations, and are working on a redesign of the electronic RFID hardware for incorporation into the tabletop design.

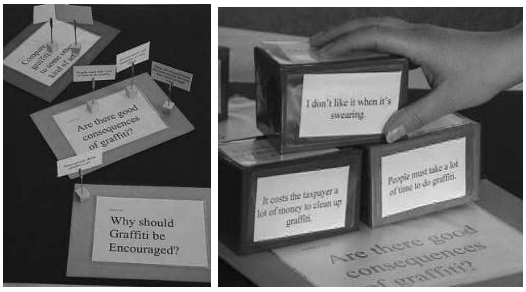

Figure 5. Iterations #8 & #9 (Small Scale)

3. CONCLUSIONS

We have found that Tangible user interfaces (TUI's) are particularly well-suited to a process of frequent, incremental and iterative design. This is because many of the most important aspects of a TUI – those around integration with the physical context of use - can be tested using low-tech prototypes which can be built quickly and cheaply. As we have shown with our early paper-only and selection prototypes and later "board game" prototypes, this allows not only for several iterations of one idea, but also for the trialling of several ideas which explore different aspects of the design space.

There are several valuable outcomes from our low-tech prototyping activities. We have discovered a novel application for TUI's in the teaching of persuasive argument to schoolchildren. We have trialled this in a classroom environment and in adherence to the requirements of the English National Curriculum. Perhaps just as important is the invalidation of our initial ideas as to how tangible user interfaces might be useful. We also now have a detailed understanding of the technical requirements that any "active" – i.e. technology-enhanced – prototype would have to meet. From our first attempts at introducing RFID technology into the prototypes we are also acutely aware of how the constraints of the electronic hardware development cycle can disrupt TUI interaction research.

4. FUTURE DIRECTIONS

This design work has prepared for the creation of an integrated system based on functioning RFID. We intend to build and trial such a prototype (possibly both in large-scale and table-top embodiments) in the next few months.

5. ACKNOWLEDGEMENTS

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