

Designing For or Designing With? Informant Design For Interactive Learning Environments

Michael Scaife, Yvonne Rogers, Frances Aldrich and Matt Davies

School of Cognitive and Computing Sciences

Sussex University

Brighton BN1 9QH, UK

+44 1273 606755

mikesc, yvonner, francesca, matt@cogs.susx.ac.uk

ABSTRACT

The value of involving people as 'users' or 'participants' in the design process is increasingly becoming a point of debate. In this paper we describe a new framework, called 'informant design', which advocates efficiency of input from different people: maximizing the value of contributions from various informants and design team members at different stages of the design process. To illustrate how this can be achieved we describe a project that uses children and teachers as informants at different stages to help us design an interactive learning environment for teaching ecology.

Keywords

Children, design, low-tech, hi-tech, informant, interactive learning environments, prototypes

INTRODUCTION

Involving users in the design process is now so deeply ingrained in the philosophy of HCI practice, that it would be difficult to imagine otherwise. Current textbooks, guidebooks or manifestos written on how to do 'good' software/system design proselytise the necessity of involving users from start to finish in the design process. Recently, however, the sanctity of this golden rule has been questioned. For example, Webb [15] has challenged the value of involving users on the grounds that it is infeasible and undesirable: "the user is not a designer and studies have shown that users' designs are generally inferior to those of interface professionals" (p. 82). He asserts further that users' inexperience and lack of design skills constrains and thus thwarts creative activity. However, one could equally argue the opposite: designers have a difficult time managing the complexity of software design and a closer involvement with the audiences they are designing for could greatly help them in their struggle. The real issue would seem, therefore, to be not one of whether involving users is good or bad but rather how to more effectively engage them in the design process.

The conventional HCI-based, 'user-centred' approach has been typically to position users as a testing or evaluation

service for designers to ensure those users' needs are met [cf. 11]. By placing users in this reacting role, designers can obtain a range of feedback as to what is good, bad and ugly about their designs. However, such a set-up means that the kind of feedback obtained from users is exclusively based on reaction rather than initiation [cf. 7]. A further problem with this kind of asymmetrical relationship is that the onus is entirely on the designers to take on board and translate the users reactions. Many obstacles can prevent this from happening in a beneficial way, ranging from the designers' own reluctance to reconsider and possibly throw away their own design ideas to organisational constraints that demand the product be shipped before any redesign can be put into practice. All too often the actual contribution made by users to the redesign of a system/interface is "too little, too late".

The more recently popularised, alternative 'participatory design' (PD) approach is to respect users more as partners in the design process and in doing so explicitly give them a more equal and responsible role. In this way users can jointly work together with the designers to develop a system to fit their needs. This kind of relationship is exemplified by the Scandinavian Approach to system design [cf 2] and more recently, by Participatory Design [13]. Here "the goal is to provide an equal opportunity design environment in which all participants can contribute as peer co-designers" [7].

Such approaches have proven to be effective for adult users, where it is possible for users and designers to view each other as peers. But what happens when the users are children and the domain is something that they know little about but which the software is specifically intended to teach them about? In what respects is it desirable, useful and sensible to set up design teams whereby children are given equal responsibilities to those of adult designers in such contexts? Moreover, is it possible for adults to treat children like themselves whilst at the same time not being patronising? Conversely, can children make contributions about the content and the way they should be taught - something which adults have always been responsible for?

The creative involvement of children early in the process of design has increased considerably in recent years. For example, Cypher and Smith not only used fifth graders in informal tests of their own examples of the KidSim rule set but also of rules written by other children [3]. Druin has long demonstrated the considerable value of inclusion of

Permission to make digital/hard copies of all or part of this material for personal or classroom use is granted without fee provided that the copies are not made or distributed for profit or commercial advantage, the copyright notice, the title of the publication and its date appear, and notice is given that copyright is by permission of the ACM, Inc. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires specific permission and/or fee

CHI 97, Atlanta GA USA

Copyright 1997 ACM 0-89791-802-9/97/03 ...\$3.50

children on design teams, arguing strongly for their competence in giving opinions and suggesting metaphors for the designer to work with [e.g. 4]. Similarly, Oosterholt, et al, describe the process of co-design of a communication device with children, pointing to the need to "enter their world", as well as to recognise the sophistication of the current generation. In the latter case the children were involved throughout the development process [9]. There is, therefore, a growing body of evidence that shows that children can and should be involved more in the design process. However it is not clear what status they should have in their relationship with designers. Should we view them in a participatory design context, where they are given the role of *partners* [4] or in a more user-centred context, where their level of involvement is more circumscribed by us?

Clearly, there is much to be gained from adopting a child-centred framework that allows for different kinds of inputs from children. In particular, they can have insight into what learning *methods* are effective and what motivates them, based on their experiences. Children are very good at letting us know what is it that keeps them engaged, which is often not what adult designers or their proxies (e.g. market research) would have expected. We also need to recognise, however, that children cannot design their own learning *goals*. Here input from teachers, psychologists and educational technologists can play a valuable role. But, again, we need to appreciate what each has to offer and not be tempted simply to use them as token guiding voices. For example, teachers are very good at informing us about what children find difficult to learn using traditional materials but generally do not have much to offer in terms of how to put interactive multimedia to good use. Similarly, educational technologists can let us know what kinds of learning metaphors might be effectively utilised in the design of interactive learning environments but not know how best to transform them into interactive media.

INFORMANT DESIGN: TREATING CHILDREN AS NATIVE INFORMANTS

Our approach to the child-designer relationship for designing interactive learning environments is to position ourselves between the user-centred and participatory design perspectives [cf 5, on a discussion of how ergonomists should do the same when designing products]. Instead of seeing children either as users or participants, we view them more as (native) informants¹. Why use the term 'informant'? Clearly it suggests that they are aware of aspects of learning/teaching practices that we are not and which we need to be told of. Sometimes this will concern content, as when they tell us what sort of feedback is fun, sometimes it will concern structural aspects, particularly when informing us about what encourages learning. A similar comment could be made about teachers, who also serve as informants here. So, by 'informant design' we

mean an interplay between privileged observations from potential users and ourselves with another set of skills. Hence, in treating children as native informants, we hope to be able to discover what we did not know rather than try to confirm what we thought we knew. We also do not treat them as equal partners, as we are realistic as to how much they can be involved, since they neither have the time, knowledge or expertise to participate in the collaborative model prescribed in PD approaches.

Another aspect of collaborative design is that it typically emphasises the use of 'low-tech' and 'lightweight' communicative and creative tools. Here, the emphasis is very much on *co-making* mock-ups and *co-constructing* rapid prototypes, as opposed to one group making them and another commenting on them. For example, one of the most well known methods, called PICTIVE, provides common office objects (such as Post-It notes, scissors, sticky tape and coloured pens) with which the users and designers can together model and design putative user interface objects for a given application. The success of such approaches has been documented elsewhere [8]. Use of such materials and methods seems particularly well-suited for children, who spend much of their time constructing. For example Druin and Solomon [4] describe a number of different ways of using such prototyping techniques. Typically low-tech prototypes feature early in the design process, before any coding begins. Our approach is to blend different *low-tech* and *hi-tech* methods that work in parallel whilst also informing each other. In this respect, the controversy over the merits of *lo-fi* prototyping versus *hi-fi* prototyping becomes a non issue [14]. Instead, the important point is to know how to use different methods, how they can inform and build on each other, and by doing so be clear about what it is that we are trying to prototype with different kinds of prototypes [6].

Where children are involved we need to consider how best to use low-tech materials to bring out their contributions. In particular, it is important to be clear what sort of data we might elicit from them. It is frequently noted that (adult) users have difficulty in articulating the ways in which a system might help them. However, children are likely to have difficulties, by definition, with articulating what needs the interactive learning environment should be meeting – since they do not know how to express concepts that they have not yet grasped. We think it useful, therefore, to try and be clear exactly what kinds of benefits accrue from the application of different methods. Likewise, we think it useful to be quite specific about what kinds of suggestions (their level and scope) a designer might expect from working with children, teachers, educational psychologists and others.

OUR FRAMEWORK

In Table 1 we present a preliminary methodological framework, based on our continuing experiences with developing interactive learning environments. It summarises the roles of the various contributors to the

¹Within anthropology 'native informant' denotes the value of seeking a view from *within* the culture while still attempting to go *beyond* it to form more general theories.

Phase of Design	Informant/Design Team Contributor	Input	Methods
Phase 1 – Define Domain & Problems	Teachers	Specify learning goals; Identify teaching practices/difficulties; Compare conventional & multimedia materials	Teacher interviews Curriculum requirements Teacher Panel
	Children	Explain difficulties with learning particular topics for identified goals	Talk with pairs of children in school context with existing materials
	Psychologists	Analyse learning goals	Cognitive-Developmental analysis
	Design team (all)	Explore and define scope of interactivity	Theoretical analysis of external representations
	Software/graphic designer	Begin prototyping	Preliminary sketches and ideas for representing domain
Phase 2 – Translation of specification	HCI analyst and psychologist	Target high-level functionality of multimedia implementation	Cognitive and interactivity analysis
	Software/graphic designer and HCI analyst	Turn requirements into software specification and determine feasibility	Storyboarding, sketching, scenario creation
Phase 3 – Design low-tech materials & test	Psychologist and Designer	Work to create low-tech materials	Cognitive analysis
	Software/graphic designer	Flesh out spec. and test design assumptions	Make low-tech materials - paper cut-outs, etc.
	Psychologists and designer	Test validity of cognitive assumptions	Facilitate child design and evaluation
	Children	Provide insight on building interface and motivational factors	Design through scenarios, games, etc.
Phase 4 – Design and test hi-tech materials	Software/graphic designer	Flesh out and validate design aims based on output from above phases	Prototype hi-tech designs using multimedia programming environment
	Psychologist and HCI analyst	Test validity of cognitive and pedagogical aims	Cognitive analysis and pre-, during and post-tests
	Children	Evaluate interactivity and iterating designs	learning tasks
	Teachers	Verify whether prototypes are an improvement over existing methods	Try out the prototype, suggest how could be used in teaching contexts

Table 1. Methodological framework employed in the study

design process, namely the 'informants' (children and teachers) and ourselves – the design team (two psychologists specialising in educational technology, an HCI specialist and a software/graphic designer).

The table shows how each informant provides different inputs to the design at various phases of the project using different methods. Each phase is only briefly described in the table so as to give an overview of the value of different methods and contributors. It should also be pointed out that each phase is not necessarily sequential, but may overlap and run in parallel. More detail will be provided in the next section where we explain our particular project, using this framework.

In the first phase of design the emphasis is necessarily on specifying appropriate learning goals and identifying the pros and cons of current teaching practices within the domain (here biology teaching for 7 to 11 year-olds). At this stage children and teachers are involved separately as informants, since they have quite different perspectives on what problems are most salient for teaching and learning. These data enabled the design team to itemise existing problems of teaching and learning a difficult topic. The output from this is a list of problems that are then turned into high level functionality requirements for multimedia implementation in the second phase. This is done through cognitive and interactivity analysis [see 10, 12]. These specifications are then used in phase 3 for designing the low-tech materials which are used by the child informants to come up with designs and suggestions as to what is motivating for them. Input from these sessions is then used for evolving the hi-tech prototypes, (which were begun in Phase 1 – owing to the amount of time required to build them). These are subsequently tested by the child informants and teachers and their design further iterated. Finally we would envisage a phase not shown in the table – the testing of prototypes in a classroom context, as part of a lesson plan.

Putting informant design into practice

In this section we describe how we put our informant design framework into practice for designing educational software. We begin by summarising the learning aims of our interactive learning environment and the learning problems we sought to address through designing interactive multimedia. We also describe briefly our experiences with using teachers as informants in the early stages of the project with the employment of a "teachers panel". Next, we describe the first prototypes we developed. Then we describe our efforts with low-tech materials to validate and extend beyond those early designs, an experience which underlined the potential value of the children as real contributors to our designs. Finally, we discuss the merits of informant design as an alternative to either user-centred or participatory design, especially for the design of interactive software for non-typical users or those who cannot be equal partners (e.g. children).

THE AIMS OF OUR PROJECT: ECO-I

One of the main aims of our project, called Eco-i², is to design interactive learning environments for domains that have proven difficult to teach using existing media. Here we focus on concepts in ecology such as food webs and element cycles which teachers and children, within the 7 to 14 year age band, have a hard time teaching and learning, respectively. Another aim is to focus on what would constitute 'good design' for learning using multimedia. In this respect we have tried to relate two things. The first is a theoretical analysis of what role traditional external representations, like diagrams or pictures, might play in learning. The second is an understanding of how new interactive technology (e.g. multimedia, Virtual Reality) might support alternative representational formats, enabling the learner to get beyond the constraints of current media. In doing this, we are investigating how new kinds of interactivity, that can only be implemented using new media forms, can support learning more effectively [see 10 and 12 for further details].

Project phase 1 – define domain and problems

We began this phase by analysing the demands of the current UK national curriculum for biology for ages 7 to 14 years of age, identifying how relevant concepts were to be introduced and what levels of comprehension were required at different points. We asked sixty children, across the age range, about their experience of being taught these concepts, probing them for the depth of their current understanding and identifying issues and teaching methods they found problematic. Children were seen in pairs, outside the class by one of the psychologists. Discussion was focused on current book/video material and classroom practices, for example: "Do you know what a food chain is? .. How did you learn about it? ..". In parallel we asked twelve teachers of this age range how they would approach the teaching task, for example introducing their pupils to concepts like food webs or the carbon cycle and what conceptual difficulties they typically encountered in class. All teacher interviews were individual, conducted by one of the psychologists. In addition to the UK sample a similar exercise was carried out with nine pairs of 7 to 11 year old children in the US public school system as well as interviews with five of their teachers. As with the rest of the project all sessions were recorded, either audio or video, for later transcription.

At this point we were also concerned to make some estimate of the current and potential value of computer-based teaching materials. One way in which we elicit this kind of information is via a 'teacher panel', conceived of as an analogue to a consumer panel. Here we had eight teachers of the 7-11 year-old group examine existing software for teaching ecology, both at home and in class, present individual reports on their experiences and meet,

²Eco-i stands for "Explaining External Cognition for Designing and Engineering Interactivity" and is a project funded by the UK's ESRC Cognitive Engineering programme (<http://www.cogs.susx.ac.uk/users/matttd/>).

under the direction of the psychologists, for a focus group discussion on what kinds of topics are problematic to teach, comparing traditional and computer-based media (or more detail, see 1, forthcoming).

All of these discussions and interviews were reviewed by the whole design team. We recognised that the data from the informants described different aspects of the same problem space and we used the data from the interviews in several ways. One was as input for a developmental analysis of the cognitive difficulties likely to be posed by different kinds of representation in learning. For example: what kind of diagram would work with an eight year old? What did they seem to understand? This discussion was linked to our analysis of how any external representation was effective, what the pros and cons of different forms might be, e.g. text versus graphic. Thus, even at a preliminary stage, the designer had a basis to begin sketching out a range of ideas for alternative representations.

The two most salient outcomes of the interviews/panel were the surprisingly wide range of approaches to teaching and the shallowness of learning evident in the students. Why was this so? Part of the problem lies in the complexity of the learning task – many of the concepts are hard, e.g. photosynthesis or energy transfer. But it is also the case that conventional media – paper, pictures, video – are ill-suited to represent these processes in ways that make them easy to visualise. Typically the child at school first encounters the carbon cycle, say, as a diagram consisting of boxes of text-labelled processes connected by arrows of uncertain meaning and where issues such as transformation of state (e.g. CO₂ gas 'becomes' C₆ sugar) may be unexplained although fundamental to understanding. To grasp such concepts requires a lot of further work – something which teachers or children rarely have the opportunity to do. It is no surprise that teachers do not have a strong common intuition about how to teach from, nor students a good grasp of what is conveyed, by these materials.

Project phase 2 – translation of specification

We chose to develop our ideas about improving the learning situation initially by producing software for children in the lower half of our age range, between 7-11 years. We began by considering how to design an interactive learning environment to teach about food webs. This is a fundamental component of ecosystem understanding. Children find it easy to understand the basic relationship of X eats Y. However, typically they do not understand that the feeding relationships are 'really' about energy transfer (they don't link to other concepts) nor can they use the food webs they construct to make inferences about the effects of species or population changes. How could we make this more accessible?

In this phase, then, we are principally concerned to take the problems identified in phase 1 and relate them to the possibilities afforded by the interactive software environment. Our point of departure was to try to devise an interactive learning environment to bridge the gap between the abstract representation (food web diagram) and the events that it represented (species interactions in the

ecosystem). We believe that this would make the underlying ecological concepts easier to understand and the material more accessible to the child. Interactive multimedia allows us to do this in a novel way by allowing dynamic changes to different displays in response to user interaction. We call this dynamic linking or 'dynalinks'. For example, for our first designs, we built a suite of interactive multimedia prototypes that used a pond as a model ecosystem. The series of prototypes leads the learner from a mode where s/he simply observes the ecosystem to one where s/he can effect changes in it which are simultaneously linked to a diagram representing the food web in the pond. Each module, therefore, introduces more cognitive complexity as well as different kinds of control of the changes that could be made to the pond. An example is illustrated in Figure 1 where clicking on a link of the web diagram activates behavioural actions in the animated pond, e.g. fish eats beetle. The important feature of this space is that the effects of manipulating a food web as an abstract representation can be directly viewed in the adjacent concrete animation. We are capitalising on a novel kind of interactivity to 'fix' a profound cognitive difficulty. During this phase much of the effort is from the interaction of HCI analyst and software designer, exploring the possibilities of mapping the interactivity ideal into runnable prototype animations.

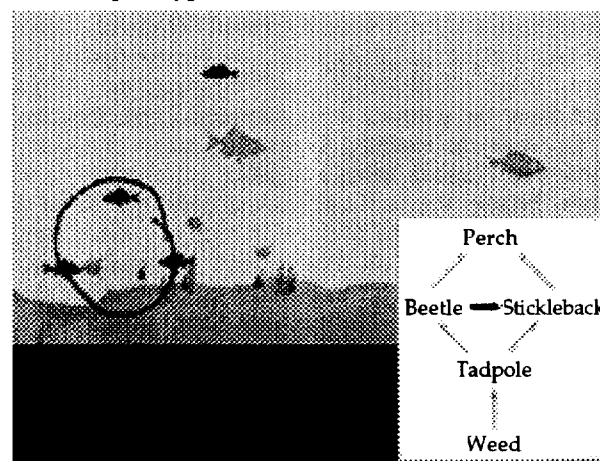


Figure 1. PondWorld ecosystem – two interlinked displays are shown: a canonical food web diagram and a concrete animation of it. The learner can 'turn on' a feeding relationship in the food web and observe the effect (circled) in the adjacent animation (see color plate 1).

Project phase 3 – design and test low-tech materials

As part of our efforts to improve and validate the design of these prototypes, as they were being built, we undertook a programme of evaluation with easy-to-use, paper-based materials. These were (i) manipulable cut-outs of a number of possible pond animals and weed and (ii) a colour print of the pond background (without animals) as used in the prototypes provided by the software designer.

These materials were taken to schools in order to test a number of assumptions about our project:

(i) *our design assumptions*: that children had no problems recognising the figures and cross-section as a pond community with a series of feeding relationships

(ii) *our cognitive assumptions*: that they could manipulate the scenes to construct a food web and that having both the web and the opportunity to manipulate the figures would be helpful in answering questions about the effects of changes to the population

Sixteen children from the ages of 9 to 11 years worked in same-age pairs, selected by the teacher, separate from the class. Teachers typically selected same-sex friends who worked together well. At the beginning of the session we explained to the children that we were developing software, primarily for CD-ROMs (since they were all familiar with this technology), and that it aimed to teach children in a better way than books currently did. What we wanted was for them to help us out by testing some of our ideas and to help us with their design. The pairs of children were seen by an adult 'facilitator', who was a psychologist from the design team. We structured the sessions as a series of three design-validation exercises.

Exercise 1: Validity of design and cognitive assumptions

For the first exercise, it was explained to the children that we were interested in how they understood food chains. They were shown the cut-outs and background and the feeding habits of each were discussed. Then the children were asked to put the cut-outs onto the background so as to convey these relationships. Any questions the children asked about the animals were answered. Next, they were asked to draw the resulting food web on paper or construct a food web diagram using a separate set of cut-outs and arrows. Finally the facilitator asked questions about the effects of changing the population such as "What would happen if the beetles all died?". Here, the children were allowed to make changes to their lay-outs and relate them to their web diagrams. This exercise demonstrated that the children could manipulate the items with ease but also that such manipulability was not, by itself, sufficient to allow them to solve novel problems - more powerful interactivity was needed.

Exercise 2: Familiarity with technology

For the second exercise we asked the pairs what they thought of software they had encountered at school or home. This produced an astonishingly wide and sophisticated set of answers. We discovered that the children had well-articulated representations of what they had come to expect from interactive software in general and its good and bad features, both in terms of enjoyment and of promoting learning. In short they seemed to have a good grasp of interacting with this *genre* of technology. Examples of their suggestions are:

- **error feedback:**

"It's boring if you have to go back to the beginning again. If you have to start all over again. You just want to go back a bit"

- **use in class:**

"If the sounds are too loud then the teacher will switch them off. She won't let you have music when you play it"

- **audio versus text:**

"Children don't find it interesting if it's got speech bubbles .. they find it more interesting if it's got sound .. it's quite boring when there's just writing"

- **need for unpredictability:**

"It can't be like a book.. where you read it again and it gets boring.."

- **interaction style:**

"The computer beeps if you push the wrong button .. that's how you know it's a mistake."

Exercise 3: Envisioning interactive software through interacting with the low-tech materials

For the final exercise we asked the children how they would design the software themselves. We decided to get around the problem described earlier - of children not being able to design for domains they have not learned about - by asking them to envisage the needs of children younger than they were, by a year or two. Typically our informants were able to remember their own experiences at this point.

The procedure we adopted was fairly loose-format. We asked the children what they thought would make a good CD-ROM for teaching about food webs. The facilitator encouraged them to use the low-tech materials that they had been working with in the previous exercises. Typically each pair of children would talk for anywhere between ten and twenty minutes about their ideas, which we recorded on audio or video tape. The children would often talk extensively without prompting but if they seemed to be stuck the facilitator would ask about the consequences of the imaginary user behaving in a certain way, e.g. making incorrect links in the food chain. At the end the facilitator asked for suggestions about special effects, such as noises made during eating. Throughout the session the emphasis was on eliciting as many suggestions for animations as possible while minimising input from the facilitator.

What ideas do they come up with?

A main finding is that the majority of children have absolutely no problem in using the paper materials to simulate an interactive game. They do this easily, providing animations, special effects, sounds and feedback with little or no prompting. Their animations were clearly understandable, mocking-up the kinds of interactions between creatures in the pond that they thought appealing. They had ideas about design at all levels, from the highly specific to the abstract. Specific examples are:

- **eating:**

"So the stickleback looks for food and sees the beetle [zooms the stickleback down onto the prey] .. grabs it .. says 'yum yum' .. [makes munching noise]"

- **sounds:**

"When it dies it makes a long moaning noise [makes noise]" (child 1) "No it doesn't, things don't make a noise when they die" (child 2)

- **duration:**

"..you could have 'beat the clock' .. you could choose if you wanted to beat the clock .. you could pull the hands round so you could have 10 minutes or half an hour"

- **input affordances:**

"You could have a mouse with three buttons .. each would have a sticker .. the left button would start the game up, the right button would finish it .. the middle one would save .."

There were also many examples of their grasp of the need for higher-level control of the simulation. For example, all of their designs involved a puzzle or game.

- **initial state setting:**

"You have all the animals lined up like this [shows a food chain] then they go away [i.e. screen clears] .. then [voice over] put them in order.. who eats who?"

- **question/answer:**

"You have questions at the bottom like for [indicates perch] and it says 'who do I like to eat?' to see if you've remembered .. to see if they've been listening or not"

- **sensitivity to age/gender differences:**

(If information was delivered as text) "...younger ones wouldn't be able to understand .. to read it .. you could have age levels (to adjust form information is delivered in)"

(On possibility of gruesome noises for animals dying) "...depends on what age they are .. if they were quite old you could have some really revolting ones .. boys prefer more gruesome noises"

The value of these suggestions, of which we have just a small set here, was immense. Firstly they validated some of the *intuitions* which we had about design – such as the value of voice over text and, equally important, they forced us to reject others. Second they provided specific design suggestions that the designer was able to incorporate such as the dying noises and the question formats. Thirdly the exercise allowed us to understand far better how to formulate scenarios for use with children that maximised the potential benefit from low-tech materials. For example the suggestions of one pair can be immediately incorporated into the exercises of the next pair, allowing them to develop the ideas further.

Phase 4 – Designing and testing hi-tech prototypes

As mentioned earlier, we already were developing a suite of interactive multimedia prototypes (PondWorld) in our project when we began to use the children as design informants. The prototypes were tested both in-house, by bringing children to our laboratory and in the school. In testing to date a total of twelve, same-gender pairs of children were involved, spread equally across the 7 to 11 year age range, with equal numbers of boys and girls. These children did not have access to the low-tech materials. The prototypes were introduced after a brief description of the project's aims. We said that we were interested in finding out what the children did and did not like about the program because we were still in the early stages and able to make changes. The children were shown the opening screen, giving them access to the four modules and then allowed to interact with the modules as they wanted. The sessions were facilitated by one of the psychologists in the team and the software designer was sometimes present as well. Intervention was kept to a minimum with the exceptions of the facilitator steering the children to take the modules in a particular order

(increasing complexity of content). In addition we sought feedback on the prototypes from teachers. We did this both at the teacher panel (group discussion) and also during some additional (individual) interviews – a total of fourteen teachers participated in this way.

Responses to the hi-tech prototypes were primarily focused on a wide range of interface issues. Typical concerns here were: the benefit of better narration, feedback and cues for action. Examples include: the need for commentary for indicating the range of possible actions which users would otherwise have to discover – such as 'add food', 'click on a link'; the need to distinguish buttons (support actions) from representations (such as circular icons in the food web). These data came primarily from the child informants. Teachers typically did not notice or mention these aspects, taking their brief to be one of commenting on the classroom value of the prototypes. One persistent concern that they had was the motivating power of the software, something they shared with the children but expressed in a different form.

In addition, we discovered how good children are at testing the non-obvious aspects of our design, stretching the limits of the software functionality. For example in one module where the task was to stock a jam jar from a 'palette' of animals, children would drag and drop animals outside of the jar just to see what happened. Finally we were able to broadly support our cognitive and design assumptions that dynamic linking of abstract representations (e.g. schematic diagram) and the physical world view (e.g. the pond) helped understanding. This remains to be put to rigorous empirical test but questioning of children, together with their spontaneous comments, suggests that many understood the links between the two views *after* interaction with Pondworld where they had not before.

Relation between findings from low-tech and high-tech prototypes

The findings resulting from the paper-based testing and design sessions were much more general in their scope compared with the more specific findings arising from the testing of the hi-tech prototypes. In particular, they highlighted the crucial importance of making learning game-like and how important 'silly' (to adults) things are. The last of these concerns is significant since it is very difficult for adults to decentre sufficiently to realise what is fun feedback. In many ways, the inherent flexibility of the 'design your own software' format lends itself to more general suggestions than eliciting responses with the software prototypes. When confronted with a piece of software that is already designed by any user – be it child or adult – the evaluating users are constrained to make suggestions at a lower level of detail. Wong [16] also has pointed out how interfaces that are presented as rough sketches are often much more appropriate prototypes for eliciting responses from users than more finished interfaces because they prevent users getting too fixated on low level issues, such as what size a button should be rather than asking more general questions like whether buttons are appropriate for the application in hand.

PROBLEMS AND OVERHEADS

The process that we have described worked well in the context of the project. However it was not without its difficulties. Firstly not all children are able or willing to be creative designers, or even informants about current practices. The demand characteristics of talking with unfamiliar adults, in a school context, can be a big inhibitor. Several of our informants offered typically short or uninformative contributions. Working in pairs helps to lessen this problem as does having the shyer children begin by commenting on the suggestions of others, rather than begin from scratch. A second, related difficulty is that it is hard for the facilitator to judge when to intervene to revive a flagging discussion: too soon or too often and the situation can become overbearing, with children possibly feeling that their contributions are not being listened to. A third issue concerns the effort that was involved in following our framework. Clearly not every project will have as many resources to draw on. So could steps be shortened or omitted? We feel that whilst such short-cuts maybe possible (e.g. spending less time on the domain definition in stage 1) such a decision would lessen the value of the process. Moreover, in doing so we would run the risk of imposing our view on a classroom culture that we had little experience of.

CONCLUSIONS

Informant design is a framework for involving various participants in the design process, that aims to maximise their input at different stages of design. We have shown how it can be used for the design of interactive learning environments – in this case the development of multimedia software for teaching difficult concepts in ecology. We believe that the framework is also generalisable to other domains, although there will need to be a different emphasis on the various contributions of the relevant informants, depending on what is being developed and for what domain. We consider it important to identify what these should be, rather than trying to build an integrated team to work together throughout the design project. In part this is because we value the use of a diversity of informants, (e.g. teachers and children) to maximise the variety of suggestions. But it is also because we see efficiency as being about specialised inputs. Thus, we see different informants as shaping the design at different points; for example, at the beginning to help us problematize the domain, in the middle to test out and reflect on our cognitive and design assumptions and at the end to evaluate our prototypes in real-world contexts. The role of informants in the design process, therefore, is multiple – as partners, users and evaluators, designing with and for us.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge support from the ESRC Cognitive Engineering Programme, project L127 30 1001 66. We also thank schools in East Sussex, UK and LA County, USA. Yvonne Rogers thanks Apple Computer Inc., and Stanford University where she has been on sabbatical. Mike Scaife thanks UC Irvine where he has been on sabbatical.

REFERENCES

1. Aldrich, F., Rogers, Y. & Scaife, M. CD-ROMS for Primary School Science: Teachers' evaluation of two contrasting formats (in prep).
2. Bjerknes, G., Ehn, P. and Kyng, M. *Computers And Democracy: A Scandinavian Challenge*. Gower, Brookfield, VT, 1987.
3. Cypher, A. and Smith, D.C. KidSim: End User Programming Of Simulations, in *Proceedings of CHI'95*, (Denver, CO, May 1995), ACM Press, 27-34.
4. Druin, A. and Solomon, C. *Designing Multimedia Environments for Children: Computers, Creativity and Kids*. John Wiley and Sons, NY, 1996.
5. Eason, K. D. User-centred design: for users or by users? *Ergonomics* 38, 8 (1995), 1667-1673.
6. Houde, S. and Hill, C. (In Press). "What do Prototypes Prototype?" In *Handbook of Human-Computer Interaction (2nd Edition)*, M. Helander, T. Landauer, and P. Prabhu (eds.), Elsevier Science B.V. Amsterdam
7. Müller M.J., Wildman, D.M. and White, E.A. 'Equal Opportunity' PD using PICTIVE, *Commun. ACM* 36, 4, 64-65, 1993.
8. Nielsen, J., Bush, R.M., Dayton, J.T., Mond, N.E., Müller, M.J. and Root, R.W. Teaching experienced developers to design graphical user interfaces, in *Proc. of CHI'92* (Monterey, May 1992) ACM Press, 557-564.
9. Oosterholt, R., Kusano, M. and de Vries, G. Interaction design and human factors support, in the development of a personal communicator for children, in *Proc. of CHI'96* (Vancouver, BC, April 1996) ACM, 450-457.
10. Rogers, Y. and Scaife, M. How can interactive multimedia facilitate learning? To appear in *CD-ROM Proceedings of the First International Workshop on Multimodality in Multimedia Interfaces*.
11. Rubinstein, R. and Hersh, H. *The Human Factor: Designing Computer Systems for People*. Digital Press, USA, 1984.
12. Scaife, M. and Rogers, Y. External Cognition: How do graphical representations work? *International Journal of Human-Computer Studies*, 45, 185-213, 1996.
13. Schuler, D. and Mamioka, A. (eds.) *Participatory Design: Principles and Practices*. Lawrence Earlbaum, Hillsdale, NJ, 1993.
14. Virzi, R.A., Sokolov, J.L. and Karis, D. Usability Problem identification Using Both Low- and High-Fidelity Prototypes, in *Proceedings of CHI'96*. (Vancouver, BC, April 1996) ACM Press, 236-243.
15. Webb, B.R. The role of users in interactive systems design: when computers are theatre, do we want the audience to write the script? *Behaviour and Information Technology*, 15, 2 (1996), 76-83.
16. Wong, Y.Y. Rough and Ready Prototypes: Lessons from Graphic Design, in *CHI'92 Conference Companion* (Monterey, May 1992), ACM Press. 83-84.