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Children's interactions with interactive toy technology

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Abstract Digital toys offer the opportunity to explore software scaffolding through tangible interfaces that are not bound to the desktop computer. This paper describes the empirical work completed by the CACHET (Computers and Children's Electronic Toys) project team investigating young children's use of interactive toy technology. The interactive toys in question are plush and cuddly cartoon characters with embedded sensors that can be squeezed to evoke spoken feedback from the toy. In addition to playing with the toy as it stands, the toy can be linked to a desktop PC with compatible software using a wireless radio connection. Once this connection is made the toy offers hints and tips to the children as they play with the accompanying software games. If the toy is absent, the same hints and tips are available through an on-screen animated icon of the toy's cartoon character. The toys as they stand are not impressive as collaborative learning partners, as their help repertoire is inadequate and even inappropriate. However, the technology has potential: children can master the multiple interfaces of toy and screen and, when the task requires it and the help provided is appropriate, they will both seek and use it. In particular, the cuddly interface experience can offer an advantage and the potential for fun interfaces that might address both the affective and the effective dimensions of learners' interactions.

Keywords: *(please add six or so keywords - see 'standard list attached)*

Introduction and theoretical background

Information and Communication Technologies (ICT), and in particular the desktop computer, are now a part of classroom culture; the expectation of their use is cross-curricular and exists from an early age (see Plowman & Stephen, 2003). Within the infant classroom and beyond, there is an increasing pressure to integrate ICT through both wired and wireless technologies. But how can this integration be pedagogically grounded, whilst at the same time innovative and engaging? This paper explores the use of digital toys and in particular their potential for offering collaborative support and engendering collaboration between peers. This exploration was conducted within the context of an educational theory that emphasises the importance of collaborative support and which acknowledges the current role of the computer as an alternative

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tool for communication and interaction (Tikhomirov, 1979).

The image of the computer as a partner providing feedback and support has been presented by others, including Papert (1980) and Chan & Baskin, 1990). This collaborative partnership role is central to this paper, which considers how and why digital technology might provide support to young learners. Scaffolding is a term coined by Wood *et al.* (1976) from the ideas of Vygotsky (1978, 1986) to account for how a more knowledgeable partner can assist the cognitive development of a less able one, and gradually foster the development of successful independent task performance. The work of Vygotsky places emphasis upon interaction between a learner and her environment. The development of the individual is the result of her internalisation of this interaction: the relationship between development and learning was the object of Vygotsky's attention when he proposed the Zone of Proximal Development (ZPD) as the essential 'ingredient' in effective instruction (Vygotsky, 1986). A fundamentally important feature of the ZPD is the necessity for collaboration or assistance from another more able partner. The need for this more able learning partner arises from the belief that the activities that form a part of the child's education must be beyond the range of her independent ability. Teachers are able to fulfil the sort of collaborative partnership role envisaged within this theory (Plowman *et al.* 1999). This paper explores whether digital toy technology provides collaborative support to young learners.

The desktop metaphor and the design of Interactive Learning Environments (ILEs) using scaffolding techniques proposed by Wood and colleagues for face-to-face interactions have been used to implement software scaffolding and have offered designers one way of implementing flexible assistance for learners of different ages. Examples of software scaffolding can be found in the adaptation of Wood's original notion of scaffolding into the contingent teaching approach implemented in the QUADRATIC tutor (Wood *et al.,* 1992; Wood & Wood, 1996) This provides a series of graded help interventions that support the learner. Peer discussion is also one of the most powerful ways of implementing scaffolding approaches. Guzdial *et al.* (1996) and Luckin *et al.* (1998), for example, describe an approach to scaffolding learners quite different to that of Wood. Assistance is tackled through support for peer collaboration rather than graded interventions by the system. There is a large literature on the benefits of peer collaboration in general (e.g. Dillenbourg *et al.,* 1995), in paired reading (Topping, 1988) and in learning through interactive multimedia (Jackson *et al.,* 1996).

Of course, the question of effective collaborative assistance is not just about the *content* of the help provided by a collaborator, human or digital, it is also about *how* that help is made available to learners. There is much emphasis within education upon learners' metacognitive skill development that brings with it a need for system designers to explore how learners seek and use the help provided. Various recent studies have shown that learners do not always make effective use of the available help (Luckin & du Boulay, 1999; Wood & Wood, 1999; Aleven & Koedinger, 2000; Luckin & Hammerton, 2002; for example). However whether concerned with designing help, promoting peer collaboration or exploring how learners ask for help, the emphasis of the work on software scaffolding has been entirely directed at the desktop computer metaphor. So, what happens when the helper is taken out of the box? This paper describes empirical studies and discusses the ways in which children requested and used assistance from the digital toy, the accompanying software, their peers, parent or the adult researcher. The toys and software used in this work are not particularly sophisticated in terms of the range of support that they can offer. They do however, offer a means of investigating how children conceive of and use these toys as potential helpmates.

CACHET is a research project that aims to construct an explanatory framework for the interaction and mediation engendered by digital toys. The electronic toys used in this project are free-standing soft toys that can move, speak and respond to a child’s touch. They can also be ‘linked’ to a PC with a special wireless unit that transmits information between the toy and the computer. In freestanding mode (they are about 30 cm. tall) these toys superficially appear like traditional soft toys but they have motors to provide movement and a ROM chip so they respond to inputs. The toys can gesture, using programmed motion; and speak, using a digitised vocabulary of more than 4000 words, so they can play simple games. Interaction operates through sensors located in parts of the toy’s body, each of which controls a different function. When combined with compatible software, and operating via wireless connection with the PC, further interaction can take place through educational software games. The software encourages basic language and number skills and the toy can comment on the child’s interaction, provide feedback and give support. The child is therefore no longer interacting solely with the computer or solely with the toy, but is also interacting with a toy that, in turn, interacts directly with the computer and mediates the child’s actions. Figures 1 and 2 illustrate the DW (Arthur’s sister character) toy without the software and the Arthur toy being used in conjunction with the software.

Fig. 1. DW Toy

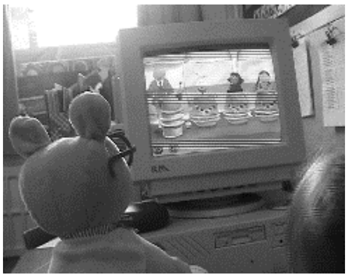

Fig. 2. Arthur Toy and software

The research explored how children interact with the toys and the associated software in the informal and formal learning contexts of children’s homes, out of school clubs and a primary school. Within these different contexts the mapping interface and interactivity were explored in order to describe and analyse what motivates emotional and cognitive engagement. This will address questions such as:

- Are the patterns of interaction goal × directed?
- To what extent do individual differences account for different patterns of interaction?

There is especial interest in the nature of the assistance that the toy and/or software may afford the children as they complete the activities provided. The findings specifically address the following questions about how children ask for and use help as they interact with this digital toy technology:

- From where do children seek assistance, the toy, software, peer or researcher?
- Do children use any assistance offered without their specific request? If so is there any difference between their reactions to the different sources of assistance?

- Even if they take notice of the help, do children interpret it correctly?
- Have children sufficient mastery of the computer interface to implement help when given?
- If the toy is absent, the same hints and tips are available through an on-screen animated icon of the toy's cartoon character, do children react in the same way to the same content delivered through different interfaces?

How help is offered by Arthur and DW

The software consists of a number of discrete games. Whilst engaged in the software activities, children are able to elicit help and useful information from the toy by squeezing its ear. If children are having difficulty progressing through a game, or persist in making the same mistake, the toy may remind them of the opportunity to get help by suggesting that the child 'squeeze my ear for a hint'. If the toy is not present during a software session, an image of the head and shoulders of the Arthur character appear on the right hand side of the computer screen within a large circle. The character seems to follow the child's progress through the games as its head and eyes move from side to side. In this manifestation, useful hints can be obtained simply by clicking on the icon. For example, one of the most popular activities on the games CD-ROM 'Arthur's Brain Teasers' is the hide-and-seek based 'Where's Pal?'. Children are presented with a picture of the Roman Coliseum, featuring a 5×6 array of windows. Arthur's dog Pal hides behind one of the windows and the child's task is to locate the dog by clicking on each window in turn. If the child's selection is unsuccessful (i.e. they don't find Pal on any given turn), they are given feedback that varies in sophistication depending on the selected level of difficulty. On the easiest level, the square glows red, green or blue depending on how close the selection is to Pal's actual hiding place, and the child is given an audio prompt such as 'You're very close/far away from Pal's hiding place' by the game's host character, Buster. In addition, children can get extra help by squeezing the Arthur or DW toy's ear or clicking on the icon. In this case, children are offered a hint along the lines of '*Why don't you try a window lower down*' or '*I think Pal's hiding in this window*', followed by one of the squares in the array flashing and buzzing conspicuously. While occasionally the correct square or at least one close to it is highlighted, these hints are often misleading, forcing the child to weigh up whether or not to take Arthur or DW's advice or to ignore it.

Taking Arthur and DW into children's schools and homes

This study took place in a range of learning contexts (at home, in a school classroom and in out of school clubs) so used a common core of data collection methods as far as possible and compared use of the toy alone, the software alone and the two used in conjunction across all sites. This common core was supplemented with additional methods, such as interview data and diaries, that were suitable for the different conditions in specific locations. The focus was on help-seeking behaviours here and so the main source of data is the video, which was transcribed and categorised as described in the next section. However, other forms of data were collected to inform other aspects of the study. These included the Wechsler Pre-School and Primary Intelligence Scales – Revised (WPPSI-R), which were used across all sites and the

Pre-school Play Behaviour Scale (PPBS)* which was used in the out of school clubs and the school classroom.

Children taking part in the studies *at home* were visited by the researcher three times over a period of approximately two weeks (at the beginning, at the midway point and at the end). Twelve children (six girls and six boys) with an average age of 6:2 years were involved in the home studies. Half of them were randomly allocated to receive the toy first and were given the software at the midway visit, the other half received the software first and were given the toy at the midway visit. In all cases, the children kept both items for the second week of the study. The toy was mainly used by individual children, although occasionally a sibling or friend would join in. The researcher gave parents a diary for completion over the whole two-week period to provide background information and data on use of the items whilst the researcher was absent. As the homes were used as a naturalistic context of use there was no control over how often or for how long children used the toys or software and video recordings were made on an opportunistic basis.

A more controlled approach was adopted in the *school classroom*, with detailed, dual-source video analysis of 32 children (16 girls, 16 boys) with an average age of 4:7 years. Children were observed on single visits and spent about 20 minutes playing with the toy on its own followed by an average of 40 minutes minutes playing with the software. Both sessions were recorded on video. Half of the children used the software with the toy, the other half used the software without the toy. Their teacher completed a PPBS for each child and parents provided data on home computer use and the child's favourite software and toys.

Fieldwork in the four *out of school clubs* was similar to that conducted in the primary school inasmuch as children used the items for fixed periods of time, were observed once and the playleaders completed a PPBS. Twenty-two children (nine girls, 13 boys) with an average age of 5.5 years participated in the sessions which were an average of 30 minutes in duration. Children used the toy/software both individually and as pairs and, as in the studies based in homes, some children were introduced to the toy first and some children to the software first.

At the start of each software session children were given brief instructions about how to select a game (by clicking on one of Arthur's friends, each of whom hosts their own distinctive activity). They were also made aware of the help that is available with a demonstration of squeezing the toy's ear or clicking on the on-screen icon. Children were told '*Don't forget, if you want some help to play the game, you can always ask Arthur and he'll give you a hint*' and the researcher ensured that the child knew how to access the help facility. At the school and out of school clubs the children were encouraged to activate the help by the researcher prompting '*Why don't you ask Arthur?*' if they appeared to be having difficulty or were asking questions of the researcher that were within the toy's help repertoire,

Analysis and results

From the video tapes dialogue and behaviour on the video tapes are transcribed in the following categories: researcher comments; action (e.g. pointing, activating toy); comments and dialogue between children (C1 and C2) and researcher; comments

* The WPPSI-*R*-tests are part of an age-appropriate, widely recognised group of psychological tools, consisting of one verbal and one nonverbal ability-rating test and are used with all participants. The PPBS are used by playleaders and teachers to enable us to compare the children's typical styles of play.

from the toy; dialogue from on-screen characters or screen events on screen (e.g. activity selection, response to help prompts).

The semistructured transcripts allowed an exploration of how, and from whom, children evoke or request assistance, and any apparent facilitative effect of the toy in terms of enhancing children's interactions with the software. An example of the transcript layout is presented in Table 1. Analysis of the transcripts enables enquiry of a range of questions about children's help seeking preferences and behaviours.

Table 1 Transcript structure

Time	Action	Child C1	Toy	On-screen/ System
1.48				Music starts
2.00	C1 takes control of mouse between Arthur and C2	I want something to play with		
2.04			Let's have a dance lesson. Squeeze my hand….	
2.06	C2 squeezes toy's ears and hand Squeeze my watch…		…toes and ears to teach me a dance.	

The findings are presented in two sections: initially the ways in which children from all contexts used the technology with examples of session transcripts. Each of the descriptions addresses one of the key questions that direct the investigations into how children ask for and use help. The second part of this section presents the results of a detailed analysis of the data collected in the school context. It reports on a particular software activity that invariably led to children seeking and using help, either from the researcher or from the technology.

- How children ask for and use help
- From where do children seek assistance, the toy, software, peer or researcher?

Children rarely seem to seek assistance. If they do, their source of help varies. In the home context queries about operational issues tend to be addressed to the researcher whereas queries about the activity's content are more likely to be directed to a parent, if available. In the school context the researcher is asked. Most help requests involve interpreting what the toy or software says ('what did he say?'), but once a child becomes competent and aware of the help facility provided through the technology she may ask the toy or on-screen icon for help. However, this is often as a result of prompting from either an adult or peer.

The transcript extract included in Table 2 is taken from almost 29 minute into a session in the home context. The child is a boy (age 6 ys. 9 mths.) with very little prior experience of computer games. He relies heavily on his mother, ignoring prompts to ask the on-screen Arthur for help. His mother is also relatively inexperienced and has difficulty figuring out what to do, so both rely in turn on the researcher. After a hesitant start, this child became extremely competent and moved rapidly through the levels and nearly exhausted the software's capabilities. As with all the subsequent transcript activities, the column used to show time and any columns without entries are omitted to save space.

Across contexts, the nature of the software task the children were engaged with had an impact upon their help seeking behaviour. One of the software games involves the different cartoon characters taking part in a quiz, another takes the shape of a searching game where children look for Arthur's dog Pal. When playing these two games children used more help, both from the toy and from the onscreen icon.

Table 2. Seeking help from a parent

Researcher	Action	Child C1	Parent	Output from characters on the screen
If at any point you want help don't forget Arthur is there to help you.				
		Do you have to try and get the dragon?		
			Yes, with the catapult.	
		Where's the catapult?		
Just below Arthur, look can you see it between Arthur and DW. If you hit the green button it will show you what it does.			*Mum points to screen* Right, try the green button.	
	Child clicks on green button and fires balloon which misses dragon			
				(from on-screen characters) So it fell a little short. Send balloons up here.
			(laughs)	
		Is that the catapult?		
			Yes.	

Do children use any assistance offered without their specific request? If so, is there any difference between their reactions to the different sources of assistance?

Children often appeared to ignore any hints or tips being given by the toy or software. The following extract in Table 3 illustrates a boy (age 6;5) failing to find the target of the game despite numerous clues from the game's host. The extract is taken from 6.46 minutes into the session. After many unsuccessful attempts the child admits defeat to the researcher.

Table 3. help from Toy ignored

Action	Child C1	Output from characters on the screen
Child tries several windows unsuccessfully		(From the on screen Arthur icon) You're very close to Pal's hiding place. You're very close to Pal's hiding place. You're very close to Pal's hiding place. You have nine guesses left. You're near Pal's hiding place. You're sort of far away from Pal. You have seven more guesses
Looking at screen	I don't know where to look.	

The main response to an unprovoked comment tended to be a look or a reaction when the toy or software offered praise. Sometimes this amounted to a smile, but it often revealed the children's irritation with the inappropriate feedback being given. In Table 4 the flattery offered by the toy is not well received. This is an excerpt from a session involving reception-class boys (4;4 and 4;11) and is taken from 4 minutes into the session. Child 1′s frustration at not being in control of the on-screen action emerges as irritation at the irrelevance of the toy's flattery. Eventually during this session, both boys begin to verbally abuse the toy and subject it to some rather rough and inappropriate treatment.

Table 4. School context, software session with toy

Action	Child C1	Child C2	Toy: Arthur
C2 in control of mouse			You're doing great!
C1 turns to R	He keeps on talking		
			You're doing great!
C1 points to on-screen printer icon	(mumble) Press that printer	No	
	Just chuck it Push…just…(mumble) throw it that hard		That looks cool. You're an artist
C1 looks at Arthur	We're not! Just stop talking for a bit		That looks cool

Even if they take notice of the help, do children interpret it correctly?

If children do notice the help offered and follow the advice given, it mostly results in success. However, when the advice given by the toy or software is incorrect (for example, suggesting the child look for Pal the dog in the wrong place) further help is ignored or disregarded. If children do ask for help and succeed in their task, the pleasure shown seems to be high, regardless of whether the child was prompted by an adult to ask for help or not. This extract in Table 5 shows a girl (age 5;3) being helped with the game by her older sister and brother. Previously the children have asked the onscreen Arthur for help and have had a mixture of correct and incorrect help offered. When the on screen Arthur offers incorrect help, the children shout abuse at him. The transcript extract occurs 4.28 minutes into the session.

Table 5. Interpretation of help

Researcher	Action	Child	Siblings	Toy/on screen Arthur	Output from characters on the screen
	Begins new game, clicks on Arthur immediately				
				Try clicking on this window. (Window flashes)	
	Clicks on suggested window				
					You're very far away from Pal
Arthur's not very good is he?			(Shouts at Arthur)		
					You're near Pal's hiding place
			Bum (points at window)		
		Bum			

Have children sufficient mastery of the computer interface to implement help when given?

The young children observed in this study proved to be sophisticated users of technology. They could co-ordinate the integration of multiple interfaces and multiple artefacts. In particular the nonscreen based tactile toys engendered pairs and larger groups of children in social interactions and collaboration between peers. When interacting in dyads, one child might be watching and holding the toy, see that help was needed and request it from the toy. This could work well, but the spoken help offered by the toy was often overridden and stopped by the child in control of the mouse or keyboard selecting some other functionality so that the help offered by the toy remains incomplete and of little or no use

If the toy is absent, the same hints and tips are available through an on-screen animated icon of the toy's cartoon character, do children react in the same way to the same content delivered through different interfaces?

Less advice was taken from the onscreen icon than from the toy itself. Children would usually stop and listen to the individual game's host for instructions at the start of a new game, only a few children (mostly, young, low ability or inexperienced learners) either asked the researcher for help immediately, or plunged straight into the game without instructions.

Playing with Pal

The transcripts from sessions across contexts give a broad view of the way children used the toy, but a more detailed analysis using the data collected in the school classroom provides greater insight into children's help seeking patterns. The analysis reported here is taken from the transcripts of the sections of video that recorded children's interactions around the game requiring them to search for Arthur's dog Pal (as described earlier). Figure 3 illustrates the results of the analysis of children's use of the toy and onscreen icon as a source of help.

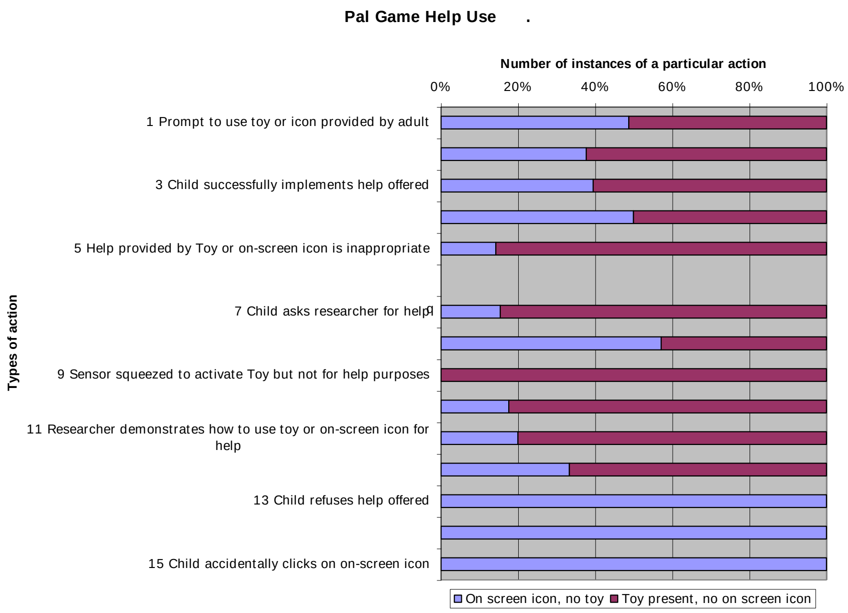

Fig. 3. Comparisons of help seeking and use behaviour with and without toy.

There were 24 children (6 pairs and 12 individuals) who played this game during their interactions with the software. One group of 12 children (3 pairs and 6 individuals) played with the software with the toy present and a second group of 12 children (3 pairs and 6 individuals) played with the software without the toy being present. Many children required assistance from the researcher or a peer in order to elicit help from the toy or onscreen icon and there were examples of children from both groups subsequently ignoring the help provided by Arthur or DW. There were, however, some interesting differences between the group of children who have the toy as well as the software, and the group of children whose representation of Arthur or DW is only through the on-screen icon.

Figure 3 illustrates the ways in which children used the types of help available to them as they played with the software. There were many more instances of interactions involving other people, either the researcher or a peer, in the condition in which the toy was present. The left hand side of the chart in Fig. 3 lists the categories of help activity that were coded from the video tapes. The values for Categories 1–4 suggest that the researcher present in the session prompted the children with the toy as much as those without the toy to seek help. At the same time they indicate that there was a slightly greater uptake of this adult prompt by children with the toy and also a slightly greater success rate from implementing the help offered by the toy in comparison to the on-screen icon. Category 7 quantifies the number of times the children asked the researcher for help and indicates that this was far more likely to happen when the children were using the toy than the on-screen icon. Similarly, Category 10 illustrates the interaction between children when working in pairs and shows that children were more likely to prompt each other to seek help and to assist in the implementation of that help when the toy was present, than when it was absent and they only had access to the on-screen icon. Table 6 summarises the contingencies between prompted and unprompted help use when the toy was present compared to when the toy was absent. There were 28 incidences of unprompted help use by the children when the toy was present (squeezing the toy's ear) compared to only eight when Arthur was represented as an on-screen icon, and this difference was significant, χ^2 (1) = 5.94, $p < 0.05$

Table 6. Contingencies use of help facility

	PROMPT		Total
	Prompt	No Prompt	
With Toy	25	26	51
Without Toy	25	8	33
Total	50	34	84

Discussion

When the descriptive results across contexts and detailed activity analysis from the school studies are combined, it is possible to start to construct an understanding of children's interactions with digital toy technology. The children in this study were more likely to seek help initially from human companions: a parent, the researcher or a fellow peer. In fact, they often didn't appear to notice or process the unsolicited clues being given by the toy or the onscreen icon. However, when prompted by their human companion they became competent at using the toy to elicit hints and encouragement and in the dyads observed there were many examples of children collaborating in this help elicitation activity. This type of activity was less common when the assistance from Arthur or DW was presented in the form of an onscreen icon as opposed to a tangible toy interface.

A difference was also observed in help use between the different activities offered through the software. Two games in particular appeared to provide the impetus for children to engage with help available from the technology. These games were a quiz and a searching game in which the tasks asked of the child were often discrete and offered a clear goal. In these cases help from the technology was both sought and used. However, even in these activities there were also frequent instances of children ignoring the help offered once they had mastered its means of elicitation. Children are discerning users and recognised that the usefulness of the content in the available help was questionable. Ineffective or irritating feedback from the technology was not welcomed and on some occasions becomes a cause of irritation and a distraction to any pedagogical activity potentially available. Children did not appreciate, nor would some of them tolerate, wholesale praise and flattery; they made their dissatisfaction very clear.

Conclusion

The toys as they stand are not impressive as collaborative learning partners; their help repertoire is inadequate and even inappropriate. However, the technology has potential: children can master the multiple interfaces of toy and screen and, when the task requires it and the help provided is appropriate, they will both seek it and use it. In particular, the 'of the desktop', tangible experience can offer an advantage, with less attention being awarded to the onscreen toy icon. When the toy is present, children interact with their peer companion in the dyads and with the researcher in both dyad and individual situations. At the start of this paper reference was made to the wealth of work for desktop systems that has produced software scaffolding. This has produced software that can offer finely graded and individually tuned help to its users. If such sophisticated systems were to be implemented in a manner that allowed them to take advantage of the potential offered by tangible, fun interfaces, such as digital toys then the results of this study would suggest richer learning interactions that might address both the affective and the effective dimensions of the experience.

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Rose:

This is an example of the kind of way that the Tables would appear if you thought this better. I must say that I find the flow of actions clearer this way. What to you think? Of course times could be added for Extract/Table 1.

Extract 2. Seeking help from a parent

Researcher:	If at any point you want help don't forget Arthur is there to help you.
Child C1:	Do you have to try and get the dragon?
Parent:	Yes, with the catapult.
Child C1:	Where's the catapult?
Researcher:	Just below Arthur, look can you see it between Arthur and DW.
	If you hit the green button it will show you what it does.
Mum points to screen	
Parent:	Right, try the green button.
Child clicks on green button and fires balloon which misses dragon	
Screen characters:	So it fell a little short.
	Send balloons up here.
Mum laughs	
Child C1:	Is that the catapult?
Parent:	Yes