Explorers or Persisters? Evaluating Children Interacting, Collaborating and Learning with Computers

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In this paper we discuss our observations of a group of 10 and 11 year old children using an Interactive Learning Environment called the Ecolab. The design of this software was informed by our interpretations of Vygotsky's Zone of Proximal Development in which *Interaction* and *Collaboration* are definitive characteristics. The relationship between the differences in interaction/collaboration style and the learning gains made by the children are discussed. The results show that children can be grouped into profiles according to the differences and similarities in their use of the system and that common interaction features are influenced by the design of the software being used. We suggest that children are poor at managing their own learning experience with technology even when the software provided offers both opportunities to complete challenging activities and support to ensure success. The children in this study needed explicit direction towards activities which are beyond their ability. However, caution with regard to this provision of *direction* is important to ensure that the child is also offered opportunities for creativity, a suggestion from the system about what and how to proceed is often sufficient.

Keywords: **Interaction, Collaboration, ZPD, ILE.**

1 Introduction

Computers are now an accepted part of classroom life for most young learners whether they are used for communication, visualization, simulation experience or simply for fun. But how do children actually interact with computers? Does the nature of their interactions vary from child to child in a way that could inform the design of the software which engenders these interactions? This paper describes a small study into children's use of an Interactive learning Environment (ILE) called the Ecolab which was designed to help children learn about ecology. The system attempts to fulfill the role of a learning partner for the child and invites collaborative interaction. Here we describe the nature of the interactions that a group of children had with this system. The nature of these interactions is considered in the light of pre and post test learning gains to explore the relationship between learning and interaction style. The Ecolab software has been designed using a framework derived from our interpretations of the Zone of Proximal Development (ZPD) [10, 11]. The ZPD describes the most fertile interactions which occur between the more and less able members of an educational culture and focuses attention on how the more able can help learners to learn. The ZPD offers a theory of instruction which emphasizes the inseparability of the teaching and learning processes and thus recognizes the inherent interactivity of children's learning with computer software. It also stresses the need for learners to have the help of a collaborative learning partner in the form of a peer, a teacher or in the case of the Ecolab, a computer. Within a Vygotskian, socio-cultural model of education human activity is mediated by tools and sign systems that have arisen through social interaction. Developmental explanations are used to address the complex internalisation process by which the interpsychological relations between partners in social interaction becomes intrapsychological within the individual learner. Interaction and Collaboration are therefore definitive characteristics of the ZPD which form the linchpin of the socio-cultural framework and thus form the focus of our investigations of children using the software.

In this paper we provide a brief description of the Ecolab software before discussing the evaluation study of its use. We report the results with particular emphasis upon the nature of the Interaction and Collaboration profiles we were able to construct from our records of system use. We provide examples of individual learner's use of the system and discuss the relationship between the nature of the interactions and the learning gains recorded after system use.

2 Ecolab Software

Ecology is a subject that involves the study of relationships between organisms within our environment. These relationships can be extremely complex; they can also be introduced in a simplified manner through concepts such as food chains and food webs. These form the foundations of more complex ecosystems and are part of the curriculum for primary school children in the United Kingdom. The Ecolab software provides 10 and 11 year old children with the facilities to build, activate and observe the relationships which exist between members of a simple food web in a woodland ecosystem. It provides a simulated ecology laboratory environment into which the child places the animals and plants of her choice. This environment can be viewed from several different perspectives, including:

World - a picture of a woodland environment and the organisms the child has chosen to place within it.
Web - a traditional text book style diagram of the organisms in a food chain and food web.
Energy - a graphical representation of the energy levels of the organisms currently 'alive' in the Ecolab.
History - a linear narrative of what has happened in the Ecolab world to date, which animal has eaten which other animal for example.

As we have already stated the nature of the relationships that can exist between organisms in the real world can be very complex. We wished to allow each of the children using our system to learn about relationships at a level of complexity that was appropriate to them. We therefore built the learning environment in a manner that would allow children to learn about relationships ranging from the simplest, between just two single organisms, to the network of relationships that could exist in a very simple ecosystem with populations of organisms. The complexity of the relationships represented within the Ecolab can be varied at any stage during the child's interaction with it. It is also possible to alter the abstractness of the terminology used to describe the organisms in the Ecolab so that a snail, for example, can be described by the words "herbivore", "primary consumer", or "consumer" as well as the word "snail".

In addition to this simulated laboratory environment, the system offers each learner a collaborative learning partner which can provide assistance of the following sorts:
Extension of the learner's knowledge through increasing the complexity of the relationships she is asked to study and/or the abstractness of the terminology used to describe what is happening in the Ecolab.
Collaborative Support which can take the shape of *Activity Differentiation:* in the form of alterations to the difficulty of the activities the learner is asked to complete, or context sensitive *Help* of variable levels of quality and quantity.

At the start of this paper we discussed our use of the Zone of Proximal Development to underpin our system design and the importance of *Interaction* and *Collaboration*. In order to explore the nature of the interactions children had with our software, the collaboration that might occur between system and learner, and the relationship between interaction, collaboration and the changes in learning outcome recorded after system use, we varied the manner in which collaboration from the system was offered to the learner. The Ecolab consists of three system variations: VIS (Vygotskian Inspired System), WIS (Woodsian Inspired System) and NIS (Non-theoretically Inspired System). These three system manipulations implement different design elements in order to effect the assistance they provide (see [5] and [4] for more detail). The way in which each of the system variations adopts a different approach is summarised in Table 1.

3 Interactions with the Ecolab

An exploratory evaluation study of the Ecolab software was conducted with a class of children aged 10 and 11 years. We wanted to investigate the extent to which the system would be able to adjust to learners of differing abilities, and also the ways in which the interactions and collaborations between user and system varied with

users of different abilities. The children's school assessments were therefore used to allocate each child to one of three ability grouping: High, Average and Low. Prior to using the software each child completed a written and a verbal pre-test, the latter of which was in the form of a structured interview recorded on audio tape. Each child used the Ecolab software as an individual for a total of 60 minutes over two sessions. In addition, a 20 minute initial session with a smaller 'demo' version ensured that all children were comfortable with the mouse skills required and the interface. After the system intervention subjects were given a written and verbal test, identical to the pre-test, and a short additional extension interview. A delayed post-test was conducted 10 weeks after the end of the original post-test. Of the 30 children who started the study only 26 completed all sessions between, and including, pre and post-test. The four who did not complete these sessions had either left the school or been absent during the evaluation period. Only 24 completed all sessions including the delayed post-test. Once again the reason for non-completion was absence from school.

Table 1 Collaborative Support within Ecolab

Collaborative Support within Ecolab			
	VIS	**WIS**	**NIS**
Levels of Help Available (different levels provide differing qualities of help - 5 represents the greatest and 1 the least)	5	5	2
Decision about Level of Help made by	system	system and child	child
Levels of *Activity Differentiation* Available	3	3	3
Decision about type of Activity and Differentiation level made by	system	child - system makes suggestions	child
Extent of Learner Model maintained by the system and used to make decisions about the support to be offered to the learner.	Bayesian Belief Network (BBN) of values representing the system's beliefs about child's ZPD formed from its knowledge about the amount of collaborative support used to date.	Record of help used to enable contingent calculation of next help level. Record of curriculum nodes visited maintained to permit suggestions.	Record of Curriculum nodes visited maintained to help child keep track.
Abstractness of Terminology selected by	system	child	child
Area of the Curriculum and complexity of the next activity selected by	system	child - system makes suggestions	child
Ecolab View selected by	mostly child	child	child

The results of the pre and post-test were used to assess the efficacy of the three variations of the Ecolab software. This work is reported elsewhere [4, 5] and is not the main focus of the current paper. It is the character of the interactions between each child and the system that we will focus upon here. We wanted to investigate what sorts of interactions had resulted in the greater learning gains and which systems had supported and encouraged various types of interaction and collaboration in order to inform the design of our next system iteration. For each child a summary record of their interactions was produced from the detailed logs maintained during their two sessions of system use and this was used to build up a picture of the types of interactions each child experienced with the system (for full information see [4]).

Cognitive or learning styles have been a subject of active interest in recent years [6, 3, 1, 8], for a brief review see [9]. The influence which a learner's style can have upon the way they interact with technology has also been recognised [7]. Within this literature there are examples of classification systems which differentiate learners according to their learning preferences; as serialists or holists, for example [6]. The analysis of the annotated interaction summaries of children's experiences with the Ecolab software takes a fresh perspective on classification using only the styles of interaction or *Profiles* which can be found in the records of each child's

system use and emphasizing our interest in the nature of *Interaction* and *Collaboration*. Characteristics were identified and children categorised into:

- **Interaction Profiles** according to the character of their interactions with the Ecolab.
- **Collaboration Profiles** according to the nature of the collaborative support provided by the system for the child.

4 Results

One aspect of the evaluation looked at whether the different variations of the Ecolab had been more or less effective in increasing the child's learning gain in terms of her understanding of the feeding relationships which exist in a food web reflected in the pre and post test data. This indicated that the system variation which the child used was relevant to her subsequent learning gain and a detailed discussion of these results can be found in Luckin and du Boulay [5]. Here we wish to concentrate upon the analysis of the records of interaction which was used to try and pinpoint the elements of VIS and WIS which led to their superior performance with particular ability groups.

Interaction profiles.

There were two characteristics which could clearly be seen as either present, or largely absent within the children's interactions. These were referred to as:

- **Busyness** and
- **Exploration**

Busyness was considered to be a characteristic of interactions in which the children completed an average or above average number of actions of any type, such as adding an organism to their Ecolab world or making one organism eat another. The interaction summaries of these children contained an above average number of events. The opposite of Busyness is referred to as **Quietness**.
Exploration was considered to be a characteristic of an interaction if the child had been involved in some sort of action which allowed her to experience more than one level of complexity or more than one level of terminology abstraction, beyond her initial starting levels. The opposite of Exploration is referred to as **Consolidation**..

Some children also switched frequently from one type of interaction to another. For example, they might switch from attempting to make one animal eat another, to looking at their organisms in a different view, to accessing a new activity entirely. Their interactions contained no, or few series of repeated actions of the same type. They were particularly prone to frequent changes of view. These users have been characterised as **hoppers**. Other learners exhibited a more persistent approach, with sets of actions of a similar type grouped together. These users have been referred to as **persisters**.

These characteristics allow the children to be categorised into 1 of 8 possible Interaction Profiles.

The three parameters of categorisation: Busy/Quiet, Exploration/Consolidation and Hopper/Persister bear some similarity to features found in other categorisation systems. Pask's differentiation of "top-down" holists from "bottom-up" serialists shares some common ground with the Hopper/Persister characteristic, for example. The differentiation of exploration from continuing activity at a level of consolidation is likewise similar to the challenge/safety division of Groat and Musson [2]. However, the motivation for the analysis reported in this paper was not the presentation of a generally applicable categorisation system. The aim was twofold:

- To investigate the relationship between interaction style and learning gain.

- To examine how each of the system variations of the Ecolab supported and encouraged particular learning styles.

Children fell into 6 of the 8 possible Interaction Profile groups. The distribution within these groups is illustrated in Table 2

Table 2 Interaction Profile Membership

Profile Description	% of children in Profile group
Busy - Exploring - Persister (BEP)	28%
Busy - Exploring - Hopper (BEH)	12%
Busy - Consolidating - Persister (BCP)	8%
Busy - Consolidating - Hopper (BCH)	12%
Quiet - Consolidating - Persister (QCP)	20%
Quiet - Exploring - Persister (QEP)	20%

Example User Interaction Profiles

S10 (Gene) was a typical example of the *Busy - Exploring - Persister* style of interacter. Her first action was to switch from world view to energy view and then back to world view. She then added 15 organisms to the Ecolab and visited energy view again. Upon switching back to world view she made one of her organisms eat another, switching to energy view to see the effect. This pattern of making organisms act, either eating or moving and looking at the effect in an increasing number of different views continued. Introductory, investigative and rule-definition activity types were completed for the first two nodes in the curriculum before her first session drew to a close. She chose not to save her current Ecolab world which meant that at the start of her next session her first actions were the addition of organisms. Once again she added all 15 and then moved into the next phase of food web complexity and used more abstract terminology to view her organisms. Whilst the nature of the actions she completed was now more advanced and several instances of help were used, her pattern of activity remained one of initiating an action or actions appropriate to the evident goal. Actions were often completed in pairs and were followed by viewing the result from different perspectives (most commonly, energy, web and world). She did not experiment with writing a program or attempt to "escape" from completing the activities offered to her.

This profile group contains only high and average ability children from the VIS and WIS system user groups. In terms of performance at post-test there was a tremendous spread: A *Busy - Exploring - Persister* style learner attained the lowest learning gain, another, the second highest learning gain. The high ability children within the group all achieved an above average learning gain, but within the average ability children there was a wider spread of learning gain scores. Membership of this group was limited to VIS and WIS users, of whom the VIS users all achieved above average post-test learning gains, including the highest learning gain within this user group.

Collaboration profiles.

Two characteristics were found to be the most useful for differentiating collaborative style within the interactions: Amount of support and Depth of support used. These collaboration characteristics were used to group the children into one of four Collaboration Profile groups.
Amount of support: the average amount of activity differentiation and the average number of help instances for the experimental group was calculated. An above average amount of either activity differentiation or instances of help was the criteria necessary for a child to be considered as using 'Lots' of collaborative support.
Depth of support: this characteristic was based upon the level of help and level of differentiation used. Once again the average levels used within the experimental group were calculated. Help or differentiation above the average level resulted in a child being considered as using 'Deep' or higher level support.

Interactions could be grouped into all 4 of the possible Collaboration Profiles. The first group was the largest and was further divided in accordance with the type of support which was most prevalent. The distribution of children into these groups is illustrated in Table 3.

Table 3 Distribution of children within Collaboration Profile groups

Profile Description	% of children in Profile	Profile sub-group Description	% of children in Profile sub-group
Lots and Deep (LD)	53%	Differentiation and Help	19%
		Differentiation	19%
		Help	15%

Lots and Shallow (LND)	12%		
Little and Deep (NLD)	16%		
Little and Shallow (NLND)	19%		

Example User Collaboration Profiles

S1 (Jason's) use of the available support was typical of the *Lots and Deep* profile group and of a user of above average amounts of both help and activity differentiation. He used level 4 help early in his first session of system use to achieve success in making organisms eat each other. His initial activities were completed with maximum differentiation of level 3. This was gradually reduced and then increased again. During his first session of system use he completed a range of activities for three nodes in the first phase of the curriculum. All instances of successful help were at level 4 or level 5. Fewer activities were completed during his second session. However, these activities were at a lower level of differentiation and there were fewer instances of help.

This Collaboration Profile group was the largest and was subdivided to account for the type of support used. Only VIS and WIS system users shared the profile. Jason was a member of the subgroup which used above average amounts and levels of both activity differentiation and help. This subgroup again consisted only of high and average ability children whose mean learning gain is above the average for the whole class (16% as compared to the class average of 11.5%). The subgroup of children who used greater levels of differentiation than help contained children from all ability groups. This second subgroup also produced above average learning gains at post-test (18% as compared to the class average of 11.5%). The last subgroup of children, who used greater amounts of help than differentiation, were all average ability children. Their average learning gain was well below the class average (3.9% as compared to the class average of 11.5%).

System variation had a greater impact upon the nature of the Interaction and Collaboration profiles than ability. A Pearson Chi-squared statistical test was also used to assess the relationship between the Ability groups, System Variation Groups, Interaction Profile Groups and the Collaboration Profile Groups. There was a significant association between System variation membership and Collaboration Profile membership (X^2 = 28.52, df = 6, $p < .0001$), and between System variation membership and Interaction Profile membership (X^2 = 25.79, df = 10, $p < .01$).

So far little has been said about the NIS user group, they have not belonged to either of the Profiles used in the examples. In fact, all the NIS users belonged to a Consolidating Interaction profile; there were no explorers in this system user group. In addition, and as has previously been mentioned, no NIS users were in the 'Lots and Deep' Collaboration profile group.

S9's (Tim's) Interaction profile which was that of a Quiet, Consolidating Persister, was typical of a NIS system user. His initial session consisted of adding a single snail and then making 11 view changes to look at this organism from all perspectives. This initial stage was followed by a series of organism adding (commonly in blocks of 4); single actions, such as 'move' or 'eat' commands, in blocks of 1 to 5; and view changes which were almost always in pairs. In session 2 he adopted the commonly seen approach of adding a considerable number of organisms to start (in this case 12) and then once again completing single actions and view changes.

Likewise S26 (Karlie)'s Collaboration profile reflecting low use of all types of help (Little and Shallow: NLND) was typical. She placed herself at the far extreme of food web complexity and started dealing with populations of organisms straight away. She only completed one type of action during both sessions of computer use: she built food webs using the *build web* command. Initially she made errors and used only occasional low level feedback, persisting until successful. The children in this profile group were all of high or average ability, but their average learning gains were well below average (5.2% as compared to the class average of 11.5%)

A further difference found within the NIS user group relates to the relationship between ability and learning gain. In the VIS and WIS user groups it was the higher ability children who achieved the greatest learning gains. By contrast, amongst the NIS users none of the high ability children made an above average learning gain, in fact the only learners who made above average learning gains were the low ability children. Whilst the numbers are small and the study exploratory this result is interesting and is certainly informing our current research. We had expected that of all three systems, the one which left most control within the hands of the

learner would be most effective with the more able learners. Our results indicate that the opposite was in fact the case in our study.

5 Conclusions

This is an initial exploratory study with small numbers of children. However, there are several observations which are informative in building up a picture of the sorts of interactions which children experienced with the version of the system they used. VIS was the system which explicitly selected the next curriculum area for the child to complete and controlled the complexity and abstractness of the learning environment. Not surprisingly, all VIS users were members of profile groups with the 'Exploring' characteristic present. The split between 'Busy' and 'Quiet' was almost even. Only two of the VIS users scored a below average learning gain at post-test and both were in the same 'Quiet, Exploring, Persister' profile group. The majority of WIS users were also 'Exploring' profile group members and only 1 did not belong to a 'Busy' profile group. However, whilst all the WIS above average learning gain achievers were members of 'Exploring' profile groups, the below average achievers were all members of different profile groups, with no common features between all of them. The WIS system variation did not set the curriculum area for the users, but did make suggestions which resulted in it being easier for a WIS user to avoid being an 'Explorer' than a VIS user. The NIS users were the children with the greatest freedom and the least finely tuned help system. It is perhaps not surprising therefore that none of them belonged to a profile group with the 'Exploring' characteristic. They were evenly split between being 'Busy' and 'Quiet' and the majority were 'Persisters'. Only two NIS users achieved above average learning gains and unlike the WIS and VIS users, both were in profile groups which shared the 'Comfortable' characteristic, they were also both in the low ability group.

These results suggest that providing children with the means for extension through becoming involved in challenging activities is not enough to ensure that these challenging activities are undertaken. The child needs to be explicitly directed towards activities which are beyond her ability. However, caution with regard to this provision of *direction* is important to ensure that the child is also offered opportunities for creativity. The success of WIS indicates that a suggestion about what and how to proceed is often sufficient. The consistency within the high and average ability groups across the different systems for above average learning gain achievement to be linked to the 'Exploring' profile characteristic is not reflected in the low ability group. The definition of the 'Exploring' characteristic may of course be too crude to encompass the possibility that the low ability children were 'Exploring' within interactions in a single phase of the Ecolab.

The manner in which each variation of the system collaborates with the child is a design feature of that variation and as such a big influence upon the resultant user Collaboration Profile. It was therefore no surprise therefore that there was a significant association between system variation and collaborative support profile membership. However, it is possible, in principle, for a user of any of the variations to interact in line with any of the Collaboration Profiles described. In reality Collaboration Profile 1 'Lots and Deep' was exclusive to VIS and WIS users, whereas Collaboration Profiles 2 and 3 'Lots and Shallow' and 'Little and Deep' were exclusive to WIS and NIS users. The only system which allocated both help and differentiation to users was VIS, so the fact that VIS users all used a high quantity and quality of help is unsurprising. WIS users often used a high level of assistance too, but in smaller quantities, they all belong to profiles where the support used was of a high level. In contrast, all NIS users are in profile groups in which the level of support is low. The choice of help available to NIS users was admittedly more limited being of only two levels, however none of the users ever chose to use the higher level of help offered.

The absence of some forms of assistance from the interaction summaries of the less successful users offers support for the suggestion that it is the combination of being challenged, or extended, plus the provision of ample quantities and qualities of support which is important for learning. The lower ability children present a somewhat different picture, there is no apparent consistency between the use of collaborative support and learning gain. The only tentative conclusions are that this group responded to interactions in which the extent of the challenge was limited and that the nature of the assistance the system could offer was not effective for them. Those who were successful took up less different types of assistance and tackled less of the curriculum than their successful more able peers. There is also evidence that these children were not good at managing their own learning. The NIS Interaction and Collaboration profiles in particular would suggest that children who are given control for their own learning experience are not good at setting themselves challenging tasks or indeed seeking collaborative support. Our current work with children is investigating this issue in more depth.

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7 References

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