STRUCTURED EVALUATION OF VIRTUAL ENVIRONMENTS FOR SPECIAL NEEDS EDUCATION

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STRUCTURED EVALUATION OF VIRTUAL ENVIRONMENTS FOR SPECIAL NEEDS EDUCATION

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ABSTRACT

This paper describes the development of a structured approach to evaluate experiential and communication virtual learning environments (VLEs) designed specifically for use in the education of children with severe learning difficulties at the Shepherd special needs school in Nottingham, UK. Constructivist learning theory was used as a basis for the production of an evaluation framework, used to evaluate the design of three VLEs and how they were used by students with respect to this learning theory. From an observational field study of student-teacher pairs using the VLEs, 18 behaviour categories were identified as relevant to five of the seven constructivist principles defined by Jonassen (1994). Analysis of student-teacher behaviour was used to provide support for, or against, the constructivist principles. The results show that the three VLEs meet the constructivist principles in very different ways and recommendations for design modifications are put forward.

1. Background

The Shepherd School in Bilborough, Nottingham is the largest school of its type in Britain, catering for 160 students with severe learning difficulties (SLD) and profound and multiple learning difficulties (PMLD), and has received commendations on its innovative approach to teaching. Many of these students' disabilities are compounded by motor skills disabilities and for the purposes of this paper all of these students will be described as having special educational needs (SEN). Students with SEN can experience problems in dealing with abstracts and often learn directly through experience with the real world. To articulate an understanding of their environment, they might use the Makaton directory of words, signs and symbols (Walker, 1976). In addition, creative work, such as drawings, pictures and textured three-dimensional models feature as communicational and expressive media for the students at the Shepherd School.

Ability to learn directly through experience depends on the range and complexity of the experiences offered. In an educational environment these may be restricted due to the limited number of real world artefacts that can be provided in a classroom setting, and there are certain logistical problems to be faced in taking a group of SLD students out of school in search of richer environments on a regular basis.

In 1991 the Virtual Reality Applications Research Team (VIRART) at the University of Nottingham, UK initiated the Learning in Virtual Environments (LIVE) programme of research (Brown et al., 1995; Gray Cobb et al., 1993; Brown et al., 1997). Discussions with teachers and students at the Shepherd school considered how Virtual Reality (VR) technology in general, and virtual environments (VEs) in particular, might be applied in the special needs classroom. The initial reaction from the school, given a demonstration of desktop VR (operating on a 486 PC, using the Superscape Visualiser platform with joystick, touch-screen or mouse input devices), was extremely positive. The enthusiasm centred around the three-dimensional nature of the medium, the freedom to roam around the environment in an autonomous manner, and then to interact with objects via a mouse or touch-screen to enter into a dialogue with the world. These features were not readily available in the other computer packages commonly used at the school. The main interest in VEs at that time was to provide an additional teaching aid to support the variety of tools already used. Following initial trials at the school it became apparent that VE could provide an ideal teaching medium suited to the way in which these students learn, offering a range of experiences that could not otherwise readily be found in a classroom. Obviously, such experiences could not replace real world counterparts, but could be used to prepare the students for them by filling in 'experience gaps' in their education caused by over-protective parenting, mobility problems and cognitive deficits.

Initially this foray into special needs applications of VEs for students with SEN was informal and somewhat unstructured in approach. There were no guidelines on VE building nor its application in education and our approach was very much based on trial and error with continual modification of the VLEs in accordance with user-teacher-researcher recommendations. During the next six years, VIRART developed more than 20 virtual learning environments. Broadly, these fall into three application areas within the LIVE programme: **experiential environments** in which students can practise everyday life skills; **communication environments** in which students are encouraged to develop their speech, signing and symbols skills; and finally, **personal and social education environments**, perhaps the most ambitious of all, where students can investigate appropriate behaviour in public situations.

Over this development period, VIRART has undertaken a continual programme of testing of the VLEs developed for special needs education. This programme has clearly identified the potential role of VR technologies in this field and has involved the following investigations:

1. The identification of virtual objects

VIRART began work in 1991 on a series of VLEs to teach communicational skills to students with SEN. The Makaton vocabulary itself consists of a library of over 350 icons representing core language concepts in eight stages of increasing complexity. The concept of the project was to display the Makaton symbol in a virtual room (termed warehouse) together with a range of virtual objects representing and encapsulating the meaning of this symbol. A virtual mannequin was also produced which would sign and speak the word associated with the symbol when activated using the mouse or a touch-screen. After students were given the opportunity to navigate around and interact with a series of environments, encountering new symbols and their corresponding objects and signs, they were given the opportunity to reflect on what had been learnt. For this they were given a random Makaton symbol and a range of four objects, one of which actually represented the meaning of the displayed symbol. A correct association between object and symbol activated the reward sequence of sound feedback and a goodwill gesture from the mannequin.

In 1992 a pilot study was carried out to determine how well the system was received by teachers and students at the Shepherd School. Eight students in the 11-18 year age range were tested, selected by teachers at the school, as being toward the upper end of ability for SEN students. The results of this pilot study (Brown et al, 1995) were:

- Three students had no difficulty identifying the correct objects in the reward warehouse.

- Three students were able to identify some of the objects in the reward warehouse.
- The remaining two students had difficulty exploring the individual warehouses and in identifying the correct objects in the reward warehouse.
- Most of the students recognised the hand sign that was displayed with each symbol and immediately mimicked the sign.
- Some of the students had difficulty in manipulating either the spaceball or mouse, preferring to touch the screen and point at objects that they wished to select.

This study provided anecdotal evidence that SEN students were able to access VLEs and that these can be used in support of standard teaching methods. However, it was evident that some students had difficulty using the VR input devices and that adapted devices may facilitate wider use.

2. The development and testing of appropriate input devices for virtual learning:

VLEs are intended to provide an intuitive interface. However, they will have little use if students cannot control the input devices used to access them. Indeed, input device design is only one of three problems facing students with SEN interacting with VLEs (Vanderheiden, 1992), the other two being the VLE design itself and the outmode modes with which it manifests itself to the user.

Initial research at VIRART concentrated on population stereotypes (Hall, 1993) and used primitive VLEs to test the ability of students with SEN at the Shepherd School to navigate around and interact with virtual objects. The study concluded that a joystick limited to two simultaneous degrees of freedom had the greatest utility in navigation. Further work extended testing of commonly available input devices and reinforced the belief that a joystick was the easiest navigation device for this user group to control. No such conclusion was reached for so called interaction devices (mouse, touch-screen, etc.). Further development of such devices was recommended (Brown et al, 1997a).

Development of new devices specifically suited to the needs of students with SEN in virtual environments has also been pursued at VIRART. *Mojo* is a seat based movement platform particularly suited to the needs of students with little fine arm motor control (Lannen, 1997). Instead the rocking motion of a student controls this device, with forward, backward and side-to-side rocking motions corresponding to similar movements in the VLE. We have found that this naturalist form of input is particularly suited to environments where a sense of movement is an important feature, for instance in the virtual skiing environment. Combined with large screen projection from the PC and other output (wind and fog machine, scratch and sniff cards, inventive modelling) a 'Kruegeresque' virtual room has been produced at an affordable cost for schools(Brown and Mallet, 1997).

3. The use of VLEs to encourage self-directed activity in SEN students

In collaboration with the Department of Learning Disabilities at the University of Nottingham, VIRART conducted a study in 1994 to assess whether VR promotes self-directed activity for SEN students (Cromby, et al, 1996a). The investigation aimed to determine whether this was happening or whether teachers were using it in a more conventionally didactic manner. The VLEs used for this study were the ones designed to teach the Makaton communication system.

- *Subjects*:18 student teacher pairs were selected, students being selected if they met the following criteria: they had sufficient motor skills and visual ability to be able to use the computer terminal, joystick and mouse and had minimal experience of using the virtual reality system. Half of the students were male. It was not always possible to keep the same teacher with each student but 11 students remained with the same teacher throughout. Their mean score on the Vineland Adaptive Behaviour communication subdomain were 14.4 for receptive and 21.2 for expressive. Compared with their age group norms this indicated levels of low to adequate communicative ability. The students' knowledge of Makaton symbols was tested before the first session and again at the end of the study.

- *Method*: Each pair had between 4 and 10 weekly sessions using the Makaton programme. The order in which the student proceeded through the programme, the number of sections they had explored, the number of times each section was explored and the length of session (up to a maximum of 20 minutes) were left entirely up to the student or teacher. Each session was recorded on videotape.
- *Analysis*: After repeated viewing of the tapes, teachers' activity was coded into 8 categories (instruction and suggestion and whether this involved utilising three dimensional moves or not, pointing, questions, physical guidance and making moves themselves) and the students' activity into three categories (spontaneous moves in three or two dimensional space and starting a move that the teacher completes). As the sessions differed in length, frequencies of behaviour categories were converted to rates.
- *Results*: Tests of intra-rater reliability were highly significant for all but one (teacher's questions) of the categories so this was omitted from further analysis. As very few pairs completed more than 7 sessions, analysis was carried out on these only. Using regression analysis significant decreases (in all cases $p<0.0001$) in rate over repeated sessions was found for all of the teachers' behaviour with the more didactic categories (e.g., instruction and physical guidance) decreasing at a rate faster than suggestion and pointing. Regression analysis could not be used for the students' results because the data was slightly skewed. Therefore rates for the last sessions were compared using a paired t-test

and a significant increase ($p<0.05$) in rate was found for each of the three categories. Using a Wilcoxon test, a significant increase ($p<0.03$) was found in the number of Makaton symbols the students knew. When a composite score was formed for all teacher categories and these figures were plotted against session, the decrease in teacher behaviour appeared to precede an increase in student behaviour which then accelerated in an apparently logarithmic manner.

This study showed that, with repeated practice, students took progressively more control over interaction with the VLE. Moreover, the students did increase their Makaton Vocabulary as a result of training in the VLE.

4. The transfer of skills from a VLE to the real world

Another study carried out in collaboration with the Department of Learning Disabilities at the University of Nottingham in 1995 aimed to assess whether SEN students could transfer skills learnt from a VLE into the real world (Cromby, et al, 1996b). The virtual supermarket was used to investigate whether some of the component skills involved in shopping could be successfully rehearsed in a VLE in preparation for shopping in the real world.

Subjects: 23 subjects between 15 and 19 were selected for the study. Selection criteria was for students who had sufficient motor skills and visual ability to be able to use a computer terminal and joystick, were familiar with VLEs having used them on at least three previous occasions and were sufficiently able to carry out a real shopping trip with minimal staff support. Students were assigned to either the experimental (11) or control (12) groups so that the groups were matched on scores from the teachers' version of the Vineland Adaptive Behaviour Scale. Two sets of baseline measures were taken:

a. Parent report of how much their child accompanied them and helped them with shopping. There was no difference between the two groups on these measures.
b. Shopping task in the real world accompanied by their teacher. Given a list with pictures of four items they were to collect, the following measures were taken: (i) Total time taken from going through the turnstile to reaching the checkout, (ii) number of items picked up, (iii) number of correct items picked up and (iv) number of items in the trolley at the checkout. No significant difference between the two groups in mean baseline time (experimental 11.97 mins, control 11.21 mins) or in the number of correct items picked up (experimental 3.3, control 3.5) was found.

- *Method*: Students in the experimental group then had twice-weekly sessions using the virtual supermarket for eleven weeks. There were five different shopping lists and four different versions of the virtual supermarket which differed only in the location of the goods in the store. Shopping list and supermarket layout were varied over the sessions. Each time a student completed a shopping list the following measures were taken: (i) total time taken, (ii) number of items picked up, (iii) number of correct items and, (iv) amount of time they spent during the session actively engaged in the task. The control group were prevented from seeing or using the virtual supermarket but used other VLEs when the experimental group used the virtual supermarket. They did, however, have sessions discussing and answering questions about the different shopping lists so that these were not unfamiliar to them when they returned to the real supermarket. Then all students returned to the real supermarket and repeated the original task.
- *Results*: Four students were not available to complete the final trip to the supermarket so data were presented from 9 in the experimental group and 10 in the control.

a. Time taken to complete task: mean times for the follow-up session were 11.59 for the experimental group and 16.92 for the control. Using an analysis of covariance with baseline time as a covariate the difference in follow-up times between the two groups were significant ($p<0.02$)

b. Whether students accompanied (but not helped) their parents shopping was significantly related to final shopping time. In other words students who helped their parents had a shorter final shopping time but this effect was the same in the experimental and control group.

c. The experimental group picked up significantly more ($p<0,05$) correct items on the final shopping trip than did their control counterparts and this could not be explained by an overall high rate of picking up items.

This study has shown that familiarity with a task, provided by training in a VLE, can improve real world skills. In this case, students who had been trained in a virtual supermarket were able to identify and select objects on their shopping list faster and with more accuracy than students who has no VLE training.

This series of studies have shown that the use of VLEs can be useful tools in the education of students with SEN. The research team thought it important at this point, however, to attempt to apply a more structured approach to design and evaluation process by:

- Examining the nature in which students with SEN use these VLEs.
- Employing contemporary educational theories to explain and interpret our findings.

This paper describes three virtual learning environments (VLEs) used within a structured evaluation study, the first of its type. The development of a structured evaluation method, based on constructivist education theory, is presented and the results are discussed in terms of how well these VLEs match the expectations of constructivist principles.

2. Virtual Learning Environments for Special Needs Education

2.1 Experiential

The domain focus for virtual environments created to provide experiential learning were suggested by the staff and pupils at the Shepherd school, and include House, Supermarket, Driving a car and Skiing. Two of these environments, the House and the Supermarket, were used in this evaluation study and are briefly described below.

Virtual House: This environment consists of a kitchen, dining-area, living room and bedroom. The kitchen is fully interactive, with opening cupboard doors, a cooker, with hob that can be turned on, and a working sink. Within the kitchen an embedded sequence guides the student in an appropriately safe way in which to make a cup of coffee. For example: if the kettle is switched on without first filling it with water, warning messages (appropriate for the SEN group) are given and the user instructed to switch it off and fill it with cold water before proceeding. In this way, the kettle can be filled, boiled, coffee put in the cups, filled with hot water and milk added (see Figure 1).

INSERT FIGURE 1 HERE

Virtual Supermarket: This environment consists of a medium sized supermarket (8 aisles) selling a range of about 60 products. The student enters the supermarket and pushes the trolley around the aisles (using the Joystick). Using their own initiative, the student can select goods (using a mouse click or touch-screen) which are placed in the trolley. When the student is satisfied that all goods have been chosen, the trolley is pushed to the checkout, onto which to goods can be placed. A coinage system then appears on the right-hand side of the screen and the appropriate money can be selected to pay for the goods.

INSERT FIGURE 2 HERE

2.2 Communication

It is important that students with SEN develop an extensive communication facility, to the best of their abilities. This faculty gives them the ability to develop independent living skills, and is important for their self-esteem and in building personal and social relationships. The Makaton communication system is an adapted vocabulary for British Signed Language, promoted and developed by Margaret Walker and others since early 1970’s (Grove and Walker, 1990; Kiernan et al., 1979; Knowles and Masidlover, 1982; Walker, 1976; Walker, 1985). It is a system developed for people with SEN in the UK, who also experience communication problems regardless of any hearing loss.

Traditionally, students learn Makaton symbols and their meaning via picture cards and, where possible, exploration of real objects. However, there is a limit to the range of objects that can be brought into the classroom. One of the problems with this approach then is that it often relies on 2D abstracts (picture cards) to teach the meaning of another abstract (Makaton symbols). In a VLE we can let the student encounter a range of 3D interactive objects, for example, cars that they can 'get into', and drive around a virtual city - to show the function of a car and its typical context. In this way, we believe the student can more readily make an association between the symbol and its meaning. In the same way many experiences, representing meaning for the Makaton symbols, can be brought into the classroom. An example of a VLE to teach the Makaton symbol and concept of 'telephone' is shown in Figure 3.

INSERT FIGURE 3 HERE

The student is free to roam around the area on the right hand side of the screen, using a joystick to move and a touch-screen or mouse to interact with the three dimensional objects which represent the meaning of the Makaton symbol. In this case, the telephone will ring and the student must answer it by lifting the receiver to stop it ringing. This environment also illustrates examples of telephones found in different contexts (domestic and public) so that students can identify generic object groupings (e.g. telephones of different sizes, shapes or colours still have the same functions).

Next, the student can use the touch-screen or mouse to activate the signing sequence of the mannequin situated in the top left-hand corner. At the same time as signing the word for telephone, the mannequin will say the word 'telephone', via the PC speaker system. The student is encouraged to say and sign the word in response to the mannequin, to reinforce the learning process. Throughout all of this, the Makaton symbol is constantly displayed in the bottom left-hand corner of the screen. Using the function keys on the PC keyboard, the student can explore separately four different Makaton symbols in each Makaton environment (to date 12 environments have been developed). They are then given an opportunity to demonstrate their learning by selecting the appropriate object associated with randomly displayed Makaton symbols (see Figure 4).

INSERT FIGURE 4 HERE

3. Education theory

Many authors have promoted the role of VE in an educational setting (Lanier,1991; Pantelidis, 1993; Stuart and Thomas, 1991), although there has been little formal attempt to evaluate its value. It is not surprising then that there has also been little structured evaluation of learning and skills transfer when using virtual environments in special needs education. The few controlled studies that have been carried out have examined familiarisation of real environments using virtual environments (Foreman, 1993) and transfer of shopping skills learned in the virtual supermarket to a real shopping experience (Standen et al, 1998).

The project reported here took a rather more fundamental approach, to examine and evaluate the basis on which virtual environments are developed and implemented to aid education. It was decided to base the assessment of the VLEs around constructivist theory; this was chosen to represent a more appropriate approach to education than alternative models such as ones of objectivism. The application of constructivist principles to virtual environment design has been proposed for a variety of training and education applications (Winn, 1993; Grove, 1996).

Winn (1993) states “Constructivism is the best basis for building a theory of learning in virtual environments.” The basis of this view lies in constructivism’s applicability to instructional design, recognised by a number of educationalists (Bonner, 1988; Champagne et al., 1982; Tennyson and Rasch, 1988).

The determination of constructivism as an appropriate education theory for VLE evaluation stemmed from examination of the attributes of virtual environments which may be considered to support learning. Over the course of the LIVE programme we have identified seven characteristics of virtual environments which are suited to learning (Brown et al, 1996). They were intended to define the reasons why VLEs are particularly suited to constructivist theories of learning, especially within special needs education. These VLE characteristics are summarised in Table 1.

INSERT TABLE 1 HERE

3.1 Constructivist principles

Constructivism supports the role of learners as active participants - allowing them to build their own intellectual structures. Relevant theories are largely based on Piaget’s views that people accommodate new information by reflecting on their existing knowledge and finding a place to fit it in (Piaget, 1950). Thus, underlying mental models are used to understand new problems (Merrill, 1992). Vygotsky’s theories emphasise how social experiences also affect how people learn, for example, the learning situation itself and the role of the teacher/instructor will influence the learning outcome (Vygotsky, 1978). Learning is considered not just as an individual internal process, but as a process where knowledge is shared and built up from social interactions (Bruner, 1986). Constructivist theorists suggest that people structure their experiences of the real world, imposing different, individual meanings and perspectives on the same events.

Jonassen (1994) has devised seven principles of constructivism. These are intended to guide the design of learning environments which will facilitate knowledge construction and form a set of heuristics defining the goals of a constructivist design model. Other authors have produced similar classifications (Cunningham et al., 1993; Black and McClintock, 1996) but we felt that Jonassen's classification provided the clearest basis upon which to evaluate the LIVE programme. However, where these other classifications have proved useful we have used them, at least, in part. Jonassen's constructivist principles were reinterpreted for the current study so that they could be used as criteria upon which to evaluate the design and use of the VLEs.

1. **Represent the natural complexity of the real world**

   It has been suggested that representing true complexity will aid in the understanding of concepts (Bednar et al., 1992). In the real world, complex inter-relationships determine how and when certain concepts are used. Oversimplification of a simulated environment may result in oversimplification of the understanding of concept, limiting their use and relevance in new cases and potentially leading to misconceptions (Bransford et al., 1992).

2. **Focus on knowledge construction, not reproduction**

   The traditional educational approach is of learning abstract concepts through repetition; it aims to communicate information and then test the success of the communication. Knowledge construction, on the other hand, must be nurtured by its environment; it involves the construction of information learned through exploration, experience and negotiation (Brown, 1989). Rather than simply acquiring abstract facts, knowledge construction can be seen as acquiring the ability to make sense of the situation, and may be demonstrated by the ability to construct plans in response to situational constraints (Duffy and Jonassen, 1992).

3. **Present authentic tasks**

   In the real world, tasks are carried out through direct manipulation or by using symbols closely connected with specific activities. These activities can be seen as a means to an end (Brown, 1989). Virtual environments can replicate this relationship, using realistic tasks which require skills similar to those which would be used to complete those tasks in the real world.

4. **Use case-based rather than predetermined sequences**

   Building virtual environments to replicate their real world counterparts should maximise transfer of useful information applied in real world situations. Brown (1989) advises that any learning environments should support student exploration without instructing and prescribing activity.

5. **Foster reflective practice**

   Developing an understanding of an unfamiliar situation by viewing it as something similar to another situation with which the student is familiar allows them to draw upon their understanding and apply it to the novel situation. Reflection on existing mental models is used to infer, explain and predict a new situation (Jonassen, 1994).

6. **Enable context dependent knowledge**

Many theorists agree that people are better at acquiring knowledge when it is specific and context dependent. Duffy and Jonassen (1992) discuss Fogelin's theory which states that context is an integral part of meaning - if a concept is demonstrated in isolation this may limit the student's understanding of it's meaning. This, in turn, will affect the application of the information learned and it may remain inert knowledge that is not applied to novel situations.

7. **Support collaboration through social negotiation**

In a good learning situation, students should be able to talk about their experiences and share their explorations. From these collaborations with others many perspectives may be discussed, enabling students to develop and evaluate their ideas. In order to be meaningful, the creation of new understandings must be justified and explained with reference to prior understanding built upon existing foundations (Draper, 1995). It should be a co-operative effort in which students try to understand and develop alternative perspectives. This is important since there is often a large gap between a teacher's and student's understanding (Perret-Clermont et al., 1991). The presentation of alternative perspectives supports discussion and its productive value in the construction of understanding (Brown, 1989).

4. Evaluation of virtual learning environments

The constructivist principles described above define features of a learning experience which, if adhered to, should enhance and facilitate the learning process. This study used these constructivist principles as the basis for a framework upon which to evaluate the utility of VLEs in special needs education. It was considered that two of the principles represent solely design criteria for a learning environment (the other five represent both design and use). These were:

Principle 1: Is the natural complexity of the real world represented?

Principle 4: Does the VLE provide real world case based environments rather than predetermined instructional sequences?

These principles could not therefore be assessed by observation of use of a VLE. Instead, they were used to provide a context for recommendations for VLE design.

A pilot study was first carried out comprising general observation of nine students using each of the three VLEs with support from their regular class teacher. These sessions were carried out under normal classroom conditions with no additional teaching support. This led to some problems to do with the teacher trying to provide one-to-one assistance to the student using the computer but being distracted by other activities within the class. However, this approach also had the advantage of naturalistic research setting. For practical reasons, it was decided to focus the study on the 'junior' classes (aged 7-11): (i) they had no previous experience of using the VR system and so would highlight problems experienced when first using the programs, (ii) they were considered less likely to try to 'perform' when being assessed than some of the older more proficient students. However, there were still a wide range of abilities within these classes and it was considered that the lesser able students, with low language and concentration levels would provide a limited insight into the use of the

VLEs. Moreover, significant non-verbal activity could make it more difficult to explicate the actions observed and subjective interpretation could then be incorrect.

All of the teachers were given training sessions in the use of the VLEs prior to the study. This training included how to operate the computer, together with instruction on how to navigate within, and interact with VLEs. No instruction was given, however, on how the teachers should use these VLEs with their students.

Direct observation was used to record student/ teacher behaviours and any problems experienced and from this 18 behaviour categories relevant to the remaining five of the constructivist principles were identified. These behaviour categories are described in Table 2.

INSERT TABLE 2 HERE

4.1 Observation study

4.1.1 Participants

Six students used in the pilot study were selected for the observation study. The selection was based on their ability to control the input devices and their concentration and speech. The students' abilities are summarised in Table 3. Having participated in the pilot study, these students were all familiar with the three VLEs.

INSERT TABLE 3 HERE

4.1.2 Method

Observation of the use of the VLEs was carried out using both direct recording and video recording of the student/teacher pairs in each of the three VLEs: the Virtual House; the Virtual Supermarket; and the Makaton environment. All observations took place in the classroom and teaching cover was provided to allow the teacher to devote all of their attention to the student using the computer. No time limits or other constraints were set.

4.1.3 Analysis

The sessions of use of the virtual environments varied from 3 to18 minutes. After the videos were collected, they were analysed in a number of ways but principally via a multiple activity analysis of up to eight minutes per interaction. A multiple activity chart allows coded behaviours to be recorded for the time that they occurred, and an examination of simultaneous and synchronous activities. Bales (1950) and Kounin and Gump (1961) used this method to code interactions and represent them simultaneously. It should be noted here that, typically in human factors investigations, analysis of video taped performance can take up to 15 times longer than the original recording. That was particularly the case in this study where a number of different behaviours were to be assessed. The purpose of the multiple activity analysis was to track the progress of the students' attention on the virtual environment and the learning tasks. An example is given in figure 5.

INSERT FIGURE 5 HERE.

Behaviours supporting each principle were coded. Codes for principles 2, 3, 5 and 6 were developed from observing students using the VLEs in pilot sessions. The descriptions of constructivist principles were used to define behaviours that supported these principles. It was necessary to develop these codes, as existing measures would not give information relevant to these features of constructivism.

For principle 7, where collaboration and social interaction was measured, a selection of codes used by a number of other researchers were used. Warren et al. (1993) coded turn taking and trainer requests for communication; Warren et al. (1984) recorded occurrences of mands (non-yes/no questions and instructions to verbalise), models (imitative prompts) and initiations made by children and teachers. Warren and Yoder (1994) described a constructionist approach to communication and interaction. They defined this as the use of models, recasts and expansions of the student's communication attempts. The use of directives (elicited imitation, mands and testing questions) were discouraged as they were said to disrupt the flow of interaction and the student's attentional engagement. This was used to determine which interaction categories would support constructivist use.

The multiple activity analysis method allowed us to calculate the amount of time spent by either student and/or teacher exhibiting each of the behaviours listed in Table 2 for each of the three VLEs. This allowed comparisons to be made concerning the amount of supportive behaviour for each of the five constructivist principles.

4.2 Results

The results are presented in terms of qualitative descriptions of the evidence supporting or not supporting each of the five constructivist principles assessed in the observation study. It is emphasised that the evaluation study focuses on how well the VLEs support each of the constructivist principles and no judgement is made concerning individual student performances. Descriptions of the students' performances are used only to identify positive or negative features of the VLEs. Each principle, and behaviour category within them, will be discussed in turn.

4.2.1 Principle 2: Facilitate knowledge construction, not reproduction

The observation study aimed to assess how the VLEs could be used to build the students' knowledge. This was assessed in terms of how much, and what type, of assistance is required or given by the teacher (see Table 2).

4.2.1.1 Teacher assists and controls navigation

It was observed that in the Virtual House the teacher took a lot of control over navigation, and indeed many of the teachers reported difficulty in navigating around this environment themselves. Closer examination of individual student performances indicate that although most of the children could manoeuvre around the individual rooms, teacher support was needed to navigate some aspects of the environment where movement space was restricted (e.g. going through doors or using the stairs). In the Virtual Supermarket and Makaton environments students took much more control over navigation.

The implications here are that students will be unable to demonstrate their knowledge construction if they cannot navigate in the VLE. In this respect, the Virtual House may restrict knowledge growth due to navigation difficulties and consequent frustrations.

4.2.1.2 Teacher Directs Movement

There were much higher instances of teachers directing movement in the Virtual House and Virtual Supermarket than the Makaton environment. This result reflects differences in the intended use of these VLEs where the house and supermarket environments are more explorative and require navigation around the environment. There was a noticeable difference in the number of directions given from the individual teachers which was not related to differences in student abilities. This suggests that individual teaching styles may influence how the VLEs are used.

4.2.1.3 Teacher selects for student

There were very few instances of teachers selecting objects for the student indicating that the students were taking responsibility for the action taking place in the VLE. Teachers did assist object selection on request of the student, more frequently in the Virtual House than the other VLEs. This is possibly because the Virtual House contains the highest number of tasks. The type of selection assistance was also seen to alter in accordance with the student's abilities; less able students requested assistance with simple selections whereas the more able students requested assistance with complex selections such as dragging open doors or selecting money.

4.2.1.4 Teacher assists reading and explanations

There was a difference in type of explanations given by the teachers in each of the VLEs. In the Virtual House many of the explanations related to the student's location in the environment whereas in the Virtual Supermarket the teachers described products on the shelves and the paying system. Much less teacher explanation occurred in the Makaton environment.

4.2.2 Principle 3: Present authentic tasks

The authenticity of the task maybe exemplified by the occurrences of real life skills. These may be displayed by a number of features when observing the use of the VLE: when the student is aware of their position in the environment, when they are aware of the effect of an action and when they select a specific item (see Table 2). In an authentic task, all actions should be seen as a way of reaching an objective.

4.2.2.1 Specific selections, effects of actions

The vast majority of selections made were specific rather than random indicating awareness of action effect of the cursor and mouse as well as a clear idea of what the student is trying to do in the environment. A much greater number of selections were made in the Makaton environment, not surprisingly as this VLE presents a predominantly selective (rather than navigational) task. There were many instances in which the students displayed frustration in the VLEs, particularly when action effects did not behave as they expected. For example, clicking on money in the Virtual Supermarket produced an increase in numerical value printed on the screen but the coins themselves did not move. Worse, in the Makaton environment in which the student demonstrates their learning, a software bug caused the Makaton symbol to change too quickly following successful selection of its associated 3D virtual object. This confused some students as they did not have time to acknowledge their achievement - this type of error in a VLE is unacceptable.

Time spent in the VLE was used as an indication of student interest and concentration. Rather than demonstrating difficulty in use of the VLE, a greater task time was used to infer a greater involvement in the task. It was observed that when students experienced problems or difficulties with interactions they would loose interest and the corresponding task time would be reduced. Task times were found to be greatest in the Virtual Supermarket, followed by the Virtual House. Much less time was spent in the Makaton environment, most likely because there was much less to do.

4.2.3 Principle 5: Foster reflective practice

Seeing a situation as similar to another helps one to understand it. Recognising an item from the real world will help in the understanding of its purpose in a new situation. Examples of recognition of real world objects and reflections were used in support of this principle (see Table 2).

4.2.3.1 Recognition of objects

The number of objects correctly identified varied between the three VLEs with the highest success rate being in the Makaton environment. This is most likely because the aim of the Makaton environment is to teach object recognition and understanding. In the Virtual House and Virtual Supermarket many of the objects in the environment are there to provide context and may not be part of a specific task activity. This can cause problems for students if they try to make sense of objects which do not replicate real world objects. For example, in the Virtual Supermarket some of the bottles had no labels or identifying marks - this confuses the student and could have a negative impact on the learning experience.

4.2.3.2 Reflection on the real world and previous use of the VE

The VLEs did facilitate reflections on past experiences but in different ways. In the Virtual House and Virtual Supermarket students talked about past times when they had done specific activities (such as going shopping or making coffee). The Makaton environment did not provoke any discussions about the real world, perhaps because the aim of this VLE is object-symbol association and there are not many real world context cues.

Students also demonstrated reflection on previous use of the VLE by remembering the sequence of actions required to make the coffee or pay for goods at the Supermarket checkout. Verbal reflections were given by some of the students with better verbal skills:

Student: *"I've been in this room before"*.

4.2.4 Principle 6: Enable content and context dependent knowledge construction

A recurring feature of the VLE should stimulate specific actions such as selection of an object, or choosing the correct sequence of events (see Table 2). Providing these cues in context adds meaning to the task and aids understanding.

4.2.4.1 Selection recalled or instructed

The actual number of selections made varied between the three VLEs and was greatest in the Makaton environment. There was no difference between the number of teacher instructions to select in each VLE. This could indicate that students are using some common attributes (e.g. a selection is always made by positioning the cursor and then pressing the mouse button).

4.2.4.2 Instruction is given for the next task

There was a much higher rate of task instruction given in the Makaton environment than the other VLEs, possibly because it requires specific task performances which are not necessarily obvious or naturalistic to the student (e.g. use the mouse to select the Makaton symbols). The Virtual House offers a much more varied range of tasks to be explored. These tasks may be interspersed with difficult navigational challenges. In the Virtual Supermarket there were the fewest teacher instructions as repetitive sequences of activity were observed involving selecting products, moving along the shelves, selecting another object, and so on.

4.2.5 Principle 7: Support collaborative instruction

In the constructivist learning environment, the student should be allowed to initiate their own interactions and guide themselves through the process. The teacher should follow the students' attentional need, respond to their interests and help to interpret the consequences of actions (see Table 2).

4.2.5.1 Use of models and recasts, direct questions and mands

The majority of models and recasts were used in the Virtual Supermarket and Makaton environment as these target learning and recognising the names of specific objects. There were also many direct questions which were used to test recognition of objects controlling the students focus of attention. The Virtual House contains a number of simple, familiar objects so models and recasts were used to help the student to describe an action or situation. This also meant there were very few 'What is this object?' direct questions in the Virtual House.

4.2.5.2 Student/teacher initiations

In all but one case the teachers initiated the majority of the verbal interaction; guiding the flow of events and the subjects brought to the students attention. This dominant trend was due to the 'knowledge gap' between the student and teacher. However different teaching styles allowed some students to initiate more and have greater control over their own learning goals supporting constructivist principles.

4.2.5.3 Discussions

The individual VLE did not seem to determine characteristics such as total rates of discussion and rates of teacher and child discussion. These trends had a strong connection with student ability. In almost all cases there are equal amounts of contribution from the student and teacher.

4.2.5.4 Types of interaction

The greatest percentage of interactions recorded in each VLE were classed as supportive of constructivist collaboration. Some of the differences in collaboration were due to individual student abilities such as speech and comprehension abilities. But the stronger link is between teaching styles and type of interaction.

4.2.5.5 Degree of collaboration

The examination of excerpts of dialogue from the study showed the extent to which each VLE supports positive collaboration. The Virtual Supermarket was the most collaborative with lowest levels of teacher domination. Positive examples of collaboration allow the construction of knowledge.

Teacher: “*What is that for?*”

Student: “*Washing.*”

Teacher: “*That’s right, washing clothes.*”

The Makaton environment produced periods of guidance dominated by the teacher and then unguided activity demonstrating a low degree of collaboration.

5. Discussion of Methodology

Jonassen's principles of constructivism were used to structure a framework for evaluation of Virtual Learning Environments. Incidences of behaviour which supported or opposed these principles were categorised, coded and recorded.

The observation study supplied a myriad of information relating to the use of VLEs. Some differences between the VLEs were identified.

The Virtual House also supported many of the constructivist principles, although it did not support social and communication skills so well. Being the largest VLE, it provided the most scope for exploration. However, specific problems in navigation produced high levels of teacher control, decreasing the student's opportunity to discover for themselves.

The Virtual Supermarket environment supported a high level of reflection on the real world. There were also a lot of models and recasts. A lot of teacher assistance was given in reading and explanation. This was because the student was learning the names and functions of new items. The supermarket also enabled the most unaided exploration. Teachers took very little control over selection and navigation (with the exception of paying for goods). Therefore, this VLE supported most of the constructivist principles.

The Makaton environment did not show much supporting behaviour in many of the categories. Particular examples were in reflection on the real world and student-led exploration and discovery of the VLE. It did facilitate the use of a high rate of models and recasts and a great deal of object recognition. This finding is important as it supports collaboration – the very essence of the Makaton environment is to teach communication skills.

These differences largely reflect the different learning objectives provided by each of the VLEs. It is possible that constructivist principles may not be appropriate metrics for all VLEs. For example, the Makaton VLE is intended to be an abstract design to focus the students' attention on the single language concept being demonstrated. This must be done within limited real world context to avoid confusion from the array of other objects in the natural world. A notable aspect of the use of the Makaton VLE was that teachers provided more instruction to the student. This, again does not support constructivist principles but may be more useful for learning than undirected use.

Furthermore, constructivist theory would support a completely student-led and initiated approach. In practice, it was found that the teachers always provided some directive or instructional role. This is not necessarily a negative aspect to the use of VLEs for education. Without teacher initiation or instruction for the next task, a student may not progress through the VLE. When teaching SEN students letting them taking all of the lead may mean that they miss some important point of focus. The teacher's role in collaborating may also achieve more from occasionally taking a more behaviourist approach. In some circumstances an eliciting prompt may stimulate the social negotiation of an important feature of VLE.

In many cases differences between VLEs may be obscured by trends in teaching styles. Some teachers allowed students to explore the VLE on their own whereas others provided much more prompting and assistance. Therefore it is difficult to obtain a true picture of the students' abilities by observation of their behaviour and interactions with VLEs when these are being influenced by a mentor's idiosyncratic teaching styles. Furthermore, if teachers are too ready to provide assistance, and therefore take control over the VLE interaction, this will restrict the student's knowledge growth.

One of the overall findings, then, was that behaviours may be influenced by individual characteristics more than simply VLE design.

Individual student ability particularly affected:

- Their awareness of their position in the VLE
- Whether or not selection or movement was instructed
- Whether instruction was given for the next task
- The student's contribution to collaboration, discussion and initiations

Individual teaching styles particularly affected:

- How much of the movement was directed
- Who initiated and how much of the discussion was teacher dominated.

The study was not specific and detailed enough to detect all relationships between the use of the three VLEs with respect to the constructivist principles considered. A number of recommendations can be made for future study.

1. Many of the behaviours observed were taken to infer certain plans or causes. The causality may have been made clearer by getting the student to narrate their actions more often.

2. The student's opinions of the VLE, questioned after use, may provide some insight as to which they found to be the easiest to use, the most difficult and their favourite. This may indicate whether the VLE is appropriately complex and may explain some of the behaviours observed in use of the VLEs.
3. The collaboration could have been investigated in much more detail. Help requested and offered could have been distinguished. This may provide an insight into how much help the students actually needs to progress through the VLE and how willing the teacher is to instruct and control the exploration. Instances where the teacher praises the student may also be recorded. Frequent occurrences may indicate that the VLE does not provide enough of its own stimulation to motivate certain actions.
4. The dialogue recorded could have been analysed in more detail. By distinguishing when and where help was requested, and offered, may have provided an insight into how the environment supports constructivist principles. Recording instances where the teacher praises the child may highlight areas where the environment itself does not provide sufficient motivation or reward.
5. Other measures that might be more appropriate for VLE evaluation include:
    - Incidence and causes of frustration/anger.
    - Time taken to complete task.
    - Time task holds students' attention.

Although the information gathered in this study was not sufficient to provide an understanding of the theoretical basis for the value of VLEs, the study does highlight features of VLE design and presentation which affect use. From these, guidelines for VLE design can be produced.

6. Recommendations for VE design

The design of each of the three VLEs were assessed with respect to their complexity and representation of real case scenarios. Overall the Virtual House seemed to best represent the complexity of the real world. Its tasks, although mostly simple one-step tasks, were the most varied. The most complex task, making a cup of coffee, followed a realistic sequence of events. The Virtual House also had a number of rooms which could be explored. The Virtual Supermarket did most closely resemble its real world counterpart and displayed some authentic branded products. However, programming shortcuts led to some products without labels or identifying marks – this caused confusions for students which is unacceptable.

Observation of user behaviours to support constructivist principles, and consideration as to whether or not these behaviours are desirable, has produced some general recommendations for VLE design.

1. The complexity of tasks in all of the VLEs should be increased to levels experienced in the real world. This may increase the length of time spent concentrating on the VLE. They would then facilitate learning for a wider variety of abilities and would not cause so many misunderstandings. The teaching method can make the same task suitable for lower ability students by sub-dividing goals. For example, for making a cup of coffee in the Virtual House, a step one task could be to turn the tap on, a two-step task could be to fill the kettle, etc.
2. The design of all tasks should not make the process more difficult than is experienced in the real world. Frustration occurs if action effects are not as the user expects. For example, clicking on money in the supermarket does not move coins. By more closely mirroring the real world, the task of paying in the Virtual Supermarket could be easy to understand. The task could allow the user to see which coins had been chosen by seeing

them represented on the screen. The selection of products in this world causes confusion as it allows selection from a long distance. Also, when products are selected they do not disappear from the shelf.

3. Representing the general environment more realistically may aid position awareness and increase reflections on real world activities in the Virtual House. This could be done by adding more effects such as pictures on the walls, items in cupboards, etc.
4. Task performances in the Makaton environment are not obvious or naturalistic. In the supermarket they are easy to learn because they are repeated (e.g. identify item, move to shelf, select item, move along). Presenting the objects of the Makaton environments in more context-related settings may aid the transfer of object recognition.
5. By allowing the user to interact with and manipulate more objects in the VLE, may increase awareness of action-effects and decrease non-specific selections.
6. Students will be unable to demonstrate their knowledge if they cannot navigate through the VLE. Restricted movement space is difficult to navigate and leads to user frustration. Movement should be simplified in key areas such as positioning the shopping trolley and manoeuvring up and down stairs, and through doors.

These examples are by no means exhaustive. A more detailed examination of the individual VLEs would allow more specific recommendations for design guidelines.

7. Conclusions

This study deliberately examined three very different types of VLEs used for SEN students. It has been found that the VLEs support constructivist principles in very different ways.

From this we can comment on the utility of the constructivist principles for assessment of VLEs and highlight aspects of VLE design that are suitable for SEN students.

1. Virtual Learning Environments would appear to offer great value in special needs teaching. It has been seen that students can learn to use the input devices to control VLEs and that their use encourages self-directed activity. Students did demonstrate learning of common features of VLE use (e.g. selections are made by positioning cursor over objects and pressing the mouse button). Overall, the students demonstrated high levels of attention, particularly when they were not aided in the exploration of the VLEs. This implies that they found the VLEs enjoyable and were motivated to explore and use them. Moreover, for students within the higher ability ranges, there is some evidence that skills learnt in a VLE do transfer to the real world.

2. The different VLEs examined in this study meet the constructivist principles in very different ways. The Virtual Supermarket supported most of the constructivist principles, especially reflection on the real world and unaided exploration. Conversely the Makaton environment supported fewer of the constructivist principles. What it did support was collaboration between teacher and student, especially important in a VLE aimed at teaching communicational skills. The Virtual House supported more of the constructivist principles, but relied more on teacher control due to the higher levels of navigation needed to access all of this environment. These differences are due to the differing learning objectives within each VLE.

3. Constructivist theory would support completely student-led approach to collaborative learning. We have, however, found that in special education it can be beneficial for the teacher to initiate a more behaviourist approach in some instances.

4. It was not only VLE design, but student and teacher behaviour which influenced the results of this study. This prompts the need for research into an appropriate curriculum for use of VLEs in special education.

5. Constructivist theory provided a useful framework upon which to structure this evaluation study. However, it only provides a limited metric by which to evaluate the use of VLEs in special education. A much fuller understanding would include the other components of particular relevance to special education. VIRART are currently investigating the following issues:

   - Usability: Ergonomic assessment of input device design, VLE design and modes of output to support the user.
   - Enjoyment: Case study information to provide student opinion of enjoyable and easy to use VLEs.
   - Skill development: The design of VLEs in partnership with User and Focus Groups to develop independent living and communicational skills.
   - Transfer of training: An experimental programme to determine guidelines for VLE design and use that promote the transfer of skills.

6. Specific recommendations for VLE design, summarised in Table 4, fall into four general categories:

(1) The first is altering task complexity to more accurately represent the real world,

(2) Increasing the complexity of the environments should aid position awareness, increase reflection on the real world and increase opportunity for recognition,

(3) Allowing the manipulation of more of the objects in the environment should increase awareness of the effect of each action,

(4) Making navigation more simple should allow the student to lead discovery and decrease feelings of frustration.

INSERT TABLE 4 HERE

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Figure 1. The kitchen in the virtual house

INSERT PHOTOGRAPH OF FIGURE 1

Figure 2. Paying at the checkout in the virtual supermarket

INSERT PHOTOGRAPH OF FIGURE 2

Figure 3. A Makaton environment

INSERT PHOTOGRAPH OF FIGURE 3

Figure 4. Testing communication levels

INSERT PHOTOGRAPH OF FIGURE 3

Table 1. Virtual environment characteristics

VE use may **encourage self directed activity**. Complete control of navigation and interaction is given to the student. This facilitates active involvement in the learning process. This is particularly important to SEN students as they experience so little control over many aspects of their lives.
Motivational. A well designed VE should encourage the student to participate in their own learning experience.
Naturalistic learning. The VE is 3Dimensional and looks like its real world counterpart. Learning concepts can be demonstrated visually without additional explanation, and can be described as using **natural semantics** (Bricken, 1991). Where textual information is included these messages are supported verbally and/or with symbols. This means that learning concepts can be acquired irrespective of learning disability, literacy level or cultural difference.
VE can provide a **safe space** in which the student can experiment with 'what happens if' scenarios and explore the consequences of their actions.
Desktop VEs offer **shared public experiences**. Both student and facilitator can share and discuss the environment and the consequence of actions. This may facilitate assisted learning.
VEs can act as an **equaliser of physical abilities**. Provided the student can operate the input devices (which may be specially adapted for them) they can make use of the same learning experiences as other, more physically able, students.

Table 2. Explanation of behaviour categories

Principle 2: Facilitate knowledge construction, not reproduction
2.1 The exploration of the VE through movement and interaction is self-led if the student moves or explores but not if the teacher tells them where to go and what direction to go in.
2.2 If the student is seen to follow rules and construct plans to achieve their objectives (e.g. move around banisters to get to stairs, or use a spoon to put coffee into the cup), it is considered that they are responding to constraints. This is not displayed if they repeatedly exhibit unproductive actions such as moving forwards into a wall or trying to select an object when too far away from it.
2.3 The teacher may assist the student's exploration by helping them to move the joystick to go where that want to in the VE. It is not assistive if the teacher takes complete control of the joystick and decides where to go in the VE.
2.4 The teacher may assist the student's interaction by positioning the cursor over objects requested by the student. It is not assistive if the teacher decides which objects to select.
2.5 By explaining the task ahead (e.g. reading and explaining messages on the screen) the teacher can enable the student to achieve greater and more complex goals.
Principle 3: Present authentic tasks
3.1 The student may demonstrate an awareness of where they are in the VE and how to get to places (e.g. goes up the stairs to get to the bedroom).
3.2 & 3.3 The student may demonstrate that they are aware of the action effect of pressing the mouse button to select objects in the VE by purposeful selections (e.g. selecting items in the supermarket to put in the shopping trolley). Failure to understand this may be demonstrated by random pressing of the button and not positioning the cursor over required objects.
3.4 If the task is not too easy or too difficult the student's concentration should be maintained and they should be able to complete the task alone or with assistance. The student may also display frustration and may even give up on the task altogether.
Principle 5: Foster reflective practice
5.1 The student may display recognition of objects in the VE, based upon their real world experiences (e.g. naming or describing objects seen in the VE).
5.2 The student may relate the situation presented in the VE to a real one, perhaps describing differences, where they have experienced it before, who uses objects, etc.
5.3 The student may reflect on a previous visit to the VE to explain a situation or help construct plans (e.g. remembering the location of an object or the sequence of events to pay for goods at the supermarket checkout).
Principle 6: Enable content and context dependent knowledge construction
6.1 & 6.3 This is displayed when the student responds to recurring features of the VE. For example, movement is achieved by moving the joystick, objects are 'selected' using the mouse.
6.2 In order to complete tasks using the correct sequence, the student must have a clear understanding of the purpose of the task. The context of the task should add meaning and therefore assist the student in their understanding.
Principle 7: Support collaborative construction through social negotiation
7.1 & 7.3 Models and recasts allow the student to observe a behaviour and repeat it in the correct situation, producing immediate, appropriate use of a newly learned skill. Mands and direct questions give the teacher control over what the student's attention is focused on.
7.2 In responsive interaction the teacher should follow the student's lead in action and discussion.

Table 3. Participant's Abilities

	A	B	C	D	E	F
Reading - words	5 to 10 symbols	30	36	36	4	150
Comprehension	1 word	1 instruction	1+ instructions	1 instruction	1 word	1+ instructions
Speech	single word	simple sentence	sentences/ phrases	sentences/ phrases	simple sentences	sentences/ phrases
Directions understood	stop/go	stop/go forward/back	stop/go forward/back	stop/go forward/back	stop/go	stop/go forward/back
Prompts used	verbal visual physical	verbal visual physical	mainly verbal some visual few physical	some verbal mainly visual few physical	mainly physical & visual	mainly verbal
Maths count to ...	10	20	20	20	9	30
Add/- to	0	10	10	10	0	20
Identifies shapes	some	yes	yes	yes	yes	yes
Identifies colours	most	most	most	most	few	all
Gross motor skills	middle	good	v. good	middle	middle	v. good

Table 4. Design modifications recommended for the VLEs

	HOUSE	SUPERMARKET	MAKATON
1	Add more multiple step tasks.	When paying the coins should move when selected.	
2	Fill drawers and cupboards. Pictures on walls.	Display groups of brand types for each product. Authentic labels on all products.	Display items in context.
3	All identical items can be manipulated in the same way e.g. cupboard doors.	Selection allowed of more than one of each item.	Allow interaction with more objects on right hand side of screen.
4	Simplify navigation on stairs and going into rooms.	Simplify navigation to checkout desk.	

Figure 5. Example of Multiple Activity Analysis Chart for observation of Teacher/student use of the Makaton VLE

Time (seconds)	Attention	Initiation	Constructivist principles					Additional information student verbalisations/[actions] (S), teacher verbalisations/[actions] (T)
			2	3	5	6	7	
0	F	T			1		B	T: “Which one is that one?” S: “Pencil”
6						B		T: Can you get your arrow onto the pencil for me?” T: “Move slowly”
12			4			A		T: “Press here, you have to get the arrow in the right place. Watch the arrow”
18						B	B	T: “Is it on the pencil yet?”
24			3			A		T: “Now you click”
30						B		S: [clicks]
36		S				B		S: [points to mannequin] T: “What did he say?”
42						3 2		S: [attempts to verbalise] T: “He said ‘Well done’ ”

Key to codes used:
Attention: F = focused. Initiation: T = teacher initiates, S = student initiates.
Principle 2: 3 = teacher assists movement, 4 = teacher assists selection. Principle 5: 1 = student recognises item name/picture/movement/sign/use.
Principle 6: A = teacher gives instruction for student to select, B = teacher gives instruction for next task, 2 = student chooses or recalls correct sequence of events, 3 = student recalls to use or move joystick. Principle 7: B = direct questions and tests.