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VIRTUAL ENVIRONMENTS SPECIAL NEEDS AND EVALUATIVE METHODS

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Abstract. This paper presents an overview of the development of the Learning in Virtual Environments programme (LIVE), carried out in special education over the last four years. It is more precisely a project chronology, so that the reader can sense the historical development of the programme rather than giving emphasis to any one particular feature or breakthrough, which are covered in other papers and available through the authors.

The project conception in a special school in Nottingham is followed by a description of the development of experiential and communicational virtual learning environments. These are followed, in turn, by the results of our testing programmes which show that experience gained in a virtual environment can transfer to the real world and that their use can encourage self-directed activity in students with severe learning difficulties. Also included is a discussion of the role of virtual learning environments (VLEs) in special education and of its attributes in the context of contemporary educational theory.

1. Background

VIRART is the Virtual Reality Applications Research Team, a group of ten researchers and programmers, based within the Department of Manufacturing Engineering and Operations Management at the University of Nottingham. Founded in June 1991, the edict of the team is to develop industrial and educational applications of VR.

At this time VIRART approached the Shepherd School in Aspley, Nottingham, the largest school of its type in the country, for students with severe learning difficulties (SLD), on the advice of a work colleague. SLD students often experience problems in dealing with abstracts and often bypass the traditional 'learn symbols - describe real world - learning process' and instead learn directly through experience within the real world. To articulate an understanding of their environment, they might use the Makaton directory of words, signs and symbols [1].

Creative work, such as drawings, pictures and textured three-dimensional models feature as a communicational and expressive medium for the students at the Shepherds School. The school is also heavily involved in the creative arts, with pupils winning Fringe Firsts at the Edinburgh Festival and attending many theatre, ballet and dance productions. To help the PMLD students gain a wide range of experience a solar-visualisation room is used. Using lights, sound, smoke, moving water and various objects this space can be used to simulate experiences as diverse as a day at the seaside, or rescue from a burning building. There is an obvious commonality between these approaches and the interactive environments which exist within a VR systems. Indeed many readers may draw parallels between this type of interactive room and that promoted by Myron Krueger [2].

Learning directly through experience is dependent on the range and complexity of the experiences offered. This can be limited within 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. It became apparent that VLEs could not only provide an ideal teaching medium, one that was suited to the way in which these students learn, but also offer a range of experiences that could not readily be found in a classroom. These experiences are not meant to replace their real world counterparts, but more precisely 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 was informal and somewhat unstructured in approach. Then, as now, the applications were suggested by those who know best the needs of this group of students: the staff and pupils at the school. They fall broadly into three camps; 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.

The development of these learning environments follows a 'develop-test-refine' developmental methodology. A strategic partnership has been developed between VIRART and the Department of Learning Disabilities, also at the University of Nottingham, to develop a testing methodology for these virtual learning environments. Testing has included a generalisation study to evaluate the ability of students to transfer skills they have learnt in experiential environments to the real world; a learning rate study to quantify the learning of symbolic communication concepts in a virtual setting; a population stereotype study to identify useable navigation and input devices for students who possess a vast range of motor skills abilities and a study to assess whether the use of VLEs can encourage self-directed activity in these students.

2. The potential of VR for special education

Many authors have promoted the role of VLEs in an educational setting [3,4,5], although there has been little formal attempt to evaluate its efforts. New technologies are often introduced first into mainstream education, only later to be adapted for special educational use. In this instance, however, the role of VLEs in special education appears at least as pertinent in a special needs setting as it does elsewhere. There exists a strong mapping between the attributes of VLEs and the goals of what is considered good contemporary special educational practices.

First, their use may encourage **self directed activity.** Many students with learning difficulties experience so little control over things other children take for granted that they may assume they are going to play a passive role all the time [6]. VLEs can stimulate a child's curiosity and to this end environments have been built that allow a student to enter an underground station and take a tube train to the destination of their choice or to find out what happens when an empty kettle is boiled. Leading educationalists [7,8,9] have emphasised the importance of self directed activity in their theories. For students who have limited opportunity to do so in real life, VLEs can offer a rich and varied set of opportunities to initiate self directed activity in a safe arena.

Second, given that their use might promote self directed activity in a group of students who are said to be deficient in this area, we must, by good design, build VLEs that are **motivational** and inspiring to use. Stuart and Thomas [5] believe that whereas the age of television has bred passive disengaged students with short attention spans, the use of VLEs may be able to captivate students attention and foster their active involvement in their own education. Our develop, test, refine methodology will employ empirical research to establish the optimal design of VLEs for the various types of learning, one criterion of which being whether students are motivated to use them.

Third, the **role of play** is given high importance in developmental theories of education. Students with disabilities may often be protected for longer than others [10], often not gaining experiences necessary for further development. Vygotsky [8], emphasised the importance of play in liberating children from constraints, whilst Bruner [7] describes how play allows the systematic uncoupling of means and ends. Students can embody themselves in other characters and play 'lets pretend'. Brenda Laurel [11] points toward the strong identification that players can feel with artificial characters in a computer database as an example of the human capacity for *mimesis*, to which Aristotle attributed the soul changing power of drama. Our team has adapted the virtual city to teach road safety; credit points are given for good action, for instance using a pedestrian crossing, whilst credits are lost for crossing the road at an unmarked junction. The aim is to gain credits to stay alive in the game.

Fourth, many computer learning systems rely on abstracted symbol systems such as English or Mathematics. VLEs have their own **natural semantics** [12]; the qualities of objects can be discovered by direct interaction with them. Children with learning difficulties are commonly termed 'concrete thinkers', learning best through direct through practical experience. Our virtual house looks and operates very much like a real house, with a kitchen in which you can learn to make a simple snack. This form of learning, independent of abstracted symbol systems, is ideally suited to the abilities of students with severe learning disabilities.

Fifth, desktop VR platforms offer a **shared public experience**. Both student and facilitator can share and discuss the environment. Bruner [7] has drawn attention to the social context out of which skills develop. The importance of the role of instruction has been developed by Vygotsky [8], in his concept of the 'zone of proximal development' defined as the distance between a child's actual developmental level as determined by independent problem solving and the higher level of 'potential development as determined through problem solving under adult guidance or in collaboration with more capable peers'. This is particularly pertinent to our environments used to encourage language development, where the student is encouraged to respond to a virtual manakin and articulate the meaning of symbols encountered to a teacher, carer or more capable peer.

Sixth, VLEs can act as a **great equaliser of physical abilities.** Provided the student can operate simple input and navigation devices (joysticks, switches, touchscreens), they can move through, and interact with, environments they may be restricted from doing so in real life, and gain experience and learn skills that their physical disabilities may prevent them from doing so in real life. This of course depends on good interface design, an issue already extensively investigated by our team [13,14]. People with disabilities already face a huge range of barriers to social and educational interaction in real life and we do not want to compound these by poor interface design, thus creating a new set of barriers to interaction with VLEs [15].

And **seventh**, VLEs can provide a **safe space** in which to practice skills that are dangerous and risky to do so in real life. Problems can be encountered and consequences demonstrated without exposing the student to any real danger. A pilot project is now underway at VIRART to develop virtual learning scenarios to teach health education to students with moderate learning difficulties. In this way a student might be approached by a stranger in the virtual city, and we can teach appropriate behaviour in response to such a situation in an non- abstract and safe environment.

3. Experimential learning environments

Students with severe learning difficulties can use experiential learning programs to access a rich set of environments, both in terms of objects and situations, to interact with them in appropriate contexts and in ways they are restricted from doing so in the real world. It is this freedom of exploration and expression which may go some way in restoring the disparity that exists in real world learning systems; to give easy and frequent access to environments that are not so in the real world, and to accommodate experiential ways of learning rather than concentration on the abstract learning systems that prevail in mainstream education.

The environments we have chosen to build were suggested by the staff and pupils at the Shepherd School, and include Supermarket, House, City and Skiing. Built using the Superscape World Building Toolkit and run on a standard PC platforms, each of the environments is now described, together with an explanation of function and layout.

(i) 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 working sink. Within the kitchen is embedded a sequence that guides the student on an appropriately safe way in which to make a cup of tea. For example: if the kettle is switched on without first filling it with water, warning messages 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, tea put in the cups, filled with hot water and milk added.
The living-room has a working television and telephone, whilst in the bedroom the wardrobe contains a range of clothes that can be chosen, depending on the whether conditions outside. Snapshots of this environment are shown in figure 1.

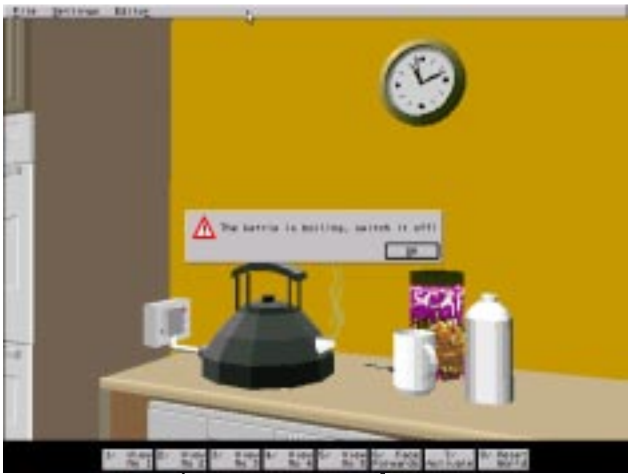

Figure 1: *Virtual House*

(ii) Virtual City: In this environment, the student can choose from several different viewpoints, including that of driving the car around the city, encountering traffic lights, road works, one-way systems and pedestrian crossings. Alternatively, the student can choose to be a pedestrian, learning where and when it is safe to cross the road. Throughout all of this, the teacher can be holding a dialogue with the student, discussing, for example, the difference between a red and green light, and the consequences of crossing either. A wheelchair viewpoint can also be selected and used to investigate where the ramp accesses are likely to be. The environment is populated with virtual people, walking on pre-set routes around the city and who will use the pedestrian crossings to test the alertness of an on-coming driver. The snapshots in figure 2 show some of the traffic situations that can be encountered.

Figure 2: *Virtual city.*

(iii) 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 touchscreen) 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 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. Figure 3 illustrates some of these sequences.

Figure 3: *Virtual Supermarket.*

(iv)Virtual Skiing: The ski-slope offers access to an environment that many students with learning difficulties (especially in Britain) may never experience. The environment consists of an undulating course with gates that must be circumnavigated. The student takes the joystick and skis down the slope, accelerating as they go, trying to pass through the centre of each gate. We have observed that most students, especially those with motor skills difficulties, respond positively to the sense of movement generated by this world. At the bottom of the ski slope the skier is automatically attached to the ski-lift which takes them back to the top of the piste. There are also three speeds to choose from, the faster can be chosen as the skill and coordination of the student increases. See figure 4.

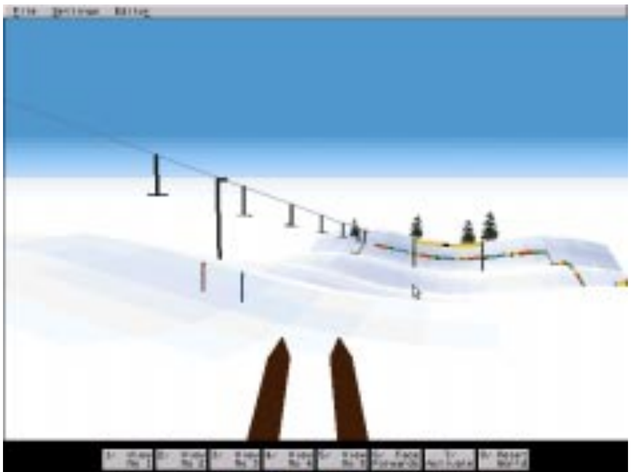

Figure 4: *Virtual Skiing*

4. Communicational learning environments

One area which was identified was the use of VLEs in the teaching of Makaton signs and symbols. The Makaton communication system is an adapted vocabulary for British Signed Language, promoted and developed by Margaret Walker [1] and others since the nineteen seventies. It is a system much focused in the education of those with severe and profound learning difficulties in the UK, who also experience communication problems regardless of any hearing loss.

It is important that students with learning difficulties develop an extensive communicational facility, to the best of their abilities. The challenge in teaching the meaning of Makaton Symbols is in bringing a sufficient range of each object into the classroom, to represent the meaning of each symbol, and then in a form that is not too abstract. For example, when teaching the meaning of the symbol for car, unless the lesson is near a car park, picture cards may be used to show examples of different cars. The problem with this approach is that we are using 2D abstracts (picture cards) to teach the meaning of another abstract (Makaton Symbol). In VLEs we can let the student encounter a range of 3D interactive cars, that they can 'get into', and drive around the 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, a whole world of experience, representing meaning for all Makaton Symbols, can be brought into the classroom via a virtual reality platform.

Previous research has revealed [16] a more rapid learning of communicational concepts during active participation in the learning process, as opposed to simply presenting the student with pictorial representations of language. This closely mirrors two approaches adopted to the teaching of Makaton Symbols at the Shepherd School: the VLE approach and the use of 2D picture cards to convey meaning. Within the virtual learning environments the student is encouraged into active participation along with the teacher to provide a stimulus context, whilst the presentation of 2D picture cards forms a passive and abstract experience.

To date, twelve virtual learning environments have been produced, each containing five distinct learning areas. In each of the first four of these areas a new Makaton Symbol is introduced and a typical example of this is shown below in figure 5.

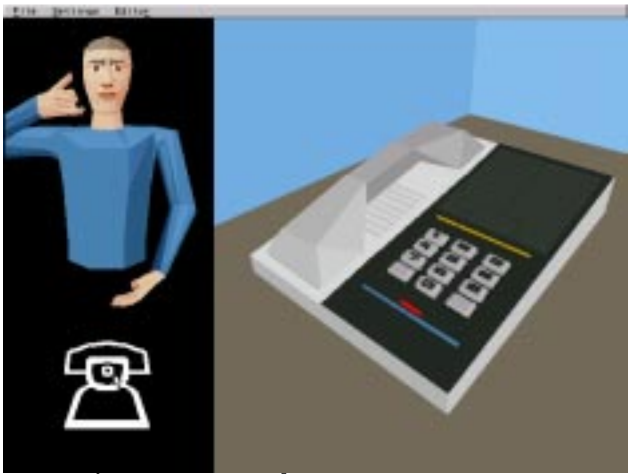

Figure 5: *A Makaton Environment*

The student is free to 'roam' around area on the right hand side of the screen, using a joystick to move and a touchscreen or mouse to interact with the three dimensional objects which represent the meaning of the Makaton Symbol. In this case, the telephone will ring randomly (from speakers), and the student must answer it by lifting the receiver to stop it ringing. Also, a range of telephones are illustrated (domestic and, public, in this case) to prevent the student from over-specifying what a telephone can be.

Next, the student can use the touchscreen or mouse to activate the signing sequence on the manakin situated in the top left hand corner. At the same time as signing the word for telephone, the manakin will say the word 'telephone', via the speakers. The student is encouraged to say and sign the word in response to the manakin, to reinforce the learning process. Throughout all of this, the Makaton Symbol is constantly displayed in the bottom left-hand corner of the screen.

There are another three learning areas of the same layout to this one above, to teach the meaning of another three Makaton Symbols. In the fifth and final area is the 'reward' world; as in figure 6.

The objective here is to test how well the student has learnt the meaning of each of the four Makaton Symbols recently introduced. A Makaton Symbol is randomly flashed on the screen (bottom left), and the student is asked to make a connection between it, and the object it represents, placed in a range of 3 objects also recently encountered (right hand side) . If the student can select the correct object, the manakin will indicate that a correct choice has been made by performing a 'thumbs-up' sequence accompanied by some positive sound feedback. If an incorrect association is made, the manakin performs a 'thumbs-down' sequence, and the Makaton Symbol will remain on the screen until a correct association is made once more.

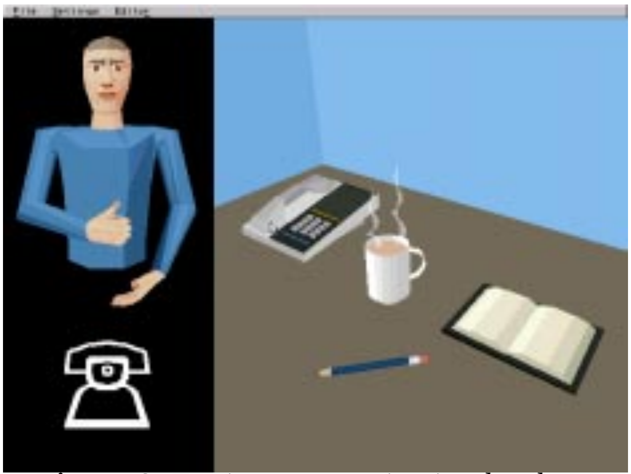

Figure 6: *Testing communication levels.*

In this way, 12 Makaton environments have been created to teach the meaning of some 48 Makaton Symbols, covering symbols and signs from the first four levels of the Makaton vocabulary development project. These environments have recently undergone a testing period in the Shepherd School, and the results of this are presented later in this paper.

5. Evaluation of virtual learning environments

Continuous evaluation of the LIVE programme is imperative if the virtual learning environments are to have long and profitable use in special education. This includes participation of the users in all aspects of the project; from identification of user needs, through the develop-test-refine process and on to appropriate marketing, support and tutoring systems to assist in the use of the programmes. Some of the major studies conducted to evaluate the use of these virtual learning environments are now described.

The most fundamental question to address when using this type of teaching medium to train SLD students is whether experience gained in VLEs generalises to similar experience in the real world. In other words, can we show that by using our VLEs students will perform better or more competently in the real world? To attempt to answer this question we used our virtual supermarket with a group of students and then recorded and compared their shopping characteristics in the real world with a group who had received no prior training.

5.1. Can students with learning difficulties use virtual environmnts to learn skills which will transfer to the real world?

Subjects: 23 students aged between 15 and 19 who had sufficient motor skills and visual ability to be able to use a computer terminal and joystick, were familiar with virtual reality programmes 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 group (12) so that groups were matched on scores from teacher's version of Vineland Adaptive Behaviour Scale. Two sets of baseline measures were taken:

1. Parent report of how much their child accompanies them and helps them with shopping. There was no difference between the two groups on these measures.
2. Shopping task in "real world" accompanied by their teacher. Given a list with pictures of four items they were to collect. Measures taken were: (i) total time taken from going through turnstile to reaching 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) or in number of correct items picket up (experimental 3.3, control 3.5).

Method: Students in the experimental group then had twice-weekly sessions using the virtual supermarket for eleven weeks (with 8-week summer break after first 5 weeks). There were five different shopping lists and four different versions of the supermarket programme which differed only on the location of 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 virtual worlds 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 are presented from 9 in the experimental group and 10 in the control.

1. Time taken to complete task: mean times as follow-up 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 ($p<0.02$).
2. 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 the control group.
3. The experimental group picked up significantly ($p<0.05$) more correct items on the final shopping trip than did the control group and this cannot be explained by an overall high rate of picking up items.

5.2 Can the use of virtual environments encourage self-directed activity in students with severe learning difficulties?

Aim: One of the claims for the usefulness of virtual reality systems in education is that it promotes self- initiated activity. This study set out to investigate if this was happening or whether teachers were using it in a more conventionally didactic manner.

Subjects: 18 teacher-student pairs, students being included 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 scores on the Vineland Adaptive Behaviour communication sub-domain were 14.4 for receptive and 21.2 for expressive. Compared with their age group norms this indicates 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 twice weekly sessions using the Makaton programme. The order in which the student proceeded through the programme, the number of sections that they explored, the number of times each section was explored and the length of session (up to a maximum of 20 minutes) were left entirely to the student or teacher. Each session was recorded on video tape.

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 (spontaneous moves in three or two dimensional space and starting a move that the teacher completes). As 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 (in all cases $p < 0.0001$) decreases 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 faster rate than suggestion and pointing. Regression analysis could not be used for the students' results because the data was slightly skewed. Therefore, rates for the first and last sessions were compared using a paired t-test and a significant ($p<0.05$) increase in rate was found for each of the three categories.

Using a Wilcoxon test, a significant ($p<0.03$) increase was found in the number of Makaton Symbols the students knew. If a composite score is formed for all teacher categories and student categories, and these figures are plotted against session, the decrease in teacher behaviour appears to precede an increase in student behaviour which then accelerates in an apparently logarithmic manner.

5.3 Current testing programme and future aims:

We have also begun investigating the learning process that takes place in students with severe learning disabilities using the virtual supermarket. The two aims of the study were:

1) to find out which of the component skills involved in successful supermarket shopping improve with practice in VLEs; and
2) to assess the contribution of self-directed activity to learning in VLEs.

We took a group of 20 students whose parents or carers had given consent for them to take part in the research, and split them into two matched groups of equal average age and ability using the classroom edition of the Vineland Adaptive Behaviour Scale (Sparrow, Balla & Cicchetti, 1985). Both groups completed the same set of baseline measures:

1. a shopping task in the virtual supermarket: students were required to find four specified items and take them to the checkout
2. a navigation task in a "shell" version of the supermarket with all the goods removed (in order to separate recognition and identification of the goods from the navigation task): students had to find an exploding jellyfish which was placed in one of the aisles
3. a recognition task: students were shown a series of screens each containing four items from the virtual supermarket, and had to point to a specified item when it appeared.

The students' performance on each of these tasks was measured by timing them, by noting any periods of distraction or disengagement from the task, and for the shopping and recognition tasks by recording any false positive and extraneous items. In order also to assess the value of self-directed activity for learning in VLEs, for the navigation and recognition tasks all control of the VLEs was given to the experimenter. Students were asked to point to the exploding jellyfish and the correct items of shopping when they appeared on the screen but had no control over movement in the navigation task, nor over the sequence in which items were presented in the recognition task.

After these baseline measures were completed, the experimental group had regular sessions practising shopping in the virtual supermarket whilst the control group continued to practise the separate navigation and recognition tasks. During this time the control group also had regular sessions driving either a car or a helicopter around a virtual city, so that like the experimental group they had extensive experience of using a joystick.

After all students had 9 or 10 sessions using the VLEs, the baseline measures were repeated and a series of analyses compared the initial and final times for each task. These analyses are summarised in Table 1 below.

Table 1: baseline and final times for virtual shopping and component skills tasks

Task & group	Baseline Time (seconds)	Final Time (seconds)	Significance
Virtual shopping: experimental control	851.22 / SD 569.53 835.72 / SD 225.11	230.33 / SD 64.58 737.33 / SD 349.22	P = .008 P = .286
Navigation: experimental control	40.56 / SD 10.35 47.82 / SD 14.76	25.89 / SD 2.98 27.00 / SD 3.71	P = .011 P = .003
Recognition: experimental control	26.89 / SD 19.18 27.09 / SD 14.3	15.22 / SD 11.45 12.00 / SD 5.71	P = .008 P = .003

In addition to the measures shown above, the final assessment included two more trials designed to assess whether the students had learned the layout of the virtual supermarket. The task involved finding an exploding jellyfish, but this time it was hidden in the full version of the supermarket which had shelves full of items. Students had to attempt this task twice (with the jellyfish in a different position each time). The first time they just had to search until they found it, but the second time they were given a clue “its next to the spaghetti”. There was no significant difference between the groups when no clue was given, but when they had been given a clue the experimental group were significantly (P = .011) faster than the control group at finding the jellyfish in the full supermarket.

This experiment showed that both navigation and recognition of items improved with practice in the virtual supermarket. However, there was an important difference between the groups. The experimental group improved significantly at virtual shopping and also significantly improved their performance at the individual component tasks. Although the control group significantly improved their performance at the individual component tasks, they did not get significantly better at shopping in the virtual supermarket.

This difference between the groups emphasises the value of self-directed activity in learning, since in this experiment the control group had no control over their on-screen movements and all of their action in the VLEs were mediated by the experimenter. By contrast, the experimental group had complete control over their movements in the virtual supermarket and were constrained only by their task of finding four pre-selected items and taking them to the checkout. Having experienced self-directed activity whilst learning, the experimental group were able to transfer their skills from one virtual environment to another. The control group, who had been denied this, proved unable to transfer their skills in this way.

This experiment highlights the unique educational value of VLEs for students with severe learning disabilities, for whom transfer of skills from training is a particular problem. It suggests that a principal advantage of VLEs over other educational aids is that they give the user control over what happens, placing self-directed activity at the heart of the learning process. Programmers designing educational systems can exploit this quality of VLEs by giving priority to choices and decisions, by making programs open-ended rather than closed, and by building in multiple routes to the same goal.

We have shown that SLD students can use VLEs to practice vital life skills on an everyday basis and that these skills can transfer to the real world. Their use can also encourage self directed activity in this group of students. Current work is now aiming to assess whether they can transfer spatially learnt skills to the real world and in due course establish which ‘types’ of learning are suitable to this approach. We aim to determine the optimal design of virtual learning environments for various ‘types’ of learning (experiential, communication, spatial for instance) in terms of VLE complexity and subsequent speeds of access, and the inclusion and balanced use of embedded sequences, scanned images, 3D sound and video (multimedia).

6. Summary

This paper describes the historical development of the LIVE programme and illustrates some of the virtual environments that comprise it. Also described are some of the potentials for VLEs in special education and the paper relates them to aspects of developmental theory, setting out some guiding principles for its use.

Summarised are the empirical results that demonstrate that skills acquired in VLEs can transfer to real world situations, and that communicational abilities can be developed within these novel environments. From these, we hope to determine precisely which features of virtual environments best facilitate learning and transfer of skills, and to which types of learning such a teaching approach is most suited.

What is now emergent is a five stage methodology for the development of virtual learning environments; from embedding this work in contemporary educational theory, the ethical partnership with User Groups in developing these learning systems, together with the systematic approach to testing, the implementation of these programs in the classroom and its curriculum, through to the production of guidelines for the optimal design of VLEs.

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