Advanced Design Methodologies for the Production of Virtual Learning Environments for Use by People with Learning Disabilities

Abstract

The authors have previously presented a methodology to guide the development of virtual learning environments (VLEs) for use by people with learning disabilities (Brown, Neale, Cobb, & Reynolds 1999). This paper presents the results of two sets of studies and shows how these studies enhance this methodology. The first set of studies are user-centered designs for VLE to teach horticultural-related employment, leisure, travel, and public presentation skills to young people with learning disabilities. These projects have allowed us for the first time to distill a set of design guidelines for the production of VLEs for use by people with a learning disability. The second set of studies aims to determine the tutoring strategies employed by support workers, teachers, and care providers when supporting people with learning disabilities using VLEs. These strategies will be embedded in the VLEs to further scaffold the learning process of our target users and allow us to expand the guidance given within the implementation component of the development methodology. These enhancements of the existing methodology are clearly developed within the paper and illustrated diagrammatically.

1 Introduction

Following an increase in its role in mainstream education, computer-delivered instruction has started to make a contribution to the education of children with learning disabilities (Goldenberg, 1979; Dube, Moniz, & Gomes, 1995; Chen & Bernard-Opitz, 1993). Interactive software encourages active involvement in learning and gives the user the experience of control over the learning process (Pantelidis, 1993). This is especially important for people with learning disabilities who have a tendency to passive behavior (Sims, 1994). The learner can work at his or her own pace (Hawkridge & Vincent, 1992). They can make as many mistakes as they like without irritating others, and the computer will not tire of the learner attempting the same task over and over again, nor get impatient because they are slow or engrossed in particular details (Salem-Darrow, 1996).

As an example of interactive software, virtual environments have a contribution to make to the education and training of students with learning disabilities (Cromby, Standen, & Brown, 1996). Cromby et al. (1996) draw attention to three characteristics (in addition to those shared with other forms of computer-delivered education) that make them particularly appropriate for
people with learning disabilities. First, virtual environments create the opportunity for people with learning disabilities to learn by making mistakes but without suffering the real humiliating or dangerous consequences of their errors. Secondly, virtual worlds can be manipulated in ways in which the real world cannot be. A simple world can be constructed within which the task could be performed, and, as the user becomes more familiar with the task, the world can become more complex. Features to which the learner needs to pay attention can be made more prominent (McLellan, 1991).

Thirdly, in virtual environments, rules and abstract concepts can be conveyed without the use of language or other symbol systems. Virtual environments have their own “natural semantics” (Bricken, 1991): the qualities of objects can be discovered by direct interaction with them. They can thus be used to facilitate concept attainment through practical activity, bypassing the need for disembedded thinking (Donaldson, 1978), which people with learning disabilities often find difficult to acquire and use.

Initial work suggests that virtual environments are effective in facilitating the acquisition of living skills, such as shopping and navigating new environments (Standen, Cromby, & Brown, 1997, 1998; Standen & Cromby, 1997) and Makaton sign language (Standen & Low, 1996) by children with severe learning disabilities. With the wider availability of computers in both primary and secondary schools for mainstream and special education (Light, 1997), there is a need to investigate a range of questions about this new aid to learning. However, at the same time, there are adults with learning disabilities who may have had little or no computer experience at school but whose continuing educational needs have been recognized by the Tomlinson Report (1997).

Approximately twenty people in every thousand have mild or moderate learning disabilities and approximately three or four per thousand have severe learning disabilities. They are unlikely to enter employment when they leave school or to achieve the level of independence expected by the rest of society. Adults with learning disabilities will have the option to attend some form of college or day center, the role of which is to provide training programs relating to the development of daily living, social, and educational skills. As in special education, VLEs have a role to play in this.

Rostron and Sewell (1984) see computers as just “one more useful facility in the general remedial framework that is available” (p. 9) but advise that they are not there to replace human teachers, just to provide them with additional teaching aids. Computers are highly motivating, but Rutkowska and Crook (1987) caution against the naive belief that unguided interaction can effectively exploit their educational potential. Interaction can be guided in two ways in this form of learning. The first is through the involvement of a human tutor. The work previously described using VLE was carried out utilizing desktop systems wherein the public nature of the display allows interactions between the learner and a tutor. A study by Standen and Low (1996) examined the strategies employed by teachers who were encouraging school-aged students with severe learning difficulties to use a VLE to learn Makaton sign language. They found that teachers contributed significantly less as sessions progressed, selectively dropping the more didactic and controlling behaviors in their repertoire.

For both children and adults with learning disabilities, it is important to learn with a tutor, but staff are responsible for too many students to be able to give one-to-one tuition on a regular basis and, when they are able to provide this function, need guidance on effective strategies. According to Hawkridge and Vincent (1992), teachers need help and encouragement to build their confidence and skills in using computers, and they deserve proper training opportunities. Resolution of this situation involves a consideration of the functions of the tutor. One of the primary functions of tutoring according to Wood, Bruner, and Ross (1976) is to allow the learner to make progress by initially providing scaffolding, for example by controlling those elements of the task that are initially beyond the beginner’s capability. As the beginner becomes more familiar with elements of the task and develops the ability to perform it independently, the tutor intervenes less. Another is to maintain the learner’s interest and motivation, marking relevant features of the task and interpreting discrepancies be-
 tween the learner’s productions and correct solutions. As proposed by Slator et al. (1999), the first of these functions could be incorporated into the software. This would be either in the form of unintrusive tutoring (giving advice but not preventing actions) or intelligent software tutoring (providing feedback based on the tutoring agent’s experience of the task and the learner’s behavior). Such a software tutor would enable a less experienced person, even a peer, to perform the function of maintaining the learner’s interest and motivation.

Desktop-based VLE applications for people with a learning disability are now approaching the end of their first decade of development. The first wave of applications included

- Virtual Makaton to teach language skills to people with a learning disability (Brown & Stewart, 1995),
- The Virtual Factory to teach health and safety skills within sheltered employment schemes (Cobb & Brown, 1997),
- The Virtual Tenancy to teach tenancy rights to people in sheltered housing (Brown & Englefield, 1997), and
- The Virtual City to teach independent living skills to people with a learning disability (Brown et al., 1999).

This work has been extended recently with a latter series of developments, extending the user-centered design and evaluation philosophy of the Virtual City. These include the Virtual Beach, used by profoundly and multiply disabled students, Virtual Employment Training for the development of horticultural-related skills, Virtual Travel Training to the Millennium Dome in London, and the Virtual Courtroom, which allows people with learning disabilities to prepare to give evidence in court.

The continual development and evaluation of three new projects has allowed us to distill an important set of guidelines to direct the development of future VLEs for use by people with a learning disability. These are termed the Greenhat Design Guidelines and are presented within this paper. Latterly, the age range of learning-disabled users within the target audience has been expanded, and a need has emerged for a set of tutoring strategies to scaffold users in their learning and training, in much the same way as they would be supported in the real world. These strategies will be embedded within the VLE. These tutoring strategies, together with the new design guidelines, have allowed us to significantly expand our design methodology to guide the development of VLEs for use by people with a learning disability.

2 New Developments in Virtual Learning Environments

2.1 Virtual Glenwood Growers

This virtual learning environment has been designed using the existing methodology previously reported on (Brown et al. 1999). The methodology was designed to guide the development and evaluation of the Virtual City, a series of VLEs to teach independent living skills to people with a learning disability. This new VLE has been designed to teach employment-related horticultural skills. Horticulture is one of the main potential job opportunities for people with learning disabilities on graduating from school. The development and evaluation methodology is presented in figure 1, and guided the software development for Virtual Glenwood Growers.

From the information gathered at the user group meetings (six users, age range twelve to nineteen, The Shepherd School, Nottingham), the following learning objectives were scoped for the environment:

- use of protective clothing,
- danger of lifting heavy weights,
- clearing up broken glass,
- first aid,
- safety when spraying,
- washing hands before eating food,
- clearing up equipment.

Figure 2 shows a snapshot of the completed environment ready for evaluation.

In keeping with our user-centered design methodology, evaluation and subsequent refinement play a cen-
tral role in ensuring usability and effectiveness of the finished software, the two prime indicators of the success of any computer-aided learning tool. A testing group of six members was used in formative evaluation, each observed over the seven learning tasks, and followed up with posttask interviews to reveal the reasons behind any observed usability problems. A sample of one of these usability content analyses for a student completing the dressing learning objective is shown in table 1. A usability scale is used, with a score of 1 indicating severe difficulty in completing the task, through to a 5 indicating extreme ease in task completion.

The related interview and observational comments were also recorded for this student for each learning task within this work-related environment. Comments include suggestions for software refinements based on recorded usability problems. Table 2 shows such an example for the lifting task.

With six students each completing the seven learning tasks, some 42 student records were created, and these are summarized in table 3.

Working closely with the Shepherd School-based user group, Virtual Glenwood Growers has been created and gained excellent usability results in its first refinement phase. These results not only prove the validity of the design methodology but have also helped to refine a set of design guidelines presented later in this paper.

There are other VLEs in development and evaluation at the Greenhat Research Team, Department of Com-
Table 1. *A Sample Usability Content Analysis for a Student Completing the Dressing Skills Learning Objective*

<table>
<thead>
<tr>
<th>Interaction 1: Dressing</th>
<th>TASK</th>
<th>MARK</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entering the sliding doors</td>
<td>2</td>
<td>Didn’t really understand how to use the mouse and what was required. Had problems actually getting through the door.</td>
</tr>
<tr>
<td></td>
<td>Navigating to the office</td>
<td>3</td>
<td>General problems with the use of the joystick and controlling movement within the environment.</td>
</tr>
<tr>
<td></td>
<td>Entering the office</td>
<td>2</td>
<td>Struggled with negotiation of the door.</td>
</tr>
<tr>
<td></td>
<td>Locate the clothes</td>
<td>5</td>
<td>No problem with this task.</td>
</tr>
<tr>
<td></td>
<td>Follow the link</td>
<td>3</td>
<td>Couldn’t remember the second part of the link instructions.</td>
</tr>
</tbody>
</table>

Table 2. *Interview and Observational Comments for a Student Completing the Lifting Task*

**General Comments**

Had general problems with the use of input devices (mouse and joystick), which would probably be improved with more experience. There is a need to create an input device that integrates both devices which is already part of an ongoing research project at The Nottingham Trent University (Lannen Brown, 2000).

**Suggested Improvements**

The doors presented navigational difficulties. Hard to improve as these had already been designed to be larger than reality and to increase the dimensions would cause greater problems of scale.

The link instructions informing the user of what to do next consisted of two parts. These should be split into two separate sets of instructions with the second part being available only after the first part has been read. That is:

1. Find the peat against the shed wall when this has been clicked on and moved to the trolley, then this should activate:
2. Move it to the table with the plants on it.

2.2 The Virtual Beach:

Earlier VLEs (The Virtual City, Virtual Makaton, The Virtual Tenancy, and The Virtual Factory) have all been developed for people with severe learning disabilities. There is, however, a group of people with even more severe learning disabilities (in British schools termed “Profound and Multiple Learning Disabilities”) for whom these environments would be inappropriate. The Virtual Beach is one of our first attempts to define a set of experiential environments for this user group, a window onto a series of worlds that most of them will
### Table 3. Usability Content Analysis Summary

<table>
<thead>
<tr>
<th>Interaction/Task</th>
<th>User1</th>
<th>User2</th>
<th>User3</th>
<th>User4</th>
<th>User5</th>
<th>User6</th>
<th>Group Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interaction 1: Dressing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering the sliding doors</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3.8</td>
</tr>
<tr>
<td>Navigating to the office</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td>Entering the office</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>Locate the clothes</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Follow the link</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Interaction 1: Total</strong></td>
<td>15</td>
<td>19</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>22.2</td>
</tr>
<tr>
<td><strong>Interaction 1: Mean</strong></td>
<td>3</td>
<td>3.8</td>
<td>4.8</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Interaction 2: Lifting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-clicking the bag</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>4.2</td>
</tr>
<tr>
<td>Steering the trolley</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Follow the link</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Interaction 2: Total</strong></td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>11</td>
<td>14</td>
<td>12</td>
<td>11.7</td>
</tr>
<tr>
<td><strong>Interaction 2: Mean</strong></td>
<td>2.7</td>
<td>3.7</td>
<td>4.7</td>
<td>3.7</td>
<td>4.7</td>
<td>4</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Interaction 3: Planting &amp; Cleaning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting the flowers</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.2</td>
</tr>
<tr>
<td>Cleaning up the broken pot</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td>Follow the link</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Interaction 3: Total</strong></td>
<td>13</td>
<td>12</td>
<td>13</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>13.8</td>
</tr>
<tr>
<td><strong>Interaction 3: Mean</strong></td>
<td>4.3</td>
<td>4</td>
<td>4.3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Interaction 4: First Aid</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find the first aid kit</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Understand the instructions</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td>Follow the link</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Interaction 4: Total</strong></td>
<td>13</td>
<td>11</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>12</td>
<td>13.2</td>
</tr>
<tr>
<td><strong>Interaction 4: Mean</strong></td>
<td>4.3</td>
<td>3.7</td>
<td>4.7</td>
<td>4.7</td>
<td>5</td>
<td>4</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Interaction 5: Spraying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find the first equipment</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td>Find and interact with the second sprayer</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td>Follow the link</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><strong>Interaction 5: Total</strong></td>
<td>11</td>
<td>10</td>
<td>13</td>
<td>12</td>
<td>9</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>Interaction 5: Mean</strong></td>
<td>3.7</td>
<td>3.3</td>
<td>4.3</td>
<td>4</td>
<td>3</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Interaction 6: Eating</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find the apple</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Find and interact with the sink</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Right-click the apple</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>3.2</td>
</tr>
<tr>
<td>Follow the link</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Interaction 6: Total</strong></td>
<td>11</td>
<td>16</td>
<td>8</td>
<td>18</td>
<td>20</td>
<td>15</td>
<td>14.7</td>
</tr>
<tr>
<td><strong>Interaction 6: Mean</strong></td>
<td>2.8</td>
<td>4</td>
<td>2</td>
<td>4.5</td>
<td>5</td>
<td>3.8</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Interaction 7: Tidying</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find the first wheelbarrow</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Find the rake</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.7</td>
</tr>
<tr>
<td>Manipulate the rake</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Find the fork</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.3</td>
</tr>
<tr>
<td>Find the spade</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Interaction 7: Total</strong></td>
<td>21</td>
<td>21</td>
<td>23</td>
<td>23</td>
<td>25</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td><strong>Interaction 7: Mean</strong></td>
<td>4.2</td>
<td>4.2</td>
<td>4.6</td>
<td>4.6</td>
<td>5</td>
<td>5</td>
<td>4.6</td>
</tr>
</tbody>
</table>
not experience due to a complex collection of disabilities, including an inability to regulate their own body temperature.

It is envisaged that these environments will be combined and integrated with other multimedia. An example of this is the solar visualization room at the Shepherd School, where projected virtual environments are synchronized with audio, wind machines, scratch-and-sniff cards, and running water (Brown, Stewart, & Mallet, 1997).

2.3 The Virtual Courtroom:

Changes in the Criminal Justice Act in Great Britain mean that, for the first time, people with a learning disability can give evidence in court and be cross-examined. This is an important step forward in terms of personal liberty, but the Ann Craft Trust (ACT—the society for the protection of people with learning disabilities from abuse) have recognized that this will also present a daunting prospect for many people with a learning disability. In a joint venture between The Nottingham Trent University and ACT, the Virtual Courtroom will provide a preparational training medium to enable users to practice evidence giving and cross-examination procedures and gain confidence and familiarity with what will be expected of them.

2.4 The Millennium Dome Travel Training Environment

MENCAP UK commissioned this travel training software to teach people with a learning disability how to reach the Millennium Dome in London's Docklands. Using the development and evaluation methodology of the Virtual City (Brown et al., 1999), a user group was formed from attendees of Greenwich Mencap. The learning objectives defined by this user group for this program were

- safely crossing roads,
- identifying the correct bus stop,
- identifying the correct bus,
- monitoring the progress of the journey,
- personal safety issues, and
- strategies for dealing with unexpected problems.

The environment is to be evaluated in conjunction with the Department of Psychology, University of East London. Case studies will be used to determine the impact of this travel training software on users’ abilities to use public transport in an independent manner. A snapshot of this VLE is shown in figure 3.

3 Tutoring Strategies and Embedded Virtual Tutors

Other researchers have promoted the use of embedded virtual tutoring agents to scaffold learners’ activities within VLE. These proactive tutoring agents do not direct student activity, but more rather visit a student when the need arises, and offer advice but not mandates for action. Researchers at NDSU offer a classification for these tutoring agents (Slator et al., 1999):

- **Deductive tutors**: Provide assistance to users during the course of their deductive reasoning.
- **Case-based tutors**: Provide assistance to players by presenting them with examples of relevant experience.
- **Rule-based tutors**: Encode a set of rules and then monitor users’ actions and wait for the rules to be broken. Advice is then offered to the user based upon this.
Our recent work has involved developing and embedding virtual tutoring agents in the VLEs presented in this paper. These tutors have become more extensively used and sophisticated with time; however, we have not used such as rigid classification as presented by researchers at NDSU.

It has proven useful to classify the embedded virtual tutoring agents in each of these VLEs. Doing so has allowed us to evaluate a variety of such tutoring strategies and has enabled us to eventually give guidance on embedding these within VLEs as part of the overall design methodology.

4 Embedded Virtual Tutoring Agent Classification

Using the NDSU classification, the types of embedded virtual tutoring agents we have utilized in past and present VLE are shown in table 4. The VLE are presented in order of their chronological development. It is obvious that as time has gone on, our use of embedded virtual tutoring agents has increased in incidence and sophistication. Employing a classification scheme now allows the various strategies to be evaluated and their impact on the effectiveness and usability of these VLEs by people with a learning disability to be assessed. This in turn helps the further distillation of the Greenhat Design Guidelines.

The only problem with the use of this classification system is that it was used to define a range of tutoring strategies embedded within VLEs to teach subjects including geology, cell biology, history, and geography to mainstream students. This classification system is linked in some ways to the educational content and aims of these VLEs by people with a learning disability to be assessed. This in turn helps the further distillation of the Greenhat Design Guidelines.

### Table 4. Classification of Virtual Tutoring Agents within VLE

<table>
<thead>
<tr>
<th>VLE</th>
<th>Deductive tutor</th>
<th>Case-based tutor</th>
<th>Rule-based tutor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Makaton</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Virtual Factory</td>
<td>x</td>
<td>x</td>
<td>E.g., detects users entering hazardous areas.</td>
</tr>
<tr>
<td>Virtual Tenancy</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Virtual City</td>
<td>Detects when user fails to deduce incorrect change from payment</td>
<td>x</td>
<td>E.g., detects when underage users attempt to order alcoholic beverages.</td>
</tr>
<tr>
<td>Virtual Glenwood</td>
<td>Detects when user fails to collect all elements for potting table tasks</td>
<td>x</td>
<td>E.g., detects when users attempt to lift peat without using the sack truck.</td>
</tr>
<tr>
<td>Virtual Glenwood Growers</td>
<td>Detects when user has overlooked a goal in their travels.</td>
<td>Shows user how to board correct bus should they fail to do so</td>
<td>If user attempts to get off at wrong stop, they are visited with advice of consequences.</td>
</tr>
<tr>
<td>Virtual Travel</td>
<td>Detects when user has overlooked a goal in their travels.</td>
<td>Demonstrates different cases of cross-examination</td>
<td>If user attempts to enter the courtroom without permission, warnings are given.</td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virtual Courtroom</td>
<td>Detects when user has failed to collate all their pieces of evidence</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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starting point, the nature of an embedded virtual tutor agent to assist in the education of a person with a learning disability is likely to be of a very different nature to those designed at NDSU.

5 The Design of Embedded Virtual Tutors for Special Education

The NDSU classification system has given us food for thought in terms of systematically classifying and retrospectively examining the tutoring strategies used in our own VLE. We need, however, to examine the teacher-student tutoring strategies employed in special-needs education as an indicator of the components of an appropriate tutor embedded within VLEs for use by people with learning disabilities. To inform the design of the embedded virtual tutoring agent, we set out to investigate what strategies human tutors used when working with adults who were learning to use VLEs, and how effective these strategies were. Adults with a learning disability are even more likely than their younger counterparts to have a lower expectation and degree of experience in using computers. Designing tutors to encompass this user group will make our VLEs more accessible by all sections of the population with a learning disability. What we are attempting is in some sense a “design for all” for the learning disabled community, if such a concept does not present a paradox in itself.

5.1 Method

5.1.1 Participants. So far, data are available on nine people attending a social services adult training center for people, with learning disabilities. They would all be described as having moderate to severe learning disabilities, but staff have yet to score them on the AAMR Adaptive Behavior Scale (Nihira, Leland, & Lambert 1998). All participants whose data are used in this paper worked with one of the researchers (TP) as tutor.

5.1.2 Design. Each participant completes up to twelve sessions, and changes from baseline and over time are examined.

5.1.3 Virtual Environments. These VLE have been developed as part of the Virtual City project sponsored by the National Lottery Charities Board. The project consortium consisted of The University of Nottingham, The Shepherd School, and The Metropolitan Housing Trust (Brown et al., 1999).

All of these VLEs were displayed on a Pentium II with 17 in. monitor, and were operated using a standard three-button mouse or trackball.

5.1.4 Procedure. Service users who wished to take part spent a session using a two-dimensional routine to learn how to use the mouse. Once this had been mastered, they moved on to the other VLEs in the same order (road crossing, café, supermarket, factory) progressing to the next only once a defined level of mastery had been achieved. Sessions were scheduled as close as possible to twice a week and lasted approximately thirty minutes. They were recorded on videotape, with the camera positioned to view both the learner and the tutor sitting next to them.

5.2 Results

5.2.1. Coding of videotapes. The coding system was developed with the help of the project research assistant who had previously carried out a pilot study on nine service users. The system went through three different phases before a satisfactory level of repeat reliability (between 75% and 80%) could be established.

Tutor behavior was coded into five categories:

- **Specific information** given to learner about achieving a goal and was further categorized as being about the mouse, the joystick, or the environment (for example, “go over to the bar now”).
- **Nonspecific information** did not provide the help a learner needed to achieve a goal but made the learner aware of possibilities and was similarly categorized as concerning the mouse (“where are you going to click then?”), the joystick, or the environment.
- **Gesture** covered any movement made by the tutor, such as pointing to direct attention to the screen or
to instruct movement of the arrow on the screen or to direct movement through the environment.

- **Touching** controls included the tutor putting their hand over the learner's or taking over the input device to demonstrate, and was further categorized as concerning either the mouse or the joystick.

- **Feedback** could be either positive such as praise or reassurance (such as “well done” or “that’s good”) or negative (“no, not like that”).

Learner behavior was categorized in terms of the number of goals they achieved in an environment and could be either positive (finding an item on the shopping list) or negative (stepping into the road before the light has turned to green).

### 5.2.2 Analysis

Sessions were divided into 10 sec. intervals, and whether or not a particular behavior started during this interval gave it a score of 1. Therefore, the maximum score for a behavior for any one session could not be greater than the number of 10 sec. intervals in that session. The score was converted to rate per minute to take account of differences in duration of sessions.

### 5.2.3 Use of Input Devices

One of the tasks of the tutor was to assist with mastery of the input devices, but specific information about them was always given at a lower rate than about the environment itself. Both touching and specific information about the mouse (figure 4) and the joystick (figure 5) did decrease over repeated sessions. Unsurprisingly there were very low levels of non-specific information throughout.

### 5.2.4 Learners' Achievement of Goals

Environments differed in the number of goals there were to achieve, and, on the early attempts at each environment, not all goals were attempted. Figure 6 shows the rate per minute at which goals were achieved irrespective of which environment the learner was working on. To give context to the activity of the tutor, it appears that learners were achieving goals at a steady rate. However, to give a true picture of achievement, rates need to be adjusted to take account of the total possible number of goals that could be achieved in each particular environment and also whether the learner had just progressed to that environment.
5.2.5 Tutors’ Strategies. Although learners’ goal achievement was remaining at a steady level, tutors provided less and less specific information as sessions progressed while giving increasingly more nonspecific information. (See figure 7.) Negative feedback was always very low, whereas positive feedback remained at a high level. Closer analysis might illustrate whether this was needed to maintain learners’ motivation or because it was a default level for the tutor and insensitive to behavior on the part of the learner.

5.3 Discussion

Although we had established a method of coding in an earlier study, a new scheme had to be adopted for this study because the participants were much more able and verbal. However, this new system retained the distinction between help with input devices and help with negotiating the environment. The amount of help given with the mouse was much lower than that given with the joystick, because specific training was given with the mouse prior to starting on the first VLE. Similar training with the joystick would have been helpful as well as a user-friendly method for determining individual settings for the controls. The distinction between specific and nonspecific information follows work on children’s learning (Wood, 1976) in which different levels of control exerted by the tutor were distinguished. Changes over time in the present study suggest that this distinction is worth maintaining. The tutors appear to be following the expected pattern of intervening or controlling less, thus allowing more time for the behaviors that maintain the learner’s interest and motivation and function to interpret the learner’s activity. This distinction might also correspond to that between those tasks that can be written into the embedded virtual tutoring agent (specific information) and those that need the presence of a human tutor. Although preliminary analysis of data shows interesting changes over time, the true value of the effectiveness of the strategies can be determined only by further, closer analysis.

6 Enhanced Design Methodologies and Guidelines

6.1 The Addition of Design Guidelines to the Development Methodology

Computer scientists are rightly concerned with developing methods to guide quality software develop-
ment and evaluation. These quality assurance (QA) procedures have been formalized in the British Standard BS5750 Part 1 and its European equivalent, ISO9001 (TickIT) (Bocij, Greasley, & Hickie, 1999). The purpose of such standards is to ensure that all elements of the software development cycle, such as requirements capture, design, and testing, are carried out consistently. These steps are analogous to those presented in our development methodology (figure 1) and other methodologies previously developed and employed by the Greenhat Research Team at the Nottingham Trent University.

What can evolve from repeated application of such standards in a particular area is the emergence of design guidelines. These represent “best practice” standards and help guide software developers in the creation of new projects. The Greenhat Design Guidelines represent the distillation of all evaluation results carried out using the VLEs presented earlier in this and previous papers (Brown et al., 1997; Brown et al., 1999). The development and incorporation of embedded virtual tutoring agents will further clarify and extend these guidelines. Together these components enhance the overall design methodology, and this is shown later in figure 8.

As part of our current European funded project (Flexible Learning Systems), an educational server has been established within the Department of Computing at the Nottingham Trent University. This will host the Virtual Electronic College for use by people with special needs. As part of this facility, the VLEs described within this paper will be accessible via this server, together with a range of other virtual reality and multimedia-based learning resources. The server and associated learning resources are to be launched in early 2001, via a series of Web addresses including www.greenhat.org. The computer-aided learning (CAL) packages on this server will be distributed freely or at low cost, in return for user-completed usability questionnaires to enable us to strengthen and extend our longitudinal evaluation studies. It will also help circumnavigate the major barrier to the usability of all CAL packages, namely the lack of a coherent and workable dissemination strategy (Boyle, 1997).

6.2 Greenhat Design Guidelines

The following guidelines are for use by programmers producing online VR-based learning, training, and education-based material for people with a learning disability (Sterland, 2000). They have been derived from examining the results of Usability Content Analysis studies of VLEs, including Virtual Glenwood Growers, the Virtual Beach, and Virtual Travel Training to the Millennium Dome.

- Instructions should be atomic in order for the user to easily remember them.
- Avoid the need to use more than one button of the input device. The use of the mouse should be restricted to the left button only.
- When the user is required to listen to instructions or learning objectives, any further interaction should be prevented until after this has terminated.
- Events requiring complicated input device actions can be useful for learning computer skills but should not be an integral part of the main program.
- If the user is required to select items in order and they select the wrong order, they should receive prompts to reiterate the correct order.
- The use of text should be avoided. Alternatives should include pictorial representations such as icons or Makaton symbols. This should also be combined with a voice-over.
- Speech therapists should be consulted to simplify text and suggest symbols.
- The use of icons and pictorial prompts should be consistent and standardized (that is, green for yes, red for no) throughout the whole of the software.
- Although the VLE should be realistic, the developers should use the environment to help overcome learning barriers that exist in the real world (visibility issues).
- The input devices to be used should, wherever possible, ensure maximum accessibility for the disabled community.
- Doorways should be wider than they are in reality to reduce the problems that are encountered when approaching them from an angle.
- VLEs should be nonimmersive.
- Dialogue boxes should remain on screen for a length of time that is appropriate for the ability of the user.
- If an object is small, the “clickable” area should be larger than the object.
- If the user is prompted to click an object, it should be visible at the time of the prompt.
- Wherever possible, an action should require only a single click of the input device.
- When there is a need to position a viewpoint or an item, allow for extra tolerance.
- The VLE should contain as many real-life cues as possible so long as they don’t distract the user from the learning objective.
- To allow for the difference in abilities, users should be able to bypass advanced learning objectives.
- When dealing with money, the user should be rewarded for giving exact money to discourage them from just picking largest denomination bill.

6.3 The Refined and Enhanced Design Methodology

The previous methodology for the production of VLEs for use by people with learning disabilities (figure 1) is presented again with the new enhanced components indicated by bolding (figure 8). This refined methodology is already in use within the Greenhat Research Team, notably to produce VLEs that mirror the strategies of computer games, in an attempt to motivate disaffected young people to return to education. This work is part of several new European grants recently awarded to the research team.

7 Conclusion

As a result of a recent spate of projects designing and delivering VLEs aimed at developing skills in people with learning disabilities, a set of design guidelines has emerged to guide further development. Concurrently
designing VLEs for a wider age range of users has meant accommodating people with a lower expectation and experience of using computers. Mirroring the tutoring strategies employed by their support workers, teachers, and care providers in special-needs arenas, embedded virtual tutoring agents are being developed and incorporated within new VLE applications. These two key features—design guidelines and virtual tutoring agents—have extended and enhanced our existing design methodology.

References


Northridge, CA: California State University Center on Disabilities.


