In this work, whether the educational role of the teacher, from a Vigotskyan point of view, can also be taken on by a computer is examined. Software including math and reading activities with three different scaffolding levels were developed and used over a period of 10 weeks (effective time was 15 hours) with third-grade low achievers. Both the achievement and the strategies employed were assessed. Results indicate that, whereas there are no significant differences as far as achievement is concerned, there was quite a clear relationship between the scaffolding level and strategy learning: the higher the scaffolding level, the more advanced the strategies used by the children. These results point towards the need for scaffolding to be meta-cognitive.

Although the literature on computer integration in the school system contains basically short term studies (Torgesen & Barker, 1995), there can be no doubt today that computers, and new technologies in general, have a wide range of application possibilities in nursery and primary education (Bailey, 1992; Bornas, Servera, & Llabrés, 1997; Elliott & Hall, 1997; Shute & Miksad, 1997). Some of the advantages of using computers are the way in which attention and motivation are favoured (DuPaul & Stoner, 1994), the possibility of instantaneously offering the learner feedback on
their choice (Burt & Ryan, 1997) and, above all, the possibility of offering individualised instruction (Bornas et al., 1997).

The educational use of computers may enhance learning in its more traditional concept (now out of place) by facilitating the acquisition of certain knowledge, transmitted in a unidirectional way (Vizcarro & León, 1998). Nowdays, however, without forgetting that children with learning difficulties will be able to benefit greatly from the increased opportunities of practice offered by computers (Torgesen & Barker, 1995), it is necessary to take into account the fact that teacher-student roles have changed. As Vizcarro and León (1998) pointed out, the student is no longer considered a passive agent and has acquired the responsibility of their own training with the help of educators. The teacher is no longer exclusively a source of information and has become a guide/adviser with the necessary knowledge to be able to offer help to their students. From this concept, learning cannot be transmitted but rather has to be built; teaching must be linked to previous knowledge and must involve activities that are significant for the learner, and all of this implies tutorship or “individual guidance.” In a similar way, Johnson (1997) stated that we are immersed in the phase of integration of technology in the curriculum and observed an outstanding tendency: “...the instructional process will become more learner-centered and less teacher-directed...As machines become more involved in the instructional process, teachers will assume more of the role of manager and guide for student-centered learning” (p. 4). This makes us think that not only have the roles of the teacher and the student changed: the role of computers has also changed, and has yet to change more, probably in a similar way in which the teacher’s role has changed.

Vygotsky’s is one of the currently most accepted theories from the constructivist perspective. One of his most essential contributions is the zone of proximal development (ZPD) (Vygotsky, 1962). A key question is whether the role of the teacher, which according to this model, is to help the learners carry out the tasks they would be unable to solve alone, could be carried out by a computer. Whatever the answer, it must be said the computer should not become a substitute for teachers. In fact, somebody has to design the learning activities, and someone has to program the computer and decide when to give feedback or how to organise the activities.

As yet, we do not possess a definitive answer to the above question. Although data seem to point towards an affirmative answer, the procedure of most studies that compare the efficiency of computer- or teacher-administered instruction is not detailed enough.
In the study with nursery school children by Elliott and Hall (1997), group A carried out math activities on a computer (basically counting and making sets) and received strategic, meta-cognitive advice by trained teachers (object identification, reasoning, strategy modelling, etc.). Group B worked with the same activities without receiving strategic instruction and group C carried out the same activities on paper and did other activities not related to math on the computer (neither did they receive strategic instruction). The results, measured with a standardised test of math aptitude, showed the most important progress in group A, followed by B. That is, computer aided teaching was more effective than traditional teaching and strategic instruction encouraged the increase of achievement in the test. These results indicated the computer could contribute to improving nursery school children’s achievement, but does not clarify the role the computer could play in Vygotsky’s ZPD, assuming the strategic instruction was administered by the educator.

In another study, Wilson, Majsterek, and Simmons (1996) used the same procedure to teach the multiplication tables, applied by a teacher in one group of subjects and by a computer in another. The results of the study suggested that both instructional formats could help to automate and learn the multiplication tables, but the percentage of right answers by the ones who received instruction from the teacher was significantly higher. Despite the intents made by the authors to compare the two modes of intervention, there appeared to be a difference which was both as important as unexpected. The opportunities to answer, and therefore the opportunities for instruction, were higher in the group receiving instruction from the teacher. Whereas the computer always followed the same routine (assess the answer, give feedback for a certain period of time, show the following screen, etc.), the teacher, who was much more flexible, advanced at a much faster pace and gave more opportunities to practice. This study seems to indicate that computers are unable to adopt the role of guide suggested by Vygostky’s theory, yet in fact it could be thought that if the software were more flexible it could work in that way.

Finally, the study by Shute and Miksad (1997) provides the novelty of controlling the scaffolding level of the instruction, that is, to what point the learner’s work is supported. In general, the scaffolding level can range from simple encouragement (the computer or the teacher reinforce the performance of the learner step by step) to the complete demonstration (the teacher or computer carry out the task whilst acting only as a model). Then, when the teacher and the computer offer the same scaffolding level in their instruction, there are no differences in the learning. In this way, as Shute
and Miskad (1997) stated, if the computer turns out to be more efficient in many studies this is because it can offer a better scaffolding level than a busy teacher, above all by capturing student’s attention and by offering immediate feedback. The results of this study clearly supported the fact that the answer to the question as to whether the role of the teacher of helping the learner carry out the tasks they would be unable to solve on their own, could be carried out by a computer, is affirmative. Yet if we go a bit further, the key question could be: what characteristics does educational software have to have in order to be able to play this role?

The study we present here, which forms part of more extensive research (Llabrés, 2000), is aimed at assessing the efficiency of a flexible computer aided teaching program with different scaffolding levels, in the improvement in learning of a group of children with low academic achievement. The results should enable us to suggest certain specific characteristics educational software should comply with in accordance to the constructivist model.

**CHARACTERISTICS OF INTERVENTION SOFTWARE**

**Integration in the Curriculum**

One of the most important characteristics of software selection is its integration in the curriculum. For this research, a software package based on the curricular materials the children used in the classroom was developed. Most of the software texts and drawings were extracted and adapted from the children’s textbooks. The teaching staff collaborated actively in selecting the software contents, by indicating the difficulty of the math problems or the length of text to be read.

**Flexibility**

Both the reading program (Figure 1) and the math program (Figure 2) were structured in modules. Hence it was flexible software. When the children were about to finish the activities programmed at the beginning, it was easy to add new modules according to the educational needs at that particular time.
read a text of about 50 words and answer five comprehension questions
memorise a list of about 6 words and identify them in another longer list
find objects shown in a photograph in a word search
build a sentence from a group of jumbled up words
build a sentence which means the same as a model, from a group of jumbled up words
build 4 sentences with the same meaning, using a group of jumbled up words
find a word model repeated in a list of more or less similar words
find a combination of three letters repeated in a list of groups of letters
remember the word left out of a sentence and choose it out of a list

Figure 1. Software reading modules

- problems on recipient capacities
- problems on fractions
- problems on time
- problems with money
- problems on tens, hundreds and thousands
- subtraction facts (one subtraction per card)
- subtraction facts (four subtractions per card)
- multiplication problems
- multiplication facts (two multiplications per card)
- mixed operation problems
- problems on sharing
- subtraction facts (four subtractions per card)
- multiplication problems
- multiplication facts (two multiplications per card)

Figure 2. Math software modules

Flexibility also depends on the navigation system that has been programmed. Navigating within these modules was different in the two programs. In the math one the child could change the module whenever he or she wanted. They could be doing a problem that needed subtraction and change to the subtraction module to practice a little more, or be doing multiplication facts and change to the recipient module where they could see how a one-litre container was filled with four quarter-litre containers. In the reading software, given the little relationship between the modules, it was considered more important to prevent the children from spending too much time on the more entertaining activities (e.g., the word search games), than the possibility of changing the module. The reading software was more linear and the child could not progress until they had finished an activity. Once finished, the software automatically presented another task from another module in a random way.
Scaffolding Level

The most relevant characteristic of the two programs was the help system or the scaffolding level offered depending on the case. Two types of very different helps were programmed, which we called “static helps” and “dynamic helps” (Bornas, Servera, & Llabrés, 1997). The static ones were very similar to the helps the children could find in their text book. Most of them referred to “pay attention” and to “go slowly.” The instructions, in the form of a text or picture, were always static. On the other hand, the dynamic helps modelled the solution process of the task step by step, by offering different ways of reaching the solution, and what is more, they did it in an interactive way. One example can illustrate the differences between the two types of help. The static help in fractions was copied directly from the subjects’ text book. As can be seen in Figure 3, the help consists of showing basic examples between the different possibilities when it comes to cutting a “pizza” into fractions.

**Figure 3.** Static help in fractions

Dynamic help for this activity consisted of a screen where the same “pizza” appeared in which the child had to click on the portions. Each time they clicked on a portion, this was lit up if it was unlit and vice versa. Depending on the portions lit up, they were shown the corresponding fractions. For instance, with four portions lit up in the first “pizza” in Figure 3, independently of the position of the portions, they were shown the fractions $4/8 = 2/4 = 1/2$. In this way, the child interacted with the program and could observe for example, how many portions were left after “eating” a quarter of a “pizza” (one of the problems posed in the software activities).
METHOD

Subjects

Sixty children from the same school took part in this study. They were doing the third grade of Primary Education and had low academic achievement compared to the rest of their peers in the same classes. In the initial assessment of the children’s school achievement, math and reading test scores based on the curriculum (Shapiro, 1989) and above all the assessment of the teachers as to the achievement of their students were used. Each of the 60 children were randomly assigned to one of the four experimental conditions (15 children to each group): Attentional Instruction (AI), Computer Driven Instruction (CDI), Computer Assisted Instruction (CAI), and Control (CTRL). Group AI worked with the software which only offered static help and the educator (see the description of this educator that follows) in this group could only refer to this software for help. Therefore, group AI had a low scaffolding level. Group CDI used the software that offered dynamic help but without the educator giving additional help to the children in this group (intermediate scaffolding level). Group CAI worked with the software that offered dynamic help and also received help from the educator (high scaffolding level). The children in the control group did no work on the computer and carried on attending the normal classes, while their colleagues in the intervention groups left the classroom to go to the computer room to work with the computers.

Procedure

After gathering all the information necessary from the curricular material and the assessments of the teaching staff, the programs were designed and built and the initial assessment was carried out during the first term of the school year. In the second term, the intervention took place. The children in the intervention groups were collected in their classroom and taken to the computer room, where there were 16 computers with the intervention software were installed. Each subject worked individually at their computer. There were two psychology students in each group who had been trained to be educators, both in the knowledge of the software and the purely educational aspects. One of them only had the function of observer but could substitute for the other when necessary (which did not happen). Two weekly
45-minute sessions were held over a 10-week period, so the total intervention time was about 15 hours.

**Measures During and After the Intervention**

*Learning strategies.* In each session, the child received a blank sheet on which to write whatever they wanted. These sheets were collected at the end of the session to obtain information on the strategies the child had used to carry out the tasks set by the computer. No comment was made to the students to this end.

*Academic achievement.* Once the intervention period was over, in the third term, the children were given achievement tests in math and reading. These tests were designed according to what the teachers said they had taught during the time the intervention lasted.

**Design**

A mixed design of two factors in this study, with repeated measures in one of them were used. More specifically, a “group” factor with 4 experimental conditions and a “test” factor of repeated measures with two levels (pre and posttreatment). Thus, in the statistic treatment of the data, an analysis of variance (ANOVA) was applied with repeated measures, which enabled the study of inter-subject and intra-subject variance, and also permitted the analysis of the interaction between factors. In the case of the interaction mentioned not being statistically significant, and also in the analysis of those variables that were only assessed after treatment, the uni-factorial way to carry out the analysis of variance was used.

It must be said, although the groups were initially made up of 15 subjects each, once treatment had started, two children from the CAI group left the intervention program—due to motives completely beyond the authors’ control. Because of this fact, the analyses of variance were carried out using the sequential method, which is the most suitable one for work in different-sized groups. The analyses were carried out using the Statistical Package of Social Sciences (SPSS Inc. 1995; 1999).
RESULTS

In general, as to the achievement in the math and reading tests used, there were no statistically significant differences between the four experimental groups. In other words, the children in the control group, who continued to attend regular classes, had the same achievement at the end of the intervention as those who had worked with the computer. The data analysed in this study refer to the two studies most worked on in the intervention program: reading comprehension and calculations (subtraction). Detailed analysis of other variables (e.g., sentence construction or solving math problems) has been carried out in another place (Llabrés, 2000).

As far as the reading comprehension is concerned, by making an analysis of the main effects we obtained a “group” factor score of $F=0.90$. Neither was the interaction between the two design factors significant ($F=0.38$), which is why the “test” factor ($F=51.87; p<.001$) was analysed uni-factorially, but none of the groups showed any significant difference between the two assessment points.

With respect to the calculations, the same pattern of lack of differences between groups is maintained. The study of the main effects of the different factors indicates there is no significant “group x test” effect ($F=1.92$) although significant “test” factor differences can be seen ($F=67.37; p<.001$). The analysis of this factor shows how despite the fact that the four groups improve significantly from the statistical point of view, the three intervention groups are the ones that show the greatest difference after treatment (Table 1).

Table 1
Calculation Score Before and After Intervention

<table>
<thead>
<tr>
<th></th>
<th>PRE</th>
<th></th>
<th>POST</th>
<th></th>
<th>F</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>AI</td>
<td>9.38</td>
<td>3.92</td>
<td>14.15</td>
<td>0.89</td>
<td>20.83**</td>
</tr>
<tr>
<td>CDI</td>
<td>8.40</td>
<td>3.48</td>
<td>13.33</td>
<td>1.63</td>
<td>39.03**</td>
</tr>
<tr>
<td>CAI</td>
<td>10.15</td>
<td>3.95</td>
<td>13.38</td>
<td>1.38</td>
<td>10.83**</td>
</tr>
<tr>
<td>CTRL</td>
<td>9.84</td>
<td>2.96</td>
<td>11.76</td>
<td>2.94</td>
<td>5.71*</td>
</tr>
</tbody>
</table>

* $p<.05$; ** $p<.01$

The analysis of the strategies employed by the children in solving the intervention tasks has been carried out with the information obtained from
the sheets of paper handed out to the children involved in the three experimental groups during the intervention sessions. The strategies of the control group were not available because if a sheet of paper was handed out while they were in class with their regular teacher it would have distorted the study. The sheets collected during the math lessons did not show any particularly interesting strategy given the fact that the children only made use of them to do the necessary calculations to solve the math problems set by the computer. In the case of reading, the sheets showed more varied, interesting strategies.

The strategies used were independently assessed by two experts, who only had a list of all the strategies used without knowing at any moment in time the subjects who had carried them out or which group they belonged to. Each expert categorised each strategy as rudimentary, normal, or advanced and gave it a score of between 1 and 10. For instance, copying the full list of new words to be remembered was considered a less advanced strategy than grouping words according to certain criteria (e.g., arm, leg, and foot, or red, green, yellow, and white). Afterwards, the value of each strategy was defined as the mean of the two scores appointed by each observer whenever they were placed in the same category and there was a difference of no more than two points between the two scores (otherwise the strategy was not taken into account in the analysis).

According to the ANOVA carried out (Table 2), the CAI group used significantly more strategies than the AI group, and the strategies they used were more advanced than those used by the other two groups.

<table>
<thead>
<tr>
<th>Table 2</th>
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<tr>
<td>Strategies Used in Reading Activities</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>AI M</th>
<th>SD</th>
<th>CDI M</th>
<th>SD</th>
<th>CAI M</th>
<th>SD</th>
<th>F</th>
<th>Contr. a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number b</td>
<td>2.26</td>
<td>1.03</td>
<td>3.42</td>
<td>1.45</td>
<td>4.30</td>
<td>2.17</td>
<td>5.79 **</td>
<td>1-3</td>
</tr>
<tr>
<td>No. X Val.</td>
<td>16.03</td>
<td>13.09</td>
<td>33.85</td>
<td>21.14</td>
<td>60.73</td>
<td>40.58</td>
<td>9.75 **</td>
<td>1-3 / 2-3</td>
</tr>
</tbody>
</table>

** p<.01; a Contrasts SNK with a significance level of .05 (1=AI, 2=CDI, 3=CAI); b Number of strategies used; c Value assigned to the strategies
DISCUSSION

The aim of this study was to provide information on the characteristics educational software should have to be in line with the constructivist model and to be able to play the role proposed by Vygotsky in relation to the ZPD. The importance of the achievement results, from this perspective, is relative: if it is a question of enabling the students to build up knowledge, it would be logical to think what is important is to see that they acquire the tools or strategies to enable this build up and not so much the knowledge they have at any given time. With this premise, the results indicating that computers have not been superior to teachers provide little information. What is more, it is worth noting that the children in the control group continued learning in class the same as what the other groups learned with the computers. Therefore, the computers have been just as efficient as the teachers as far as academic achievement is concerned.

From the constructivist perspective, the results obtained as to the strategies are the most important point. Unfortunately, a good way of assessing the strategies used in math was not found and this needs more research in the future. In addition, it should be said that the procedure used to know the students’ strategies has a clear limitation: a blank sheet does not mean that the student has not used any strategy. However, the blank sheet procedure was chosen because it is less reactive than directly asking students what strategies they had been using. Further research is needed to develop better strategies’ assessment procedures. Despite this limitation, which recommends caution when reading the following discussion, the authors believe that the results on the strategies in reading deserve close consideration.

Statistically speaking, only the CAI group used strategies which were more advanced than the other groups working with computers. Comments on this result are subsequently made, but it would now be worth noting the differences between the three groups. The AI group worked with software offering a lower scaffolding level and the value of the strategies employed was 7.80. When the software offered an intermediate scaffolding level (CDI) the corresponding group used rather more advanced strategies (13.14). When the scaffolding level was the highest (CAI) it was found that much more advanced strategies (21.42) were used. The progression, at first glance, is curious: the value of the CDI group strategies practically doubles the value of those used by group AI, and the value of those used by group CAI practically triples this value. These data seem to indicate the scaffolding level is a key variable when it comes to determining the efficiency of
educational software from the constructivist perspective. The higher the scaffolding level, the better the strategies acquired by the students. The fact that this was not reflected in the academic achievement could be simply a question of time. It could be supposed that on a more long term basis, the children who acquire advanced strategies will have higher achievement.

Let us now focus on the CAI group which statistically used more advanced strategies than the others. This group, like the CDI group, worked with the computers that offered dynamic helps, and in this sense the scaffolding level was higher than that of the AI group, which used static helps. The difference between the CDI and CAI groups was not in the software employed but rather in the additional scaffolding provided by the educator. Whereas in the CDI group it was minimal or non-existent (the whole responsibility was the software’s), in the CAI group the educator actively helped the children who asked for it. Hence, the human factor seems to have been decisive.

If this factor is analysed a bit more one can see that the scaffolding provided is meta-cognitive, whereas the scaffolding provided by the software is cognitive. The software with dynamic helps provides cognitive strategies but does not deal with (at least not intentionally or explicitly) the meta-cognitive aspects. For instance, knowing when it is convenient to use a particular strategy, which makes it possible to generalise its use in different tasks or activities is not provided by the designed software. On the other hand the educator, despite having instructions not to teach cognitive strategies directly, could suggest or remind the child of a previously learned strategy. Thus, he was putting himself in a meta-cognitive scaffolding level and this could then explain how this CAI group used statistically more advanced strategies than the others.

To close, let us look at the key question posed at the beginning of this study: can computers act as teachers in the ZPD? From the results we believe we can give an affirmative answer, but with certain comments. Without forgetting the other software characteristics used (integrated in the curriculum and flexible), the focus was on the scaffolding level. If the scaffolding level offered by the software is minimal (as in the case of the AI group), the computers do not seem to help the children acquire the knowledge-building tools, although they can help them acquire knowledge. When the scaffolding level is cognitive, computers can begin to be useful from the constructivist perspective, by making it easier to learn adequate strategies. However, so that they can really play the role expected according to Vygotsky’s theory, the scaffolding level of the software must reach
meta-cognition. At present, apparently, this type of software is not available and it is not easy to predict when it will be developed. Specific meta-cognitive aspects could probably be introduced without too much difficulty, and this is a challenge for research into educational software in the near future, but meta-cognition also involves flexibility and speed in adapting to children’s needs, something which only people are capable of doing as yet.

References


