

## **The application of a computerised strategy to teach and learn mathematics in primary education**

Paloma González-Castro, Luis Álvarez, José C. Núñez,  
Julio A. González-Pienda and David Álvarez  
Universidad de Oviedo (España)

The aim of this study is to supply information on the effects of strategic training in the area of mathematics (1) on the real level, as well as the perceived competence in terms of the skills the students show to select, organise and produce information and (2) their attitude and motivation towards working in this area of the curriculum. 104 students took part in this study, 57 of whom were the control group and 47 the experimental one. The teachers and students who took part in this experience followed an *on-line* course to handle the “hypertext” strategy for three months, approximately. The results show that the strategic training implemented in this study highly improves the written understanding procedures, increases the perceived competence for internal information handling and generates positive changes in terms of attitude and motivation of the students towards working in the area of mathematics.

*Key words:* Mathematics, primary education, strategic training.

*La aplicación de una estrategia computarizada para enseñar y aprender matemáticas en Educación Primaria.* El objetivo de este estudio es suministrar información en los efectos de la educación estratégica en el área de matemáticas en un nivel real, así como la competencia percibida en términos de habilidades, que los estudiantes muestran para seleccionar, organizar y producir información y sus actitudes y motivaciones hacia el trabajo en este área del currículo. 104 estudiantes participaron en este estudio, 57 de los cuales fueron el control del grupo y 47 los experimentales. Los profesores y estudiantes que participaron en esta experiencia, siguieron un curso *on-line* para manejar la estrategia del “hipertexto” durante tres meses aproximadamente. Los resultados mostraron que la educación estratégica implementada en este estudio, mejora ampliamente los procedimientos escritos y comprensivos, aumenta la competencia percibida de una información interna manejando y generando cambios positivos en términos de actitud y motivación de los estudiantes hacia el trabajo en el área de matemáticas.

*Palabras clave:* Matemáticas, educación primaria, estrategias educativas.

In Western countries there has been rising worry for the fact that the majority of students, as well as the general population, have serious difficulties in understanding and using the mathematic knowledge. The failure rates in this subject are very high, particularly in secondary education. Many of these students who are very capable in the verbal area show scarce success in mathematics, generally due to a low competence perception (Möller, Streblow and Pohlmann, 2006). If this is so, we may ask ourselves: why is there such a high and generalised failure level in this subject? Are mathematics really so difficult or are they being badly taught? What is the origin and the meaning of the clear differences in mathematics competence among students? And above all, what can be done about this situation?

The interest to find an answer to this problem has been rising since the 1990s and has had multiple theoretical and applied contributions as a consequence (e.g., Confrey, Castro-Filho and Wilhelm, 2000; Jitendra, Sczesniak and Deatline-Buchman, 2005; MacKie, 1992; Kaput and Thomson, 1994). Such researches are mainly focused on the study of the causes in order to understand, represent and select the most suitable solution processes (Gilmore and Bryant, 2006; Hegarty, Mayer and Monk, 1995; Montague and Applegate, 1993; Pericola, Harris and Grahajan, 1992; Van Lieshout, Jaspers and Landewé, 1994). This approach has led the current reflection on learning difficulties in mathematics to be mainly focused on training-type issues (Montague and Bos, 1986; Scheid, 1990). The new conception on special needs have undoubtedly contributed to this fact as they encourage the need for greater adjustment between skills and knowledge and the resulting emergence of training models based in the strategic teaching-learning processes (Carnine, 1997; Jones, Wilson and Bhojwani, 1997; Montague, 1997). However, in practice, the real applicability of these models is limited as they are generally created regardless the operation of the educational centres. Cooperative research has started to be used as a way to link the research results to school practice, in order to overcome this handicap. The fundamental idea is that cognitive research leads the steps of educational changes. This may only be possible if applied research is performed involving the centres in a way that the own development of the experiences generates changes in the system and that later, once the research has been finished, the generated changes continue to improve it (Confrey *et al.*, 2000).

This is the frame of the current research which intends to empirically contrast the usefulness of a new training method to improve the teaching and learning process in mathematics. This model is based in the use of a tool called *hypertext*, which is a normalised representation of the hierarchical hypertext as it contains at a structural level the basic principles of *progressive differentiation* and of *integrating reconciliation*. The

principle behind progressive differentiation shows as the most characteristic and significant design that of the triangular hierarchical structure, in order to avoid undefined lineal sequences (not more than two concepts on a vertical line) prone to mechanical and memory learning. Furthermore, in order to facilitate a deeper and more significant understanding, this type of hierarchy selects what is important inside of an ellipse, connects it with linking sentences and specifies the last hierarchical levels with examples which are close to the previous experience and knowledge the learner has. The second principle, integrating reconciliation, is a principle by which the contents blocks must be horizontally sequenced so that each hypertext net fits onto the previous one by means of bridge-concepts, graphically represented by rectangles in order to be recognised. This way, each hypertext becomes a previous organiser for the following one and so on, in order to promote sequential processing. The synthesis of these two principles originates a new hypertext representation which facilitates navigation, combining in the same structure two types of processing, the semantic and the syntactic one. This allows the teacher to use the strategy as methodological tool to facilitate the organisation of contents and the students to apply it as a knowledge construction tool to reach more significant learning (González-Pienda *et al.*, 2002). The fundamental idea will therefore be that the student, by means of hypertext (first with paper and pencil and after with computer means), actively implies himself in his own teaching-learning process. His implication level will increase as a consequence of the use of this type of tool and so will his self-confidence on his ability to perform this type of information handling processes (selection, organisation, production), his attitude towards working in the mathematics class will be more positive and consequently his future implication will be greater, etc.

As a consequence, this study presents information on the effects that working in the class with this type of tools has on 1) the skill level students have for information selection, organisation and production, on 2) their attitude and motivation towards working in the area of mathematics and on 3) the assessment they will make of learning with hypertext.

## METHOD

### *Research Method*

Bearing in mind the proposed objectives, the aim is to contrast the efficacy of the strategic training model from a nearly experimental perspective by making a non-equivalent pre-test and post-test design of the control group. The control and experimental groups are not equivalent as the dynamics of the own didactic departments makes it impossible to have a randomized equalization.

### *Participants*

104 students in the 3rd year of primary education took part in this study (57 of whom took part in the experimental group and 47 in the control group), they are schooled in two educational centres in Asturias (Northern Spain). The 3rd year students of one of the centres participated as experimental group (GE) and the ones from the other centre as control group (GC). Students from the two centres were chosen without any connexion among them in order to avoid any kind of contact or previous knowledge which may corrupt the application process. In the assessment session previous to the intervention several measurement tools were applied (they are described in the following section), these constitute the pretest measures in this study. In order to check homogeneity in both groups in terms of these variables, several multivariate analysis (MANOVAs) were performed before the intervention.

Regarding *understanding competence* (assessed by means of a reading understanding test, PROLEC-SE), the multivariate contrasts corresponding to the pretest indicate that, in general, there are statistically significant differences between the experimental and the control group in terms of the skills to perform processes of literal, inferential and total understanding ( $\lambda = .674$ ,  $F_{2,101} = 24.375$ ,  $p < .001$ ,  $\eta^2 = .326$ ). These differences found at a global level also occur for each of the two understanding types [*literal* ( $F_{1,102} = 4.364$ ,  $p < .05$ ,  $\eta^2 = .041$ ), *inferential* ( $F_{1,102} = 47.998$ ,  $p < .001$ ,  $\eta^2 = .320$ ) ], as well as for the *total* scoring ( $F_{1,102} = 40.048$ ,  $p < .001$ ,  $\eta^2 = .282$ ). Therefore, it is possible to indicate that the experimental and control groups have been found to significantly differentiate in the reading understanding pretest levels. In particular, when observing the measures of the three variables, it is found that the students in the control group as compared with those in the experimental one show higher levels both in literal and inferential understanding (particularly standing out this last one) and as a consequence in the total reading understanding measure.

In terms of *competence perception* to select, organise and produce information, the multivariate contrasts performed for the pretest indicate that there are statistically significant differences between both groups at a general level ( $\lambda = .587$ ,  $F_{3,100} = 65.348$ ,  $p < .001$ ,  $\eta^2 = .413$ ). These differences found at a global level are also observed for each of the three dimensions of the *Cuestionario de Valoración de la Comprensión, CVC* (Understanding Assessment Questionnaire), [*selecting* ( $F_{1,102} = 56.703$ ,  $p < .001$ ,  $\eta^2 = .357$ ), *organising* ( $F_{1,102} = 27.828$ ,  $p < .001$ ,  $\eta^2 = .214$ ) and *producing* ( $F_{1,102} = 7.432$ ,  $p < .01$ ,  $\eta^2 = .068$ )]. As in the case of the real competence to perform the understanding processes, in the case of competence perception to perform this type of processes it is also possible to observe that the GE obtains significantly lower scorings

than the students in the GC for the three types of competences (selecting, organising, producing).

Contrary to the previous cases, in terms of the motivational and attitudinal variables, which were assessed by means of the *Inventario de Actitudes ante las Matemáticas (IAM-R)* (Inventory of Attitudes towards Mathematics), the multivariate contrasts performed for the pretest indicate that there are no statistically significant differences between both groups at a general level ( $\lambda = .914$ ,  $F_{6,97} = 1.513$ ,  $p = .182$ ,  $\eta^2 = .086$ ). This lack of differences at a global level is also observed for each of the dimensions of the IAM-R, taken individually. Therefore, it is possible to indicate that the experimental and control groups do not significantly differentiate in the levels of the six attitude dimensions before intervention (pretest).

### *Materials*

#### *Instruments for information collection:*

*Test de Procesos de Lectura (PROLEC-SE)* (Reading process test), produced by Ramos and Cuertos (1999). The PROLEC-SE is an assessment test for the reading processes in students within 10 and 16 years old, approximately. In particular, it assesses the lexical, syntactic and semantic processes as well as reading understanding. This last ones and the semantic processes have been used in this research to assess understanding through the presentation of two explanatory texts to the students. The tasks presented involve that after carefully reading the text, the participant must answer several questions on the contents of the mentioned text, half of them are *literal* (the information required is stated in the text) and the other half are *inferential* (to answer the questions it is necessary to apply inferential processes- the information required does not explicitly appear in the text)-, so it is necessary to have efficient processes of information selection, organisation and production).

*Cuestionario de Valoración de la Comprensión (CVC)* (Understanding Assessment Questionnaire). This tool has been designed and validated in previous researches (González-Pienda *et al.*, 2002) so that the own student values if, in an ordinary way, he/she is able to select the important ideas and concepts, to sum them up and related them to others and finally apply them following the established rules for the semantic and syntactic process. This tool is made up of 10 items which originate three scoring blocks: perceived ability to *select* (e. g. within wide information, are you able to identify the sections it is divided into?), *organise* (e.g. in a section of a topic, do you fit the ideas into others depending on their importance?) and *produce* (e.g. in each lesson, do you relate the

ideas in the unit to other previously studied ones?) the information in a text. The measuring scale is a likert type one (1=Never,..., 5=Always).

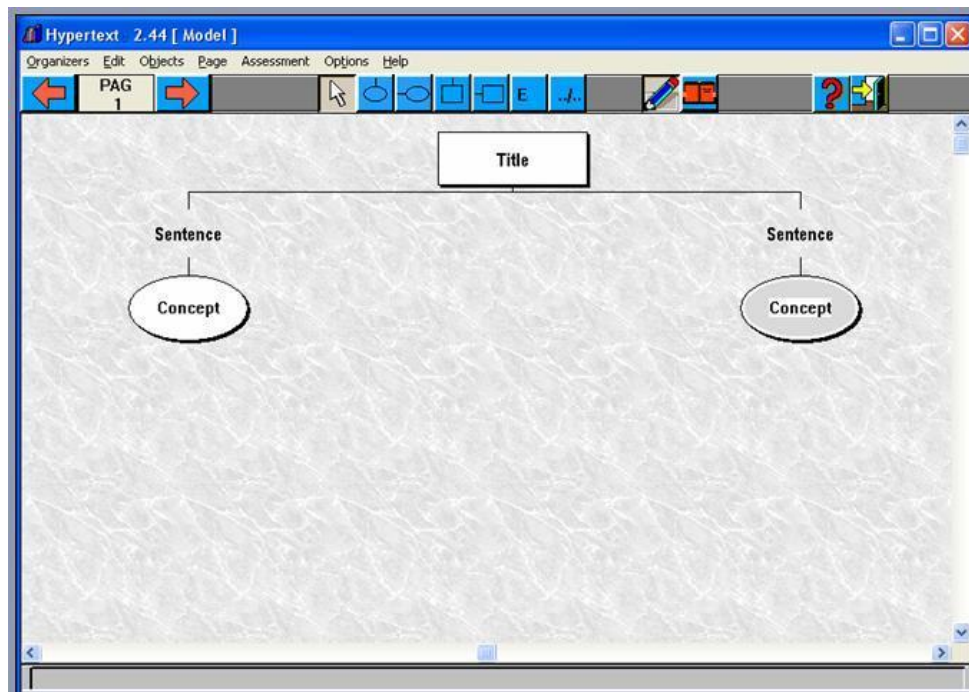
*Inventario de Actitud hacia las Matemáticas-Adaptado (IAM-A)* (Inventory of Attitudes towards Mathematics). IAM-R is an enhanced version made by E. Fennema and J. A. Sherman (Fennema and Sherman, 1976) with significant modifications in the scales to assess attitudes towards Mathematics (FSS). It has been used since then by a great amount of researchers on learning and teaching of Mathematics (Gonzalez-Pienda *et al.*, *in press*). The current research uses the scales relating to the following components: (a) *behaviour in the class* (e.g., the teacher usually tells me of for my behaviour in class), (b) *learning autonomy level* (e.g., if there is work to do, I prefer to do so in tasks I already know than in new things), (c) *asking for help* (e.g., normally I do not ask the teacher for help, even when the task is difficult), (d) *fright of failure* (e.g., I try to avoid difficult tasks), (e) *effort level* (e.g., I try hard to get good results in Mathematics) and (f) *avoidance of showing competence* –to avoid being rejected by their equals– (e.g., it is important for me not to look more clever than the average of the class). The measuring scale is a likert type one (1 = I completely agree,..., 5 = I absolutely disagree).

#### *Intervention programme*

The intervention model proposed combines the learning of the hypertext strategy and its application both to teach the contents of mathematics as to solve the problems derived from them. Each teacher followed an ten-session *on-line* course to learn how to handle the tool. After finishing the course (two months approximately), the teachers applied the strategy to mathematics in the 3rd year of primary education. After this phase, the teachers taught the strategy to their student groups following the steps in the SIM model (*Strategy Intervention Model*, by Deshler, Ellis and Lenz, 1996) throughout eight one-hour sessions twice a week. On the whole, four weeks. Initially, the students try to reflect on their way of learning. Then, the teacher describes the strategy and applies it, modelling the process and introducing the appropriate verbalizations to facilitate the representation and long-term recollection. Once the description and the previous modelling have finished, a practical phase is proposed. The teacher and students will first act as mediators and then it will become autonomous. This last phase, which is the core to handle the strategy, was structured in seven steps: 1) presenting the contents; 2) identifying the title and writing it inside a rectangle; 3) selecting the key concepts and writing them inside ellipses; 4) relating the selected concepts with linking sentences; 5) summing up some of the final concepts in the hierarchies with examples and writing them under dotted lines; 6) writing an essay from the new hypertext structure, placing the punctuation marks on the correct places; 7) checking the resulting lineal text as well as

the developed process with the “Hyper” CD (Álvarez, Soler, Tamargo and González-Castro, 2001), by means of the computerised version (Figure 1, also at [www.grupocerpa.com](http://www.grupocerpa.com)).

Figure 1. Main hypertext page in computing language



Once the programme has been mastered, it can be used as a strategy for combined conceptual and procedural representation. Both representation types are integrated and their application to problem solving follows the steps in the ISI model (*Integrative Strategies Instruction*, by Ellis, 1993a, 1993b). The first step intends to activate the *previous* organisers (e.g. Figure 2) to face a first *internal representation* of the problem (e.g. Figure 3). It is about thinking first so that the objectives to be reached can be established. On the second step, the conceptual and applied representation is performed. It is about to thinking during the process, relating the *data and unknown quantities* by means of applying the *appropriate operations* (production) in order to reach the final solution (e.g. Figure 4). Finally the third step consists on formulating the *final solution* and from it the *reversibility* of the procedure followed, generalising the model in the initial representation to new headings and therefore developing metacognitive strategies. On the whole, it is all about applying the acquired skills and strategies to other problems (e.g. Figure 5).

Figure 2. Knowledge activation

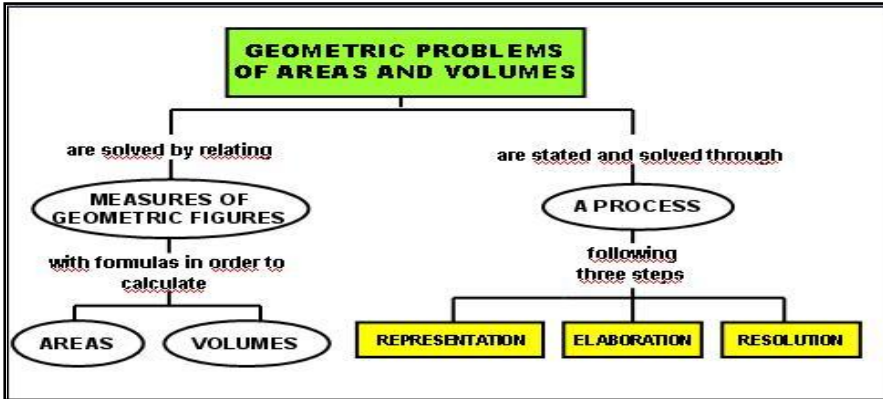


Figure 3. Internal representation

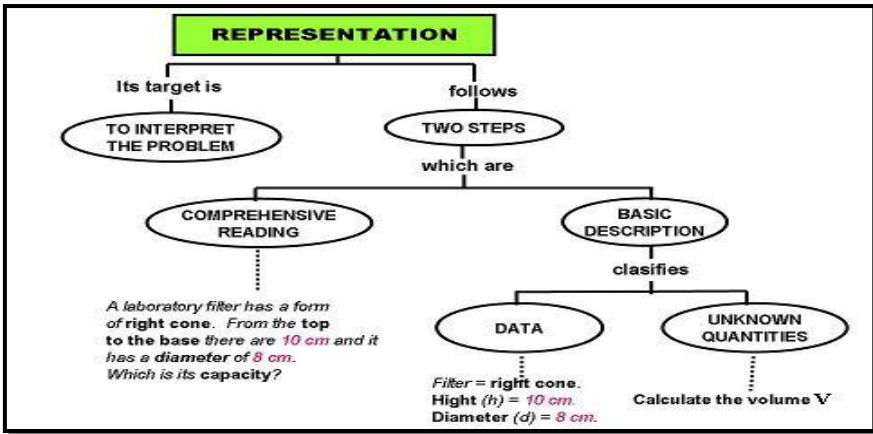


Figure 4. Relating data and unknown quantities

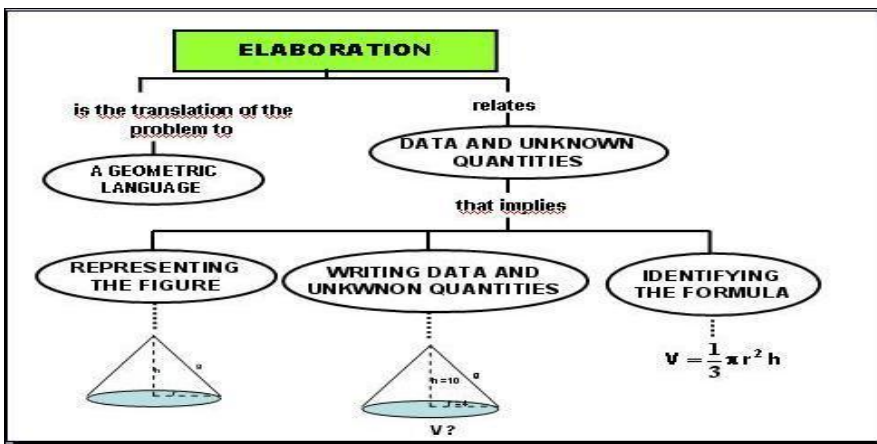
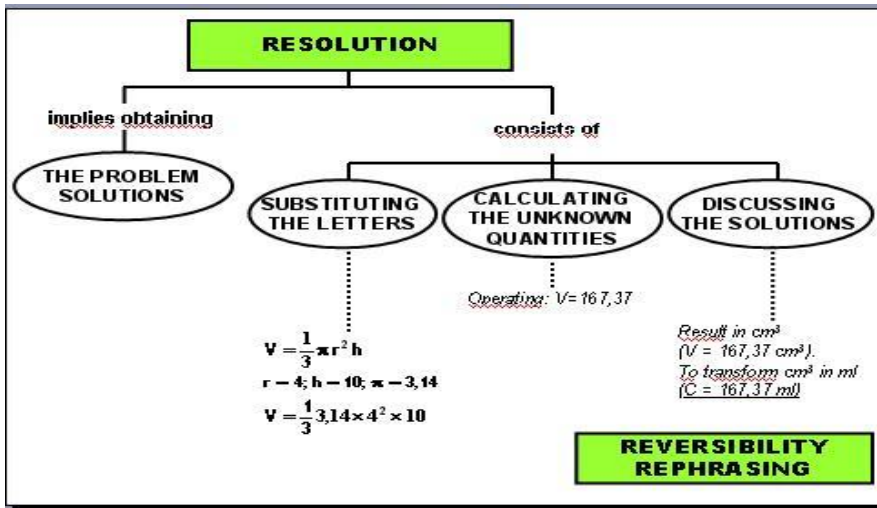




Figure 5. Solution and generalization



### Hypothesis

Once the proposed intervention has been performed, it is expected that the students in the GE group as compared with those in the GC group (1) show greater domain in the understanding processes, both at a literal and inferential level, (2) show greater confidence in their competence to select, organise and produce important ideas and/or concepts and (3) show a more positive attitude towards learning mathematics in the following sense: a) they show less behaviour problems in the class, b) they show greater interest in working in this area, c) they show greater help demand from the teacher, d) they show greater implication in the difficult activities/tasks, e) they make more effort and f) they show less fright to show competence in this area of the curriculum.

## RESULTS

Hypothesis contrast is performed by covariance analysis (ANCOVA). Each of the variables assessed in pretest and posttest as are taken as dependent variable, the control-experimental condition as independent variable and the scorings in pretest corresponding to each VD as covariate variable. This procedure shows if there are statistically significant differences in the posttest, after statistically controlling the effect of the VD pretest levels. The size of the effect is also represented. This will be interpreted according to the following criterion:  $\eta^2 < .10$  (no significance),  $\eta^2 > .10$  to  $.25$  (small),  $\eta^2 > .25$  to  $.40$  (medium),  $\eta^2 > .40$  (big). The results are described in three blocks: (a) the effect of the intervention on the real understanding skills, (b) the effect of intervention on

the perceived competence to efficiently perform the information selection, organisation and production processes and (c) the motivational and attitudinal effects of intervention.

(a) *Literal and inferential understanding.* The statistic indicators corresponding to the development of real understanding skills which were assessed by means of PROLEC-SE can be found on Table 1. This standardised test produces two measure types: a) development in terms of *literal understanding* of a text and b) development in terms of *inferential understanding* of a text. Apart from these two specific measures, a total or *general measure* is also used for the understanding of the texts (by combining the two previously described scorings).

Table 1. Means and standard deviations corresponding to the pretest and posttest assessment of the control Group (GC) and the experimental group (GE) regarding the understanding processes

	PRETEST				POSTEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
Literal Understanding	8.81	.99	8.33	1.27	7.96	1.67	9.37	.86
Inferential Understanding	7.25	1.22	5.22	1.67	5.11	1.91	8.44	1.03
Total Understanding	16.06	1.52	13.56	2.33	13.06	2.05	17.81	1.27

Bearing in mind that statistically significant differences had been found in the pretest, the mean differences were analysed in the posttest by means of a covariance analysis, ANCOVA, (taking as covariate variable the level of VI in pretest). As it has already been mentioned, this procedure will show to what extend the differences found in the posttest are due to the effect of the training programme or are partly the result of the initial differences in each of the independent variables. Then, statistically controlling the effect of the covariate variable, the results of the analysis performed show statistically significant differences between the control and experimental groups after the intervention in terms of understanding competence, both the literal and the inferential ones [*literal* ( $F_{1,101} = 43.915$ ,  $p < .001$ ,  $\eta^2 = .303$ ), *inferential* ( $F_{1,101} = 271.029$ ,  $p < .001$ ,  $\eta^2 = .729$ ) and *total* ( $F_{1,102} = 393.398$ ,  $p < .001$ ,  $\eta^2 = .796$ )]. They always favouring the GE. The results obtained based on the PROLEC-SE indicate that the training followed by the experimental group has been successful both to improve the processes of literal understanding of a text as for the performance of inferential processes (particularly for these last ones), despite the fact that the GE students started from lower levels than the GC before the intervention.

(b) *Competence perception in understanding skills.* As above, given that there are statistically significant differences in the pretest, the posttest analyses are performed with ANCOVAs (taking as covariate variable the VI levels in the pretest). Table 2 shows the statistic indicators corresponding to the dimensions of the *Cuestionario de Valoración de la Comprensión* (Understanding Assessment Questionnaire), which have to do with: a) the perceived competence to *select* the important information in a text, b) the perceived competence to *organise* the previously selected main ideas, c) the perceived competence to *produce* the information relating the new items with those the student already knows.

Table 2. Means and standard deviations corresponding to the perceived competence to select, organise and produce information by the control and experimental group in pretest and posttest

	PRETEST				POSTEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
Perceived competence to select	3.57	.60	2.80	.45	3.04	.56	4.18	.49
Perceived competence to organise	3.38	.92	2.62	.53	2.98	.70	4.07	.55
Perceived competence to produce	3.28	.64	2.96	.55	3.06	.57	3.84	.62

The results of the posttest analysis indicate that there are statistically significant differences between both groups regarding the three types of competence assessed. The experimental group is favoured in all three cases [*selection* ( $F_{1,101} = 166.889$ ,  $p < .001$ ,  $\eta^2 = .623$ ), *organisation* ( $F_{1,101} = 169.149$ ,  $p < .001$ ,  $\eta^2 = .626$ ), *production* ( $F_{1,102} = 60.201$ ,  $p < .001$ ,  $\eta^2 = .373$ )]. It must also be mentioned that the intervention has had an important effect on the dependent variables, particularly in the case of selection and organisation which reach a big effect size (.623 and .626, respectively). Therefore, the results obtained indicate that the students in the experimental group as compared to those in the control group: a) show a higher level in the perceived ability to perform information selection processes with a text, b) feel more competent to organise the selected information, c) and feel more qualified to significantly produce the information by using their previous knowledge to make sense of the new one.

(c) *Attitude towards the learning of mathematics.* One of the most important aspects in this work was to check the impact of the intervention at a motivational and attitudinal level. Table 3 shows the statistic indicators corresponding to the dimensions of the IAM-R considered in the current study. Such dimensions are: behaviour problems, autonomy level at work, asking for help (when the student has difficulties), effort level, implication level in difficult tasks (due to failure fright), avoidance of showing competence in mathematics (due to reject reaction from the equals).

Table 3. Means and standard deviations corresponding to the scales in the IAM-R, for the control and experimental groups in pretest and posttest.

	PRETEST				POSTEST			
	Control Group		Experimental Group		Control Group		Experimental Group	
	M	SD	M	SD	M	SD	M	SD
Behaviour problems	4.56	.79	4.24	1.08	4.37	.79	4.57	.56
Autonomous work	3.31	1.10	3.01	1.13	3.33	.96	3.28	1.08
Looking for help	3.83	.93	3.99	.95	3.46	.87	4.15	.73
Implication in difficult tasks	2.95	1.13	3.08	.97	2.82	.87	3.36	.93
Effort level	1.84	.85	2.06	.89	3.11	.64	3.34	.58
Avoiding the show of competence	4.34	.92	4.29	1.10	3.77	.80	4.22	.80

When checking the initial levels in the pretest, it is observed that although the differences between both groups of students are not statistically significant, there are some differences which could be masking the real effect of the intervention. This is the reason why the differences in the posttest have also been analysed by means of ANCOVAs (taking as covariate variable the pretest measure for each VD).

Once the effect of the covariate variable had been statistically eliminated, the results of the analyses performed show that the differences regarding the VD considered in the posttest are statistically significant in all cases. [*behaviour problems* ( $F_{1,101} = 19.283$ ,  $p < .001$ ,  $\eta^2 = .160$ ), *asking for help behaviour* ( $F_{1,101} = 42.814$ ,  $p < .001$ ,  $\eta^2 = .298$ ), *implication in easy tasks due to failure fright* ( $F_{1,101} = 19.790$ ,  $p < .001$ ,  $\eta^2 = .164$ ), *effort level* ( $F_{1,101} = 5.974$ ,  $p < .01$ ,  $\eta^2 = .056$ ), and *Avoidance of showing competence in mathematics* ( $F_{1,101} = 29.219$ ,  $p < .001$ ,  $\eta^2 = .224$ )]. Except for *the autonomous working level* where there are no statistically significant differences ( $F_{1,101} = 2.285$ ,  $p = .134$ ,  $\eta^2 = .022$ ). Nevertheless, the size of the effect is smaller in the case of the perceived competence to handle information and in the level of real understanding. Bearing in mind the size of the means in the pretest and posttest, the results obtained indicate that the training followed by the experimental group has proved to be effective for five out of the six assessed dimensions. The students in the experimental group as compared to the control ones, (a) show a descent in terms of behaviour problems in the class, (b) ask more for help from the teacher when they need it, (c) get involved in difficult activities, as they show a lower failure fright, (d) show greater effort level when performing their academic tasks in the area of mathematics and (e) avoid less that their classmates see that they are good students in mathematics.

## DISCUSSION

Frequently, the efficacy of the new training models is contrasted both in relation to the improvement criteria in the competence of strategic information handling (e.g. Carbonero and Coromoto, 2006; Hofer, Yu and Pintrich, 1998; Weinstein, Roska, Hanson and VanMater Stone, 1997) as in relation to a motivational and attitudinal level (e.g., Beghetto, 2007; Aunola, Leskinen and Nurmi, 2006; Hofer *et al.*, 1998; Lawson, Banks and Logvin, 2007). In the current research, the intervention has been assessed according to such criteria: change in the competence to handle the information internally, change in the perceived ability to perform such processes and modification in the attitude and motivation of the participants.

In general, it can be stated that the training programme implemented in the experimental groups has generated significant and positive differences as compared to the control group, both in terms of understanding skills, the perceived competence to perform the selection, organisation and production processes as in terms of motivation and attitude. The most important success has been obtained in terms of the understanding processes whereas the perceived competence and the smallest ones have been obtained in terms of motivation and attitude. In particular, it has been proved that the working programme has generated great improvements in terms of the ability to perform inferential processes (size of the intervention effect .729) which involve important skills to select the relevant ideas, organise them and relate such information with the previous knowledge. The improvement in terms of literal understanding has also been significant, although much lower than in the previous case (effect size .303). However, this result is not a negative one if it is considered that literal understanding has more to do with memory capacity than with inferential reasoning.

In terms of the perceived ability to perform effective processes of information selection, organisation and production the effect of the intervention programme has also been a very positive one, particularly in the important ideas/concept selection processes and their organisation, whose intervention effect size is big (.623 and .626, respectively). These results are very logical, as the learning of hypertext principles implied the learning of rules to select information and to organise it; the production processes are less explicit as they involve the use of the previous knowledge the student has.

The improvement observed in terms of the skills to handle information constitute an excellent result for this research. However, the increase in the perceived competence is also very important because, as the current self-regulated learning theories

indicate, a person has to believe in his/her ability to reach an objective so that he/she moves towards it (Britner and Pajares, 2006; Pintrich, 2004; Rosário *et al.*, 2005; Zimmerman, 2002). Furthermore, the perception the students have of this important change, with longer training, would make it probably possible for the strategy to be generalised and applied as a tool for self-regulation and autonomous learning (Pintrich, 2000). This change also affects the literal understanding processes and above all the inferential one, which shows that with hypertext the students are able to understand the contents object of this study in a deeper and more significant way. Although this understanding type is very important for any kind of contents and subject, it is even much more important for mathematics, as it allows the students to apply the analysis performed to problem solving, starting from previous understanding and extrapolation.

The attitude towards the learning of mathematics has experienced an important evolution which has been confirmed by all the variables assessed except for autonomous working, where the perception the students acquire after using the strategy does not get to be significant and more intervention time would be needed. The students in the experimental group continue to think that it would be good to have less mathematics activities and homework, but they pay more attention, ask the teacher more, make more effort in more requiring activities because they have less failure fright and they do not mind showing competence before the others because they interpret that this aspect is no longer valued as negative by the rest of the group. This change in the attitude improves the class atmosphere and mathematics can be handled with better predisposition and greater success opportunities.

Finally, due to the existence of some research limitations, our data have to be interpreted with certain caution. Firstly, in order to generalise the results obtained, it would be necessary to count on more experimental and control groups. Furthermore, our teacher sample should be a representative one (e.g. experts, novices, different levels). Secondly, although the items assessed were the understanding level, the perceived competence and the attitude towards the subject, it would be convenient to consider other variables such as the (initial and final) amount of knowledge, the students' goals, etc., in order to grade in a more objective way the changes suffered by each of the participants in the research. Thirdly, it would be interesting to incorporate a more complex design type, with different application levels (only hypertext, hypertext combined with one or more strategies, hypertext for concept learning only or for the procedural one), with a later follow up (checking if they continue to use it or if they abandon it after the research has finished) and with what contents and under which conditions it works better. Finally, the model application time is very important, with more time, would the effects be the same?

or would the application and long-term use improve? These and many other questions which affect the interpretation and generalisation of the results should be considered for future researches.

### ACKNOWLEDGEMENTS

This work has counted on the support from the R+D+I Research Project (MEC-06-SEJ2006-10013) from the *Ministerio de Ciencia y Tecnología* (Ministry of Science and Technology) in Spain.

### REFERENCES

- Álvarez, L., Soler, E., Tamargo, J., and González-Castro, P. (2001). *CD Hyper: herramienta para construir Hipertextos [CD Hyper: Tool to construct hypertexts]*. Madrid: CEPE.
- Álvarez, L., Soler, E., González-Pienda, J.A., Núñez, J.C., and González-Castro, P. (2001). *Hypertexto. Una estrategia para comprender [Hypertext. A strategy to understand]*. Madrid: CEPE.
- Aunola, K., Leskinen, E., and Nurmi, J. (2006). Developmental dynamics between mathematical performance , task motivation , and teachers' goals during the transition to primary school. *British Journal of Educational Psychology*, 76, 21-40.
- Beghetto, R.A. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching*, 44(6), 800-814.
- Britner, Sh. and Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, 43(5), 485-499.
- Carbonero, M.A. and Coromoto, J. (2006). Training higher education students in mathematics learning strategies. *Psicothema*, 18(3), 348-352.
- Carnine, D. (1997). Instructional Design in Mathematics for Students with Learning Disabilities. *Journal of Learning Disabilities*, 30(2), 130-141.
- Confrey, J., Castro-Filho, J., and Wilhelm, J. (2000). Implementation research as a means to link systemic reform and applied Psychology in mathematics education. *Educational Psychologist*, 35(1), 179-192.
- De Corte, E. (1995). Fostering cognitive growth: A perspective from research on mathematics learning and instruction. *Educational Psychologist*, 30, 37-46.
- Deshler, D., Ellis, E.S., and Lenz, H.K. (1996). *Teaching adolescents with learning disabilities: Strategies and methods*. Denver, Colorado: Love Publishing Company.

- Ellis, S.E. (1993a). Integrative strategy instruction: A potential model for teaching content area subjects to adolescents with learning disabilities. *Journal of Learning Disabilities*, 26, 358-383.
- Ellis, S.E. (1993b). Teaching strategy sameness using integrated formats. *Journal of Learning Disabilities*, 26, 448-481.
- Fennema, E. and Sherman, J.A. (1976). Fennema-Sherman Mathematics Attitudes Scales: Instruments designed to measure attitudes towards the learning of mathematics by males and females. *JSAS Catalog of Selected Documentes in Psychology*, 6(1), 3b.
- Geary, D. (1993). Mathematical disabilities: Cognitive, neuropsychological, and genetic components. *Psychological Bulletin*, 114, 345-362.
- Gilmore, C.K. and Bryant, P. (2006). Individual differences in children's understanding of inversion and arithmetical skill. *British Journal of Educational Psychology*, 76, 309-331.
- González-Pienda, J.A., Núñez, J.C., Álvarez, L., González-Castro, P., Soler, E., González-Pumariega, S., and Roces, C. (2002). Aplicación de la estrategia de Hipertexto para la enseñanza y el aprendizaje de las Matemáticas en la Educación Secundaria [Application of Hypertext's strategy for teaching and the learning of Mathematics in Secondary Education]. In J.N. García-Sánchez (Coord.), *Aplicaciones de intervención psicopedagógica [Applications of psicopedagogic intervention]* (pp. 215-228). Madrid. Pirámide.
- González-Pienda, J.A., Núñez, J.C., da Silva, E.H., Rosário, P., Mourao, R., Soares, S., and Solano, P. (in press). Atitudes face à Matemática e rendimento escolar no sistema educativo espanhol [Attitudes toward mathematics and school performance in Compulsory Spanish teaching]. *Psicologia: Teoria, Investigação e Prática*.
- Hegarty, M., Mayer, R.E., and Monk, C.A. (1995). Comprehension of arithmetic word problems: a comparison of successful and unsuccessful problems solvers. *Journal of Educational Psychology*, 87, 18-32.
- Hofer, B.K., Yu, S.L., and Pintrich, P.R. (1998). Teaching college students to be self-regulated learners. In D.H. Schunk and B.J. Zimmermam (Eds.), *Self-regulated learning. From Teaching to self.reflective practice* (pp. 57-85). New York: Guilford Press.
- Jitendra, A.K., Sczesniak, E., and Deatline-Buchman, A. (2005). An Exploratory Validation of Curriculum-Based Mathematical Word Problem-Solving Tasks as Indicators of Mathematics Proficiency for Third Graders. *School Psychology Review*, 34(3), 358-371.
- Jones, E.D., Wilson, R., and Bhojwani, S. (1997). Mathematics Instruction for Secondary Students with Learning Disabilities. *Journal of Learning Disabilities*, 30(2), 151-163.



- Kaput, J. and Thomson, P. (1994). Technology in mathematics education research: the first 25 years in the JRME. *Journal for Research in Mathematics Education*, 25, 676-684.
- Lawson, A.E., Banks, D.L., and Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching*, 44(5), 706-724.
- Mackie, D.M. (1992). An evaluation of computer-assisted learning in mathematics. *International Journal of Mathematical Education in Science and Technology*, 23, 731-737.
- Mercer, C., Jordan, L., and Miller, S. (1994). Implications of constructivism for teaching maths to students with moderate to mild disabilities. *The Journal of Special Education*, 28(3), 290-306.
- Möller, J., Streblov, L., and Pohlmann, B. (2006). The belief in a negative interdependence of math and verbal abilities as determinant of academic self-concepts. *British Journal of Educational Psychology*, 76, 57-70.
- Montague, M. (1997). Cognitive Strategy Instruction in Mathematics for Students with Learning Disabilities. *Journal of Learning Disabilities*, 30(2), 164-177.
- Montague M. and Applegate, B. (1993). Mathematical problem solving characteristics of middle school students with learning difficulties. *The Journal of Special Education*, 7, 175-201.
- Montague, M. and Bos, C. (1986). The effect of cognitive strategy training on verbal math problem solving performance of learning disabled student. *Journal of learning disabilities*, 19, 26-33.
- Pericola, L., Harris, K., and Graham, S. (1992). Improving the mathematical problem-solving skills of students with learning disabilities: Self-regulated strategy development. *The Journal of Special Education*, 26(1), 1-19.
- Pintrich, P.R. (2000). Educational psychology at the milleninum: A look back and a look forward. *Educational Psychologist*, 35(4), 221-226.
- Pintrich, P.R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review*, 16(4), 385-407.
- Ramos, J.L. and Cuetos, F. (1999). *PROLEC-SE. Evaluación de los Procesos Lectores* [PROLEC-SE. Evaluation of Processes Readers]. Madrid: TEA.
- Rosário, P., Núñez, J.C., González-Pienda, J.A., Almeida, L., Soares, S., and Rubio, M. (2005). The academic learning viewd from the perspective of John Biggs' «3P model». *Psicothema*, 17(1), 20-30.

- Scheid, K. (1990). *Cognitive-based methods for teaching mathematics to student with learning problems*. Columbus, OH: Information Center for Special Education Media and Materials.
- Van Lieshout, E.C.D., Jaspers, W., and Landewé, B.H. (1994). Mathematical word problem solving of normally achieving and mildly mentally retarded children. In J.E.H. Van Luit (Ed.), *Research on learning and instruction of mathemaatics in kindergarten and primary school* (pp. 344-365). Doetingchem/Rapallo: Graviant Publishing Company.
- Weinstein, C.E., Roska, L.A., Hanson, G.R., and VanMater Stone, G. (1997). *EDP 310: A course in strategic learning*. Paper presented at the annual meeting of the American Educational Research Association, Chicago.
- Zimmerman, B.J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, 41(2), 64-70.

Received October, 25, 2007

Revision received January, 9, 2008

Accepted January, 12, 2008