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ABSTRACT

In most strategy research, the focus is on ready-made models provided by the teacher or a textbook. However, in this research project the effects are described of an experimental program in primary maths education, concerning the construction and use of models by pupils in guided co-construction. Learning how to construct models is said to enhance the occurrence of transfer. Therefore, pupils in the experimental condition were expected to show a larger amount of transfer of the learned material than pupils in the control condition. In a field experiment, in which 239 grade-5 pupils were involved, this hypothesis was tested. In a series of experimental lessons, pupils were taught to design models as a tool in the learning of percentages. The scores on the transfer test of pupils in the experimental condition were compared to the scores of their counterparts in the control group, which was based on the teachers' strategy of directly providing ready-made models to the pupils. The conclusion, then, is that children in the experimental condition significantly outperform children in the control condition in terms of transfer. (Contains 35 references.) (Author/ASK)

The learner as designer: effects on transfer of an experimental curriculum in modeling

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Summary

In most strategy research the focus is on ready-made models provided by the teacher or a textbook. However, in this research project the effects are described of an experimental program in primary maths education, concerning the construction and use of models by pupils in guided co-construction. Learning how to construct models is said to enhance the occurrence of transfer. Therefore we expected pupils in the experimental condition to show a larger amount of transfer of the learned material than pupils in the control condition. In a field experiment, in which 239 grade-5 pupils were involved, this hypothesis was tested. In a series of experimental lessons, pupils were taught to design models as a tool in the learning of percentages. The scores on the transfer test of pupils in the experimental condition were compared to the scores of their counterparts in the control group, which was based on the teachers' strategy of 'directly providing ready-made models' to the pupils. The conclusion, then, is that children in the experimental condition significantly outperform children in the control condition in terms of transfer.

The learner as designer: effects on transfer of an experimental curriculum in modeling

In most strategy research the focus is on ready-made models provided by the teacher or a textbook. This paper, however, reports on a research project aiming at describing and analyzing the effects of an experimental curriculum in primary mathematics education, which is focused on the construction and use of models by pupils.

Point of departure for this paper is twofold. Firstly, the statement that the curriculum should aim at the empowerment of learners for creating their own knowledge. This is consistent with Romberg's position (Romberg, 1992) with respect to mathematics learning as well as with research of Gravemeijer which states that actively constructed emergent models play an important role in the learning of mathematics (Gravemeijer, 1997). A second starting point relates to the now famous dilemma in learning theory and strategy research: providing or designing models and strategies (Rosenshine, Meister & Chapman, 1996).

In a field experiment, pupils were taught to design models as a tool in the learning of mathematics and more particularly percentages and graphs. Our experimental curriculum is aimed at empowering students and exceeding the above mentioned dilemma by promoting strategic learning in pupils (van Dijk et al, 2000; van Parreren, 1993). As we shall explain below, in our view this pertains to enabling students to design models in a process of guided co-construction (Freudenthal, 1991).

The research question focuses on how pupils cope with mathematical problems under the two conditions and how they choose, use and construct models. The major issue, however, in this paper lies in the problem of transfer. Will transfer of knowledge and skills proceed in a different way when pupils learn to collaboratively design models, in comparison to pupils who learn to work with ready-made models? Main question in this article is:

> What are the effects in terms of transfer of an experimental curriculum, in which pupils participate as model designers in a process of guided co-construction, on the learning outcomes in primary mathematics?

The effects of this program were assessed in terms of learning outcomes and transfer. The results of the experimental program were compared with the outcomes of a program in a control group, based on a strategy of 'directly providing ready-made models' to the pupils by the teacher.

We expect to find that the strategy of learning to design models collaboratively will have positive effects on the pupils' performances, like a change in learning processes, more occurrences of transfer and better learning results of pupils in mathematics. The basic idea underpinning this hypothesis is that pupils will gain deeper insight into maths problems. In line with the Vygotskian perspective on learning we may furthermore assume that the students will gain a more reflective insight due to the interpersonal (collaborative) activity in

which they have appropriated these actions. We expect this deepened, reflective insight to help pupils see through structures of new and unfamiliar problems. Hence, we may expect that the strategies acquired can be used to solve new problems and therefore enhance transfer.

But what definitions are used to describe transfer? And how can transfer be enhanced? These questions will be addressed in the next section.

Theoretical background

Views on Transfer

It is widely assumed that transfer of learned knowledge and skills is considered as a fundamental goal of education (Marini & Genereux, 1995). Simons (1999) mentions three sorts of transfer: (a) from prior knowledge and skills to new learning; (b) from new knowledge and skills to new learning situations (learning now preparing for later learning) and (3) from new knowledge and skills to applications in work and daily life (learning for practice). Of course, teachers would like to see that pupils apply their learned knowledge and skills in new situations. However, transfer often doesn't seem to work that way. Research by Verschaffel and others demonstrated that children often do not transfer their 'outside' knowledge to school problems (Verschaffel, et al. 2000). Verschaffel provided a test with several standard word problems (S-problems) and several problematic word problems (P-problems). He found that in the P-problems most of the children did not use their 'outside' knowledge to solve these problems, and therefore gave unrealistic answers. For example: '450 baseball fans will go to the stadium by bus. Each bus can hold 36 fans. How many buses are needed?' Children tended to say that the answer is 12,5 buses, thereby forgetting that half buses do not exist (Yoshida, Verschaffel, & De Corte, 1997).

This example shows us that when people are confronted with new situations they tend to apply knowledge, skills and specific strategies that they experienced as useful in other more familiar domains. They tend to neglect the new parts of the situation and apply even without thinking knowledge and skills that are inappropriate for this new situation, thus generating negative transfer.

Common sense leads us to believe that 'when someone has acquired knowledge in one particular setting, it should save time and perhaps increase the effectiveness for future learning in related settings' (Larkin, 1989). But viewing the evidence on transfer, some, like Detterman, claim that cases of significant transfer are 'rarer than volcanic eruptions and large earthquakes' and as difficult to predict (Alexander & Murphy, 1999). Alexander & Murphy argue against this view, by pointing out that transfer takes multiple forms with differing probabilities of occurrences. In their view, transfer isn't that rare at all! Moreover, they say: 'Not all transfer is as powerful as an earthquake and most occurrences of transfer go unnoticed'. Some authors even claim that transfer and learning is almost equal. Their arguments: can you speak of learning when no transfer of the learned knowledge takes place? (Simons, 1990).

Transfer remains an intensively discussed topic in educational psychology (see for example Anderson, Reder, & Simon, 1996; Bimmel, 1999; De Corte, 1999; Greeno, 1997; Larkin, 1989; Perkins & Salomon, 1996; Simons, 1999; Van Oers, 2000). Discussions never resulted in one generally accepted definition of transfer. Though, these earlier discussions heavily influence the way we think of transfer these days, and therefore we would like to discuss some of these views in short.

One of the important ways of thinking about transfer in the twentieth century is the metaphor of the mind as a muscle. This theory suggests that, like a muscle, the more the mind is invoked, the more it develops and therefore less time is needed for the learning of new knowledge and skills (Larkin, 1989). In this view, transfer can take place between two totally different domains. When learning occurs faster in a new domain, it is assumed that this can be attributed to previous practicing of the related actions.

A reaction on this 'mind as a muscle' metaphor is the theory of Thorndike about identical elements (see De Corte, 1999). In Thorndike's experiments transfer did not appear to work across the board, and learning in one domain did not automatically speed up learning in another domain. Thorndike stated that only when several identical elements between two tasks are found, learning in the second domain would proceed faster than the learning in the first domain. This assumption of identical elements is still a popular idea in explanations of transfer.

Some researchers, such as Alexander & Murphy (1999), define transfer as the process of using knowledge or skills acquired in one context in a new or varied context. According to Larkin (1989) this definition isn't correct. He argues that application of old knowledge in new situations occurs all the time. Think for example of searching a phone number in the phonebook. This means using the ability to read: a skill probably learned a long time ago. Therefore Larkin decided to define transfer as 'the application of old knowledge in a situation which is so new that it also requires the acquisition of new knowledge'. In the hypothetical case transfer did not exist, problem solving in a new domain should require a whole new set of knowledge. However, Larkin states that transfer leads to transmission of (some part of) former knowledge from earlier experiences, and that pupils already possess that part of the knowledge.

Greeno, Smith and Moore (1993) interpreted transfer from their 'situativity-theory'. In their view, 'learners acquire an activity in response to constraints and affordances of the learning situation. Transfer of an activity to a new situation involves a transformation of the initial situation and an invariant interaction of the learner in the new context. Transfer can

occur when the transformed situation implies similar constraints and affordances as the initial context that are as such perceived by the learner'.

The importance of the 'affordances' of the situation for the occurrence of transfer is also acknowledged in the work of the Dutch psychologist Van Parreren. In pursue of Allport; Klüver; and Katona, Van Parreren (1966) criticized the theory of 'identical elements' on two main points. Firstly, as a follower of Kurt Lewin's activity theory Van Parreren speaks of the 'valence' of situations. He preferred to speak of 'equivalent situations' instead of 'identical elements', while stressing the role of the characteristics and intentions of the learner in recognizing situations as equivalent. Thus, whether or not a situation is perceived as equivalent does not simply depend on the identical elements present, but depends also on the recognition by the learner. Secondly, transfer does not occur automatically as the theory of identical elements suggests. Transfer is always connected to efforts of the learner. Transfer, in Van Parreren's point of view, has to be actively constructed by the learner. This point is picked up and developed further by Van Oers (1998; 2000).

From an activity theoretical and a socio-cultural point of view, transfer is inconceivable as a simple transmission of knowledge (meanings) or views from one situation to another. Basically, transfer is held to be a process of transformation, in which knowledge is transformed to fit a new situation. Theoretically, however, the relationships between the old and the new situation need further explanation. In order to recognize equivalence between situations it is necessary to specify the symbolic-material basis for this process. Activity theory assumes that the inscriptions and symbols in a situation suggest possible meanings and support the process of transfer and transformation of associated meaning.

Conditions to Accomplish Transfer

It is important to distinguish two dimensions, when speaking of transfer: distance and degree of generalization (Bimmel, 1999). Distance concerns the difference between the *task* trained and the task in which transfer has to take place. The polar adjectives on the 'distance' dimension are called 'near' and 'far' transfer. Near transfer takes place when pupils work on tasks that are seen as quite similar to the tasks used in training, and in a similar domain. Far transfer takes place when pupils are asked to use their knowledge in different sorts of tasks or in other domains than the tasks or domains they practiced in.

The degree of generalization, on the other hand, pertains to the scope, or the reach of previously acquired *actions or operations*. It can be said to correspond to the number of specific tasks on which the learning outcomes can be applied (Marini & Genereux, 1995). Opinions differ whether learning general strategies can enhance transfer. Research pointed out that general principles of reasoning, learned in combination with self-monitoring practices and potential applications in diverse contexts, could indeed stimulate transfer (Perkins &

Salomon, 1989). In contrast, Garnham & Oakhill (1994) state transfer in general to be specific: knowledge and skills that are taught in a certain domain usually transfer only within the boundaries of that domain. In this respect, they refer to a review by Bransford, Arbitman-Smith, Stein & Vye (1985). Some important 'thinking skill' programs, though, could not prove that the development of general skills led to transfer in a broad area of domains. No strong indications were found that pupils improved in tasks that did not exactly match the tasks they explicitly practiced.

Thus far we have identified two broad conditions that seem to enhance the occurrence of transfer. One category has to do with task characteristics ("distance") while the other is related to the quality of the acquired learning outcomes. Several studies have yet exemplified how the organization of the learning process might influence the quality of the learning outcomes and, consequently, the quality of the learning outcomes that may influence the occurrence of transfer. Near transfer is achieved, for example, by frequent repetition of an insight or skill in diverse and changing contexts, with routines as a result (Perkins & Salomon, 1996; Simons, 1990). However, far transfer is fostered by avoiding routine, and stimulating pupils to get through the learning material in a productive manner. As Witteman (1997) argues: "Transfer of factual knowledge can only lead to expertise if learners adopt an active stance towards the incoming knowledge. Only the active handling of information will eventually lead to expertise. And only the learners themselves are capable of transforming knowledge to a strategic tool with which they can master a complex domain".

Verschaffel et al. (2000) mentions an alternation of contextualizing and decontextualizing of the learning materials as a favorable condition for transfer. Starting out from a meaningful context for problem solving, pupils can be stimulated, according to these authors, to look for general principles or concepts that subsequently can be applied to new concrete problems. Reflection is an important element in these learning processes. This latter idea is confirmed by Simons (1996).

In their studies with young children Brown and Palincsar (1989) specified the conditions for transfer still further. They showed that transfer of old knowledge to new problems can take place when (a) learners are shown how problems resemble each other; (b) when learners attention is directed to the underlying goal structure of comparable problems; (c) when the learners are familiar with the problem domains; (d) when examples are accompanied with rules, particularly when the latter are formulated by the learners themselves, and (e) when learning takes place in a social context, whereby justifications, principles and explanations are socially fostered, generated and contrasted. By taking into account these conditions, transfer can take place.

A last means that is described in literature for the promotion of transfer is letting pupils participate in an 'expert-culture' as much as possible (Collins, Brown & Newman,

1989). In an expert-culture 'practice situations' are created in which pupils have the chance to practice their skills on their own. Moreover, we may assume that these expert communities explicitly encourage and explicitly necessitate pupils to explore transformations of their already acquired knowledge and skills.

It is impossible to know beforehand whether learning results will be transferable. Only in new situations the proof can be visible: when pupils have to show and use their previously learned knowledge and skills. In sum, some of the conditions to enhance the occurrence of transfer are: productive processing of the learning material, alternation of contextualizing and recontextualizing; enhancing reflective activities; and participation in an 'expert-culture'. All these conditions are assumed to contribute to the quality of the learning processes and, consequently, to the quality of the learning outcomes. As such they contribute to the degree of generalization of the acquired actions. As we have said before, another condition is related to the perception of the situations as equivalent and requiring actions or cognitive operations that are already available in some form. This latter issue is probably related to the material contextual cues (symbols, tools, inscriptions) that appear in a situation. In our research we tried to elaborate this point by teaching students to see problem situations as equivalent with respect to the tools that can be used and (re)constructed. We assumed that the construction of schematic models for problem solving contributes to both the degree of generalization of the acquired actions and can help to bridge –by analogy- the distances between seemingly different situations. Therefore we now turn to modeling as a means for transfer in the next section.

Models as a Way to Enhance Transfer

'Theories of analogical transfer have pointed out the crucial role of models in enabling transfer' (Mayer, 1989).

Mayer pointed to conceptual models, but other research shows that also representational models have this function. In Dutch realistic mathematics education, models are used as a means to bridge the gap between concrete situations and abstract maths. This can also be seen as a way of transfer, like Gravemeijer pointed out. Gravemeijer discussed different levels, following which models can develop (modeling), from 'model-of' to 'model-for'. He calls this process 'progressive mathematizing' (Gravemeijer, 1997). Eventually this process leads to algorithms, concepts and notations that are anchored in the students' personal learning histories. These outcomes are assumed to retain their intrinsic relationships with the real, informal, self-experienced knowledge where they started. If modeling is seen as an organizing activity, pupils practice this form of mathematizing. Such experience can become useful when pupils have to deal with applied mathematics problems.

Pupils are then asked to tackle a new problem as a situation that needs to be mathematized, instead of a situation in which just another problem solving way needs to be applied.

> " An organizing/modeling approach may enable the student to find an adequate informal solution. Moreover, the ability to organize, and the attitude to approach a new problem as a situation to be mathematized, may have a more general value than any ready-made solution procedure" (Gravemeijer, 1997).

Although it is assumed that models are useful for learning mathematics (Gravemeijer, 1997; Mayer, 1989), it is, however, doubtful whether the imposition of ready-made models on pupils' thinking, will help them master the mathematizing activity (Van Dijk, Van Oers & Terwel, 2000). From a sociocultural point of view, Wertsch contributes to the understanding of this dilemma by using concepts as *mastery* and *appropriation*. Mastery, in our view, has similarities with 'providing', in the way that it means "'knowing how' to use a cultural tool, without really making it your own". In contrast to the term mastery, we can make this concept of appropriation more clear: appropriation means 'to bring something into oneself, to make something one's own' (Wertsch, 1998). The correspondence with concepts like providing or designing is not hard to imagine.

The quality of the tools contributes to generalization of previously learned knowledge (Van Oers, 2000). Following Freudenthal, we assume that the appropriation of the mathematical structuring ability might be more helpful than the mastery of mathematical structures. It was already pointed out that the mastery of particular strategies at itself isn't enough to enhance transfer. But what if you involve children in a social activity, like learning to design models? And let them gradually (re)invent what is earlier invented by others?

> 'If the learner is guided to reinvent all this, then valuable knowledge and abilities will more easily be learned, retained and transferred than if imposed' (Freudenthal, 1991, p 49).

Reese too, (1977) argues that, in general, constructing a scheme yourself for the organization of information leads to better recall of knowledge, than a scheme that was made by another person. Taking these researches into account, we wondered if it might be more rewarding if we taught pupils to design models themselves, in co-construction with peers and the teacher (Gravemeijer & Terwel, 2000). The idea behind this point of view was that pupils who learn to design models in co-construction would choose to make models that are more in harmony with their competence level and their day-to-day routine. Therefore it should help them to better understand the subject matter the model is about. Having learned how to construct adequate models presumably places the pupils in a better position for solving new problems for which no ready-made models are provided or available (Van Dijk et al, 2000).

Many authors already have pointed out that when learning material makes human and personal sense to the learner, it is easier to use that knowledge in other (and different)

situations (Van Parreren, 1966; Donaldson, 1978; Van Oers, 2000). Van Oers furthermore argued that it seems undeniable that some elements of culture can be handed over to other people (like models). It is mainly the inscriptions (symbolic means) that assume that role, but the meaning of those elements must be reconstructed by every individual in every new situation (Van Oers, 2000). We therefore assume that models provided by the teacher make less 'personal sense' and therefore will be less easily used for new knowledge and tasks than models that are developed by pupils themselves. We expect it to be more effective for pupils to learn models co-constructively by guided reinvention, which thereby gives them possibilities to assign personal sense to the material learned.

Methods

<u>Program Characteristics</u>

In a research conducted by researchers at the faculty of Psychology and Education in the Department of Educational Psychology of the Vrije Universiteit Amsterdam, the elements known in literature to enhance transfer were applied in an intervention program aimed at learning how to solve mathematical problems in real life situations and especially how to design models to represent the problem situation in such a way that the problem becomes approachable for mathematical activities. Students were stimulated to:

- work in a productive and active manner in a setting that combined challenging, open problems with more reiterated tasks;
- contextualize and recontextualize the issues in different contexts;
- share in class-wide discussions the way they dealt with the tasks, thereby giving them the opportunity to reflect on their ways of solving and the opportunity to learn from each other;
- learn by teacher demonstrations of several ways of solving the tasks.

The research project can be described as a pretest-posttest-control group design with an experimental and a control group. In both conditions the mathematical content was the same but the main difference concerned the modeling. In the control group a restricted range of models was *provided* by the teacher and the textbook, while in the experimental condition pupils were stimulated *to design* their own models.

Although both conditions emphasized the same elements, some differences were made: Working in a productive and active manner meant in the providing condition that children worked with and drew ready-made models, whereas children in the designing condition learned to design and develop their own models. Sharing the ways of problem solving in the providing condition meant that pupils discussed the way they worked with models provided to them. The design of the research and the outcomes in terms of transfer of this intervention program will be discussed in the Methods and the Results section.

Design

In this field experiment, with an experimental group and a control group, 8 schools, 10 classes, 10 teachers and 239 grade-5 pupils (age 10-11 years) were involved. A pretest-posttest control group design was used. 118 pupils were assigned to the 'providing' condition: teacher-made models were provided to the pupils while they were learning the percentage-concept. This 'model providing' approach is the way in which regular education takes place in most primary schools in the Netherlands. The experimental ('co-constructing') group, consisting of 121 pupils, was exposed to the same mathematical content, but here the emphasis was on 'guided co-construction' of models by pupils and teacher. This co-constructive learning approach can be characterized as a form of teaching in which the pupils participate as model designers in a mathematical context, and jointly construct mathematical models for the solution of complex problems. In earlier studies we found positive effects of this teaching method, like better learning results of pupils in mathematics (see Van Dijk et al, 2000).

The schools participating in the experiment were situated in, or near two cities in the center of the Netherlands. Experimental and control schools were either middle-class schools or schools with high proportions of ethnic minority group children. Both types of schools were equally represented in the two conditions. The ages of the teachers in the sample varied: the youngest teacher was twenty-six, the oldest teacher was almost sixty years old. Their experience in teaching therefore varied from a couple of years to more than thirty years.

The grade-5 classes were randomly assigned to the control condition or the experimental condition. From the schools that participated with two teachers and two classes, one class was assigned to the control condition, and the other class was assigned to the experimental condition. There were no 'drop-outs' (teachers or classes) during the study.

Procedures

The experiment started with a workshop, for each of the conditions separately, in which the program and the teacher manual were explained and materials were discussed. The teachers participating in the experiment joined one of the two workshops. In the autumn of 1999 all teachers started the program in the same week and ended the program three weeks later.

The intervention consisted of a one-hour lesson every day for (almost) three weeks. It was composed of 13 lessons: an orienting lesson about models and their functions, and 12 lessons on percentages and graphs. For each condition a particular version of the program was made. These versions differed in the way pupils learned to work with models: in the experimental condition the pupils co-constructively learned to design models, as a tool for solving percentages problems. In order to strengthen the conditions for the development of representational ability (as needed for modeling) special attention was paid to the construction and use of graphs. In the control condition the pupils learned to apply ready-made models and graphs that the teacher provided. They did not learn to design or choose models themselves. More information about the tasks in the intervention can be found in Van Dijk et al (2000).

All teachers were visited at least two times in the course of the investigation, to give them opportunities to ask questions about the material and to give the researcher the opportunity to control the course of the lessons, the validity of the conditions and the integrity of the intervention. In addition, the teachers filled out a small questionnaire after each lesson.

Instruments and analyses

This research can be typified as a quasi-experimental pretest-posttest design with an experimental group and a control group. We administered a National standardized pretest and a special designed posttest in order to find effects of the program in terms of transfer of learning results (transfer test). The pretest and transfer test were equal for both groups.

The pretest (covariate) was meant to check pupils' mathematical knowledge and skills before the intervention started. Afterwards, the learning outcomes were measured by a transfer test with problems in situations and domains not closely related to what was taught in the lessons. The transfer test consisted of several items that were slightly (or totally) different from the kinds of mathematical problems the pupils worked on during the program. For example, pupils were asked to work with promilles, after a short textual introduction. The principles behind promilles resemble the principles for working with percentages, but children need to reconsider their way of problem solving in order to solve the promille-tasks correctly. It isn't enough to apply the way that was learned for percentages.

The transfer test consisted of partly open and partly closed tasks. The test was meant to give information about what the pupils had learned of percentages and graphs. Pre- and posttest proved to be reliable with alpha's of respectively .90 and .75. It should be noted that the alpha of the standardized pretest is based on oral reports of the Dutch National Institute (CITO) that developed the tests and that no publications are available yet.

Results

Outcomes

The data presented in this paper were analyzed with the statistical program SPSS. In order to determine the intervention effects, One Way ANOVA, Regression Analysis and Effect Sizes were used.

(insert Table 1 here)

In Table 1 the characteristics are presented of the distribution of the pretest and posttest. From Table 1 it can be seen that the experimental groups gain more on the transfer test than the control group. The difference in transfer test score is about two points in favor of the experimental group.

There were no initial differences between the experimental and the control group on the pretest. In a one-way analysis of variance of the pretest no significant differences were found (pretest: $F(1,237) = .484$, $p = .487$). However, a one-way analysis of variance showed a significant difference between the two conditions on the posttest (transfer test) in favor of the experimental group ($F(2, 236) = 128.765$, $p = .000$). Hence it can be concluded that in general there is a positive effect of the experimental program on learning results in terms of transfer. This result is in line with the hypothesis of the study.

We, then, considered the effects of the variable 'intervention' and 'pretest' on the transfer test outcomes. A Multiple Linear Regression Analysis was conducted, in which a dummy variable was created for intervention (0 stands for the control group [providing condition] and 1 for the experimental group [designing condition]). The variables 'pretest' and 'intervention' were subsequently included in the equation by the stepwise method. The outcomes are presented in Table 2.

(insert Table 2 here)

From Table 2 it can be concluded that the pretest explains 51 percent of the variance in the posttest (transfer test). The intervention explains 1 percent over and above the variance already explained by the pretest. Thus, in this study we were able to explain 52 percent of the transfer test variance in total.

We decided to compare the regression equations of the two groups in this study. In Figure 1 we plotted the individual results of the children in the providing group and the experimental group on the pretest and posttest. For these tests we calculated the regression lines. The regression equation of the control group is: transfer test = -11,605 + .236 pretest. The regression equation of the experimental group is: transfer test = - 11,663 + .246 pretest. This means, in general children benefited from being in the experimental group. Although children from the control group also show gains, the 'experimental group' slope is slightly steeper and the intercept is higher, as can be seen in Figure 1. The slightly steeper slope indicates that the high achieving students tend to benefit most from the intervention.

(insert Figure 1 here)

We hypothesized that the pupils' learning processes in the experimental group would progress in such a way that a greater increase in results on the transfer test would be demonstrated, as compared to the growth of control group pupils. The results confirm our hypothesis: pupils in the experimental group significantly outperformed pupils in the control group on the transfer test. Taking the ANOVA and Regression Analysis into account, we can see that the results are significant and therefore we may conclude that the experimental program has a significant effect on the learning results.

Effect sizes were calculated: this is the difference between the posttest means of the intervention group and that of the control group, divided by the standard deviation of the control group. The effect size in this study is .22. This is considered as a small effect (Cohen, 1988). Effect sizes of +.20 - .25 are seen as meaningful in educational environments (Slavin, 1996, p. 31).

In the next section we will draw some conclusions and discuss our findings. Implications for curriculum theory and practice will be discussed.

Conclusions and discussion

Summary of Findings

Before going to the conclusions something needs to be said about the limitations of this study. In this paper we could not address the question on the learning *processes*. Extensive, qualitative descriptions of the learning processes will be presented in another paper. A second limitation concerns the way the analysis was executed. The data were analyzed by way of conventional analysis of variance and regression analysis at the individual level. However, there are at least two levels involved: pupil and class. A more accurate analysis could be obtained by using a multi- level model. While the conventional analysis was able to identify significant differences between the two conditions, it was not able to identify the variance components at each level and to determine more precisely the differential effects for low and high achieving students. Therefore, in the future an ML-analysis is needed to allow a more accurate estimate.

In this paper we addressed the question of transfer from a theoretical and empirical stance. Our research question was:

> 'What are the effects in terms of transfer of an experimental curriculum, in which pupils participate as model designers in a process of guided co-construction, on the learning outcomes in primary mathematics?'

On theoretical grounds we expected to find the strategy of learning to design models having positive effects, like changes in learning processes, and a higher score on the transfer test in mathematics. In order to investigate this, we created learning situations in different groups that presumably differently affected the degree of generalization of the learned actions. In this paper we could not address the question on the learning processes per se. Nonetheless, we did find differences in occurrences of transfer and learning outcomes in both conditions. The outcomes of this study clearly show the expected learning results: significant differences in the outcomes between the experimental and control group were found.

In addition to this main conclusion, we also found a large effect of domain specific pre-knowledge on transfer. No less than 51 percent of the variance on the transfer test could be explained by domain specific knowledge as measured by a standardized pre-test in mathematics. These outcomes are in line with both Ausubel's famous statement about the influence of pre-knowledge on learning and with the literature about transfer which indicates the domain specific character of transfer.

Although this additional finding urges us to be modest in our expectations about the effects of instructional programs on learning and (especially) transfer, we may conclude that pupils who learn to design models themselves score better on a transfer test than pupils who learned to work with ready-made models provided by the teacher. Learning to design models helps pupils to get more insight in the mathematical subjects of percentages and graphs. It can be the case that pupils who learn to design models in co-construction choose to make models that are more in harmony with their competence level and their day-to-day routine. It should help them to better understand the subject matter the model is about. Having learned how to construct adequate models presumably places the pupils in a better position for solving new problems for which no ready-made models are provided or available.

In short: the process of designing models can be a way of constructing tools for the solution of percentage and graphs problems and in addition enhance transfer to new situations. Therefore, in curricula and classroom practices more attention to the process of model designing could be useful.

Future Research

We are now working on the analyses of a more qualitative research question, with respect to transfer. In future research this question will be addressed:

> 'Are differences in the quality of models made by children in both conditions due to the program they followed? And what is the nature of the models in the different conditions on the immediate tests and transfer tests?'

We expect to find that pupils in the designing condition will produce models that are more accurate, better structured, conveniently arranged, more complete and less standard

than models that pupils use in the providing condition. Future analysis will provide us with the answers.

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Figure Caption

Figure 1: Comparison of Experimental Group and Control Group.

Figure 1: Comparison of experimental and control group

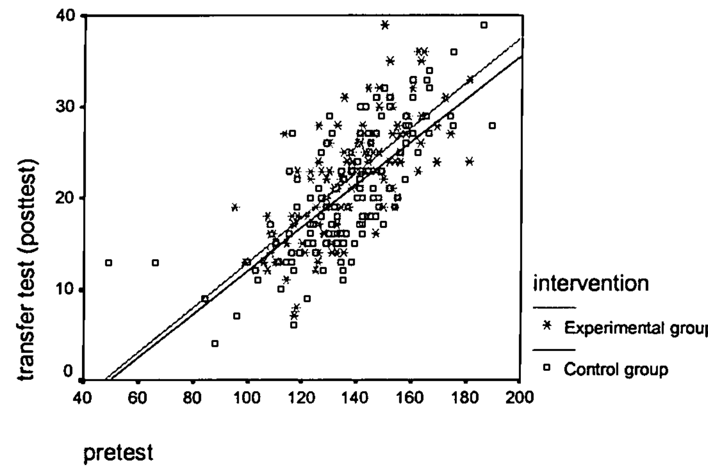

Table Caption

Table 1: Characteristics of the Distributions of the Standardized Pretest and the Transfer test for All Students

Table 2: Summary of Multiple Linear Regression Analysis for Variables Predicting the Scores on Transfer test

Table 1:

Characteristics of the Distributions of the Standardized Pretest and Transfer test for All Students (N-students = 239, N-classes = 10).

	M	SD	Min	Max
Control program N-pupils = 118				
Pretest	136,07	22,02	49	189
Transfer test	20,51	7,02	4	39
Experimental program N-pupils = 121				
Pretest	137,87	17,80	95	181
Transfer test	22,02	6,36	7	39

Table 2:

Summary of Multiple Linear Regression Analysis for Variables Predicting the Scores on Transfer test (N=239)

Variable	R	R^2	R^2change	Fchange	Sign R^2change	B	SE B	ß
Pretest	.715	.511	.511	247.6	.000	.240	.015	.710
Intervention	.722	.522	.011	5.3	.022	1.399	.607	.104

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