DISSERTATION ABSTRACT

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Factors influencing problem solving and successfulness in mathematics

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INTRODUCTION

Quality and *successfulness* are among the significant goals of education, but to meet these standards, the terms must be related to widespread conceptions of *evaluation* and *control* in schools. Students, teachers, parents, and school officials need to know the quality or acceptable levels of a performance, product, process, or activity more precisely to formulate and classify educational objectives. Undeniably, mass education involves *a drap in the conventional level*. *It is important to form cognitive objectives, to determine the skills and mental operations students need to learn the material.*

Findings from international and Hungarian studies appeared to indicate that our schools should broaden their definition of educational achievement, to tap the potential in as many students as possible. By nurturing *many different kinds of abilities and skills* we would allow more students to succeed in learning. But in many schools there are no internal evaluation systems (*Szekszárdi*, 2000).

Because our society places so much emphasis on grades, there is an ongoing debate about how to improve marking and reporting. For example, the present grading, marking, and reporting systems might be insufficient to let us judge our students' problem-solving abilities in mathematics. The purpose of this program of research has been to address *successfulness in mathematics* from an educational standpoint. The challenge of *quality* leads directly to the learnable aspects of problem solving: to *know mathematics* is to be able to *apply* concepts and principles in a creative way, the students can use their maths knowledge and their intellectual and affective thought processes to create meaning from instruction in order to solve maths problems.

The dissertation aims to give an overview of the literature on problem solving and relevant issues, to construct and develop adequate tests, to interpret and understand relationships between variables, and to highlight a need for a new approach in instructional practice and evaluation, which could result in more efficient teaching.

APPROACHING SUCCESSFULNESS IN MATHEMATICS: FACTORS INFLUENCING PROBLEM SOLVING

One of the main purposes of this study is to give an overview of key terms and ideas that illustrate the role of thinking in student achievement, and successfulness in maths. We indicate that teachers must understand student characteristics, and use ideas about the nature of the learning process and problem solving. This natural base, however, is often missing in actual teaching practice. The problem has been attacked by many researchers (*Majoros*, 1992; *Csapó*, 1999).

Teachers seem much more often concerned with problem solving procedures and methods than with the kind of problems that teaching can bring. For example, students work the problems in front of the class and are helped by the teacher if help is needed. For many students, in fact, the impression might be that subject matter in mathematics could be mastered in bite-sized chunks: the "problems" could be solved in just a few minutes - if only they knew the right procedures. Seldom if ever do they see problems of any other kind (*Csapó*, 1998, 1999).

Most teachers do not appreciate that students spend a lot of time thinking: procedures are presented in a step-by-step fashion, and the students are told to memorise them. This is where practice at home comes in. Most of the routine problems can be solved by mechanically within a few minutes. Clearly any mathematical problem-solving performance is built on a foundation of basic mathematical knowledge. Among the kinds of knowledge relevant to such performance are facts, definitions, routine procedures, and the like (*Nagy*, 2000). In our work we have attempted to present ideas about the nature of problem, and to outline the educational possibilities.

To discuss the processes involved in problem solving, researchers find it useful to depict problem solving as a *linear process* involving a series of steps to be completed to arrive at a correct answer. But they do not capture the dynamic inquiry involved in problem solving. Efficient *control* strategies – one that helps students to select appropriate techniques – might enhance their performance in mathematics (*Schoenfeld*, 1985). The *metacognitive component* in problem solving should be in the centre of interest of the teachers. *Metacognition* has become one of the "top topics" in the literature.

Other key areas addressed in the context of problem solving include *creativity*, *flexibility* (*insight*), and *attitudes towards maths*. Although teachers know the fundamental concepts well, it appears that this theoretical background has not been utilised altogether to solve teaching problems routinely. Up to now creativity has no generally accepted definition, there is no complete theory. In short, the authors use various approaches to understand creativity, and we are waiting for the integration of the diverse views. Not many attempts have been made to apply *Gestalt principles* to teaching (*Tóth*, 2000). Finally, the affective domain is generally seen as an important factor leading to successfulness in maths. However, research into mathematics disability has concentrated unduly on cognitive rather than personality factors. Of course, in dealing with thinking and problem solving, attitudes are of interest to researchers and teachers (*Csapó*, 2000; *Nagy*, 2000).

The brief introduction to problem solving provokes a number of questions. Of interest here is *how* a problem solver looks at a problem situation in a new way. To provide a framework for our research, we suggest that creativity, adaptable mind, flexibility may be influential in maths successfulness.

The concept of flexibility, in conjunction with the subjective experience of "seeing" the complete solution in the mind's eye, serves as a natural bridge to the views of *insight*. Flexibility is nothing more than switching to a new combination of responses associated with a problem situation or, in the jargon of the day, moving from one idea to another. Within the field of mathematical problem solving, it is possible that the central difficulty of the *algebraic word problems* is in understanding the underlying structure or principles; the novices tend to focus on the surface characteristics. One of the main purposes of this research is to report the attempts made to define variables that affect the difficulty of word problems.

The concept of motivation helps us understand and explain certain intriguing facts about successfulness in mathematics. It embraces several terms: needs, interests, attitudes, and incentives. In an effort to study students' attitudes towards maths, we constructed an *attitude scale*.

This work has developed from the realisation that mathematics learning demands *skills and strategies which have to be learned in such a way that they can be transferred to fit new problems not previously encountered*. There is much evidence that many students greatly dislike maths. Such emotions can arise with repeated failure in problem-solving, and especially when no strategy can be devised even for an attack on a problem. When teaching succeeds, it is not primarily because it helps learners to acquire more information, but because it helps them to acquire more information and to develop the kind of *qualities* noted above.

RESEARCH QUESTIONS

The primary objective of this study was to provide insight into problems of educational evaluation. More precisely, we examine some problems of successfulness in mathematics that might arise in carrying out the tasks of teaching but neglecting the cognitive processes of learners. Recently it has been noted that capable students get better marks in primary schools, but in secondary schools students of small abilities could get good marks, and the capable student could do less well (*Csapó*, 1998). *It was not a task to report the nation-wide situation.*

This work takes the more modest route. *Not only a nation-wide (usually expensive) research, but a synthesis of many different studies might be practically useful* (*Csapó*, 1998). Our findings are likely to be trustworthy in the given places.

The research involves five primary goals.

1. Creativity and successfulness in maths. With its focus on correct answers rather than on strategies or processes, school assessment procedure may provide invalid information about the ability to perceive relationships, apply knowledge in a variety of contexts, and solve problems. Mathematical problem solving plainly involves a search for what one is trying to do. Not only do these cases illustrate *flexible thinking*, they also attest *creativity*. It was a task to map the relationships of maths grades with factors of *creativity tests* among primary school and secondary school students.

2. Grasping the structural relations of problems and successfulness in maths. In solving maths problems there are situations in which students do not already know what to do. To be efficient, they need flexibility in how to manage the resources at their disposal (*Fisher*, 1999). *Flexible thinking* (*Dreyfus* and *Eisenberg*, 1998) has been concerned with (mathematical) problems (brainteasers and riddles). In this view, it is possible to use *insight problems* to develop *puzzle problem tests* relevant to flexibility. Our goal was to examine the relation between flexibility abilities and successfulness in maths.

3. The role of linguistic and structural variables in solving mathematical word problems. It is commonly assumed by both theoreticians and teachers that practice on a large number of word problems is the best way of gaining problem-solving skills. As a consequence, we might expect relations between *word problem tests* and maths successfulness in the secondary schools. To explore specific guidelines for the difficulty of the word problems, we studied several linguistic and structural variables which describe the textual statements of story problems (*Lepik*, 1990). In addition, it was decided to examine the role of these variables on reliability.

4. Students' attitudes towards maths and successfulness. The interest in value education forces all teachers to be aware of what influence their teaching has on the attitudes of student. To meet these needs, guidelines are offered to assist teachers in developing *attitude questionnaire* for collecting data about the affective behaviour of the students. One might, for example, suppose at the outset that the grade alone tends to be the main factor in the development of attitudes towards maths. In this study, it was expected that grading interferes with motives (attitudes, interest).

5. The relations among the constructs specified in our model of maths successfulness. Finally, we examined the relationships among the variables of the four tests. These findings can serve as a basis for understanding of the perspectives. Our model might offer promise for developing useful tests of student thought processes that influence achievement. The model specified the hypothesised relations among the constructs examined in this research.

In this research, we were *not* interested in evaluating changes in relations that relate to changes in time, therefore we did not need to use one of the developmental designs. However, it should be noted that *cross-sectional design* provides useful developmental data. Thus, in some instances we made comparisons.

METHODS

The **pilot study** took place in Somogy county in May and June 1996. The sample included secondary school students from Barcs and Kaposvár. The 218 subjects were 9^{th} and 10^{th} graders.

One objective of this study was to develop and pilot the tests. We designed a *subquestionnaire* with a few questions concerning attitudes towards maths. From the educational standpoint, for a conventional psychometric test, the battery of tests suggested by *Zétényi* (1989) was used. Using the above mentioned four tests, we designed two versions: each test consisted of two (*verbal* and *figural*) subtests. In the first task, the subjects solved verbal subtests (*Unusual Use Test*, UUT; *Remote Association Test,* RAT). Then they were given figural subtests (*Picture Completion Test*, PCT; *Circles Test*, CT). *Insight problems* of puzzle problem tests were scored with a true-false system: only *correct* and *incorrect responses* were distinguished. In analysing an item, the basic characteristics that we needed to consider were the possible answers. To improve the context of problems (items), incorrect responses were differentiated further: the frequent wrong answers were grouped into content-based categories. This method gave us the opportunity to construct better problems, items whose "correct" answer is simply the best among the alternatives. The *word problems* of mathematical tests were *motion problems*. These tests are useful to assess the students' ability to detect the problem structure.

The **second study** was conducted in three counties of Hungary (Bács-Kiskun, Csongrád and Somogy) in spring 1998. The 2780 subjects were 5^{th}, 7^{th}, 9^{th} and 11^{th} graders.

In this study the creativity tests were the same as before. But we made new tests targeting *flexibility* (grasping the structural relations of problems): in an attempt to make valid tests, we used the *matchsticks problem* as an indication. Most problems were drawn from the literature on insight using the taxonomy of problems proposed by *Weisberg* (1995). The other problems were selected or constructed on the basis of the procedures presented by *Gick* and *Lockhart* (1995). The tests targeting the performance on the maths word problems were also redesigned. The context is fully given in the text of any motion problem. Furthermore, the text contains exactly the information required to solve the problem. The formulation is also clearly given in the text of the problem, and only one solution can be accepted as the correct answer. The methods of approach are thus reduced to properly interpreting the problem situation and choosing an algorithm, from among those previously learned. Performing the necessary calculations, the solver arrives at the *numerical answer*. The solution of any test problem is related to the formula $v = s/t$. It was also considered that the students had already learned to draw the graph of a linear function. Because the role of linguistic and structural variables is of interest, the numerical data in the problems were chosen so that a correct solution could easily be obtained even without using a calculator. Nevertheless, the students were allowed to use calculators.

The **supplementary study** focused on the *students' attitudes towards maths*. The data collection took place independently of the second study in spring 1998. The sample included 189 students from a secondary school in Kaposvár. Only 9^{th} and 10^{th} graders were selected. The attitude questionnaire was developed using a *Likert procedure*. The nine statements were derived from the literature (*Tobias*, 1978).

The teachers participating in the data collection of the research program were given the necessary information about the details of testing. The students solved the tests in well-managed classes: at all times the teacher in charge was in control seeing to it that students were spending their time on appropriate tasks. The tests were distributed proportionally and randomly, but the neighbouring students were not permitted to solve the same test variant. Information on background variables was collected with the *data sheet*.

RESULTS

The results of the creativity studies

In the **pilot study** only the fluency, flexibility and originality factors of UUT were correlated with mathematical successfulness. The students' beliefs offered additional important information.

The results suggest that creativity could be related to *refusal of drills*. Such relations were found in connection with the factors of RAT and CT. Creative thinking process can be defined as the forming of associative elements into new combinations which are in a way useful. On this view, then, creative students might decline *learning by rote*. However, creativity factors were negatively correlated with the daily average learning time. Mainly the originality factors were good predictors (four from six). Among the six factors there were four from the five factors of RAT. It may also be suggested here that useful combination of ideas will presumably relate to the degree to which learning time can be reduced. At the same time, as indicated by our results, successfulness in mathematics and daily average learning time show relationship to each other.

Of course, searching for possibilities to solve a problem needs more time. Students with higher UUT scores usually refuse to accept that the slowness of mathematical problem solving indicates weak mathematical ability. Solving this subtest involves removing mental blocks. Problem solving might be hindered, for example, when the solver can think of using an *object* only for its most common or habitual use: to solve a problem, the solver must often redefine the givens.

From 18 creativity factors only *one* is related to rejecting *maths anxiety*. This is consistent with the fact that *creativity taken as a whole is hardly to be reflected in mathematical successfulness.*

Findings of the **second study** and other studies suggest that *it is necessary to reform the evaluation system*. However, as we have already seen in the pilot study, we can hardly expect a straightforward model of relationships owing to the nature of the variables. It was assumed that studying the correlations between test scores and maths grade *in the different age-groups* could provide important information about trends.

In primary schools the creativity factors used appeared to be good predictors of the maths successfulness measure. But the data related to secondary schools are thought-provoking: out of the 36 correlations only three reached significance among 9th graders, while in the 11th grade sample the two significant correlations were negative. These results support that *creativity is hardly to be considered an influential factor of the maths achievement in secondary schools*. This hypothesis is supported by our other observation: the variations in grades at the level of sub-samples are hardly to be explained by the variations in creativity test scores. Perhaps the point is that there are many problems with current assessment procedures regarding creativity, and we need to develop new assessment procedures that better reflect current understanding about the ways in which knowledge is constructed and the mathematics that students should learn. Although critics claim that there might be troubles with improving creativity, too (*Szabó*, 1987, 1990).

Findings for grasping the structural relations of problems

First, it should be noted whether *insight* occurs depends not only on the type of problem being solved but also on the skill of the problem solver, as representation of problems is partly based on the expertise of the solver. For example, insight may not occur for experts who have no difficulty with the representational stages of the

problems given (*Gick* és *Lockhart*, 1995). Consequently, in our *flexibility studies* the test problems were called *head-splitting tasks* (puzzles) instead of *insight problems* (see *Dreyfus* and *Eisenberg*, 1998).

In the **pilot study** flexibility test scores proved to be significantly correlated with maths successfulness. However, the relation between test performance and daily average learning time is not significant.

Out of the 6 relations between puzzle problem test and creativity two relationships are significant even if the effect of maths grade is removed. The other correlational relationships may result from the action of maths successfulness. It is interesting that the variant *A* of the puzzle problem test seemed to be correlated with the factors of UUT, while the variant *B* was correlated with the factors of RAT. The variant *B* was also correlated with the average originality factor of CT. Out of the 12 geometrical problems of test variant *B*, however, only one was found to be correlated with the above mention factor of the figural CT.

As for the attitudes towards maths, no more than the relationship between test variant *B* and refusing drills reached significance. School achievement might influence both of the variables, causing them to vary together.

In the **second study**, according to the *primary school students*' data, *puzzle problem* test scores were significant predictors of successfulness in maths. At the level of test problems (items), out of the 66 relationships between problems and maths grade 61 reached significance. The results suggest that the concept of flexibility is closely related to understanding and comprehension. In the case of problem solving, the emphasis in discussions of flexibility is on grasping the structure (the relations) of a problem. For example, it may be the case that some of the approaches that appear to be appropriate are not. Selecting goals, assessing solutions as they evolve, and revising or abandoning plans, when such actions should be taken, might enhance the performance. The term *verification* can be used to describe moments when the solution is tested and/or carried out. Clearly any problem-solving performance is built on a foundation of some basic knowledge. Students are hardly to be successful unless the relevant *resources* are available to them.

As regards the *secondary school students*' data, out of the 160 relationships between puzzle problems of the two test variants and maths successfulness in the four sub-samples only 24 were significant. Relations proved to be significant only among the 9th graders. According to the data, *none of the relations between flexibility variables and maths grade reached a significant level in the 11th grade*. This new information is similar to findings from our creativity study. In the case of creativity, there were significant correlational relationships between creativity factors and maths successfulness (out of the 36 relations 3) among the 9th graders, while in the 11th grade none of the positive correlation turned out to be significant.

All the results here support our prediction: *in secondary schools, students' abilities are hardly to be good predictors of the maths grades*. It is presumable even if several relations were found in the 9th grade. The reason might be that in the first half of the school year comparatively not *much maths knowledge* is to be learned by the 9th graders: although the subject-matter of instruction (content) begins to grow in the 9th grade, we could not yet talk about the "real secondary school maths" (e.g.

trigonometry, exponential and logarithmic equations, analytic geometry etc.). It raises the question: Might there be any relationships using maths grades given at the end of the school year?

Our results indicate the problems of secondary education instruction: teaching, for the most part, focuses on mastery of facts and procedures. Consequently, the students might be able to do the right things almost automatically when working on familiar tasks, but examining the problem-solving performance of these students can reveal some unpleasant realities (*Csapó*, 1998).

The results related to word problems

In the **pilot study** there were several significant correlational relationships between performance on algebraic word problems and successfulness in maths.

None of the creativity factors were significant predictors of the word problem test scores. As for the problems, there were significant correlations, but these relations showed a rather complicated picture. Out of the 20 word problems only five were positively correlated with creativity factors, whereas there were five negative correlations as well. Regarding UUT related to maths successfulness, negative correlations could be found.

According to data, word problem test might be related to puzzle problem test. But the correlational relationship between test variations *A* results from maths successfulness, while in the case of variations *B* the relation is on the verge of probability.

It turned out that students achieving high on the word problem test are frequently steady problem solvers. Considering successfulness in maths, maths anxiety usually is not expressed by good problem solvers.

Daily average learning time was correlated with only one word problem. It should be noted, however, knowledge required to solve these problems complies with the requirements laid down already in the primary school.

The results of the **second study** support our belief that performance on word problems has connection with maths successfulness.

Regarding the *linguistic variables* that might affect performance on word problems, in our study the linguistic variables carry more weight than in *Lepik*'s study (1990). Almost the same relations could be identified in the vocational secondary stream and the among the academic secondary students (8 relations apart from two variables). It seems that higher values of problem length variables are predictors of lower performance. The *text* of algebraic word problems appears to be a factor that affects the difficulty level of such problems. These results can be summarised by the conclusion accepted generally in public education: *literacy skills* need to be taken into account in understanding student characteristics, selecting and using teaching methods to achieve best results. In our study test scores were correlated with literature grade, and grammar grade as well.

As for the *linguistic variables and reliability*, the proportion of words with 9 or more letters was a significant predictor of problem reliability. According to our data, 9th graders with different abilities might be separated by such problems more reliably. In the case of academic secondary students, mean word length and the

proportion of words with 6 or more letters might be related to reliability. This means applying more longer words in word problems so that they will discriminate better between relatively greater versus less achievement. Among vocational secondary students, mean sentence length related to words gives information about reliability. Between the variables negative correlational relationships could be observed.

The finding of *Lepik* and other studies was generally supported in that *the structures of word problems in arithmetic determine their difficulty levels to a large measure*: out of 16 relations, 12 negative correlations were detected in secondary schools. In this study the number of equations proved to be the best predictor of difficulty. The number of known quantities and the number of unknown quantities also indicate the level of performance properly. It is assumed that the solver works within some definite *problem space* defined essentially by the distinctions and relationships that the solver uses. Thus, in addition to the working memory limitations, the dimension of problem space might be a critical factor in solving "complex problems".

Regarding *structural variables and reliability*, we found more significant correlational relationships than in the case of linguistic variables. At the same time, a noteworthy difference could be seen between the students in the vocational secondary stream (1 relation) and academic secondary students (10 relations). According to our data, the number of formulae required to apply in the solution of the problem could be used to explain reliability. The more formulae students have to *know* to solve the problem given, the more differently students perform on the task. However, the number of formulae was not significantly correlated with the performance measure used. These results show that students might learn the subject-matter of instruction well, but learning (esp. memorisation) does not mean automatically deeper understanding. That is, education should foster *transfer*.

The results of attitude studies

In the **supplementary attitude study** we found significant relationships between students' attitudes towards maths and successfulness in maths. This finding is in accordance with the fact that attitudes might be regarded as a factor influencing cognitive achievements.

Frequency of success in class is closely related to maths grade. Clearly to be successful, students act to accomplish the objectives set by the teachers. Family pressure alone could not be connected to maths grade linked with performance. If pupils' attitudes are antagonistic toward maths learning, efforts of parents and teachers are not likely to be fruitful. Learning to get better grades has a connection with grade. In the case of continuation of studies, of course, good grades are of interest. From pedagogical viewpoint, it is crucial that working at different abstraction levels could be related to successfulness. It is also important that persisting in problem solving is connected with grade. If students do not learn to work unaided, they might lose their confidence. Finally, they could desist from attempts. Overall, students who found maths interesting possessed usually positive attitudes to maths.

Interestingly, maths successfulness was not correlated with the following statements: (a) I find maths interesting, (b) I like to learn maths, (c) I do not feel anxiety in maths lessons, (d) even though I study, I cannot perform better in maths.

The test results within the relationship framework

In the **second study,** analyses of data were performed for the most part with regard to 9th graders because of the word problem test. However, data of 7th graders were also used when maths attitudes were studied and multiple regression analyses were used.

1. The remaining correlation between puzzle problem test and word problem is not significant when the effect of maths successfulness is eliminated. Four puzzle problems were negatively correlated with performance on word problem test. According to our data, *the role of flexible thinking is not straightforward in solving word problems*.

Regarding test scores and maths successfulness, partial correlation between word problem test and maths grade to remove the effect of puzzle problem test reached significance. Similarly, correlation between puzzle problem test and math grade remains significant when the effect of word problem test is removed.

2. Puzzle problem test can be related to factors of creativity test. So, flexible thinking can be described not only by flexibility factors of creativity tests, but we can use fluency and originality factors as well.

A further interesting result was that *verbal* UUT was related only to variant *C* of puzzle problem test, while *figural* CT was connected merely to variant *D* of puzzle problem test. At the level of problem, we also found paradoxical examples. A few puzzle problems are positively correlated with some factors of creativity, while they are negatively correlated with other creativity factors. In comparison with previous studies of insight problems, *Barkóczi* (1994a, 1994b) reported that the more creative subjects were not generally better problem solvers than the less creatives, but they had a better access to the available information and were more able to use it in a new problem solving context.

3. Among the relationships between word problem test and creativity factors only two are significant: in the case of the average originality factor of UUT the correlation is negative, and in the case of the average originality factor of PCT the correlation is positive. Surprisingly, negative correlations can be found only in the case of variant *B* out of four word problem test variants. Moreover, in this case there are five negative correlations.

4. In the *second study*, one of the questionnaires included eight statements which were similar to the questions applied in the supplementary attitude study. Consequently, relations between all variables considered in this research might be studied among more 9th graders. Maths attitudes were also studied in the 7th grade.

Cluster analyses of attitudes were performed in two age groups (among 7th and 9th graders). As for the 7th graders, the role of "learning under pressure" might be used to explain the formation of groups. According to our data, 7th graders who dislike maths learn under constraint, namely they learn under parental control to get better grades. Maths-lovers learn *with pleasure* (not only to get good grades). The situation is similar among 9th graders. The dendrograms revealed that in the 9th grade sample the effect of home pressure is farther, while successfulness is nearer (ahead of the statement related to abstraction), to attitude and interest.

Comparing the data of the two age groups we found that out of the 8 statements only one showed significant difference: 7th grades, according to their answers, are generally more persistent in solving difficult problems.

As would be expected, *most of the attitudes showed significant correlations with the measure of maths successfulness*. Only in the 7th grade, the relationship between *maths grade* and *learning (exclusively) to get better grade* proved to be not significant.

Regarding creativity, out of 144 possibilities (18 factors x 8 statements) only two significant correlations can be found in the 9th grade. Both of creativity factors are associated with originality. It is also interesting that out of the statements only the math attitude emerged.

Regarding flexible thinking, performance on puzzle problem test might be related to four statements. Correlation between test score and *self-confidence* remained significant when the effect of maths grade was removed. Students competent in solving puzzle problems are usually able to cope with maths considered a problem solving subject (or conversely). However, the correlations between test score and (a) *maths attitude*, (b) *successfulness*, (c) *learning under pressure* could only be due to the influence of math grade.

As performance on word problems is in connection with maths successfulness, it was expected that relationships between word problem test and maths attitudes might be found. Indeed, the correlations between the variables might be explained by maths grade. At the same time, there is no relationship between persistence in problem solving and achievement on the word problem test. These findings suggest that students might learn the subject matter knowledge and they are able to reproduce it.

5. Multiple regression was also conducted where the measure of maths successfulness was the dependent variable. First, all variables were entered together. Finally, only the significant predictor variables identified before were entered.

In the 7th grade the following model could be set up: the measure of *math successfulness* is influenced by flexible thinking, two creativity factors (fluency and originality factors of UUT), and attitudes (maths attitude, successfulness and self-confidence). These predictors account for 43,4 percent of the variance in successfulness. As could be expected, the contributions of maths attitudes proved to be important (22,0%). Similarly, the cardinal variable contributing to successfulness is *flexibility* (grasping the structural relations of problems) (18,1%). The remaining two creativity factors have little effect (in sum 4,1%).

In the 9th grade, however, flexible thinking and creativity fell out of the model. We suppose (and other investigations also suggest) that regarding successfulness the subject matter knowledge is more determinant than cognitive skills measured by puzzle problem test and creativity tests of this research. Indeed, the results show that algebraic word problem test score might be an effective predictor (18,5%). However, performance on maths word problems is a less effective factor than interest (altogether 27,5%).

Then, we were interested in studying additional variables: physics grade, literature grade, and grammar grade. The results of regression analyses used to determine the degree to which each variable independently contributes to variation in measure of math successfulness were similar in the two age groups. As for the difference, among 9th graders flexibility and creativity did not appear (they are not significant predictors). In this model performance on word problems could be found together with attitudes, beliefs (maths attitude, successfulness and self-confidence). Cognitive variables studied in this research have little effect: in the 7th grade 7,5 percent (flexibility and creativity), in the 9th grade 6,9 percent (performance on word problems). *The contribution of the three grades together to math grade can be larger than the effect of all the other predictors*: in the 7th grade 52,9 percent, and in the 9th grade 33,8 percent. In addition, *successfulness* might be effective.

The results are in accordance with the belief that students' subject matter knowledge and thinking skills are not so determinant in grading as it could be expected (*Csapó*, 1998).

CONCLUSION

The results of other studies revealed that our students know quite a lot, but they are not able to apply their knowledge in new situations. The investigations reveal low levels of instructional efficiency concerning the comprehension problems students face when learning maths. Moreover, grades might be loosely tied to thinking skills. Within this context, research might offer a useful approach towards the relationships between *school successfulness* based on grades and certain *thinking skills* measured by achievement tests, and ability tests. Students' attitudes, in this sense, is also fundamental to learning and successfulness. The dissertation examined *math successfulness* in connection with *creativity*, *flexible thinking*, *word problem solving skills*, and *maths attitudes*.

First of all, the tests constructed in this research might be of importance. To assess creativity, two *creativity test variants* were constructed with the help of creativity tests found in the literature (*Zétényi*, 1989). To assess flexibility, *puzzle problem test variants* were developed. The *algebraic word problem tests* are not only *achievement tests*, but they can be used to study *linguistic and structural variables* as well. Because of the problem structures, the role of *schemata* might also be studied. In addition, an *attitude questionnaire* connected with maths was devised.

The most important results of our research, in our opinion, are the following:

1. *Regarding creativity*, our results are consistent with the findings of other Hungarian studies. It was found in the primary school that the more creative students receive generally better maths grades. However, in the secondary schools performance on creativity tests cannot be related to maths grade. The results might also indicate that teachers have problems when assessing creativity.

2. *The results related to flexibility* are similar to the results of our creativity study. In the secondary school, flexibility thinking plays an unimportant role. In the primary school, however, more significant positive correlational relationships be-

tween puzzle problem test scores and maths grade could be found. The results suggest that in the primary school, certain thinking skills could be identified in the background of maths successfulness. Successful students were able to solve test problems, because they perform well on maths problems in general, showing that they are able to find or construct the appropriate problem representation (to understand the structure of a problem), and their metacognition might be better developed.

3. *In connection with the word problems* we report that students' subject matter knowledge is a good predictor of maths grade. However, word problem solving skills are not so determinant in grading as it could be expected. Indeed, everyday situations might often demand the use of formulae or equations for translating problems identified from natural language to the corresponding mathematical expressions.

4. *The results of attitude study* suggest that students interested in maths are usually successful, they receive better grades. The data support that only parental pressure has little effect on intensity and permanence of learning. Concerning practice, it is particularly important to note that *successfulness in class* proved to be a serious factor related to maths grade.

5. *Regarding all the relations*, we found mixed results. Significant positive correlational relationships between puzzle problems and word problem test can be detected. However, negative correlations, although to a lesser degree, can be observed as well. Similarly, there are positive relationships between puzzle problem test and certain creativity factors, while negative correlations can also be discovered at the level of test problems. This problematic issue remains to be solved. Considering creativity, originality is the best predictor of performance on word problems. But a further question might be asked if there were no *mistakes*: What accounts for the negative relationships between word problem test variant *B* and some creativity factors? Finally, maths attitudes could rather be related to test scores associated with maths grade. Most of the significant correlations were found by word problem test. It is noteworthy that relations between maths attitudes and creativity can scarcely be found.

Though there might be many useful implications for current teaching practice, there are also many open questions in the research. One task might be to evaluate *changes* in components and relationships that relate to changes in students' age using a developmental research design. Then, information on background variables might be better involved in the analyses. These works would contribute to the deeper understanding of relationships.

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