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Relation between Pupils' Mathematical Self-Efficacy and Mathematical Problem Solving in the Context of the Teachers' Preferred Pedagogies

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Abstract: In research focused on self-efficacy it is usually teacher-related phenomena that are studied, while the main aspects related to pupils are rather neglected, although self-efficacy itself is perceived as a belief in one's own abilities. Evidently, this strongly influences the behavior of individuals in terms of the goal and success in mathematical problem-solving. Considering that alternative teaching methods are based on the principle of belief in one's own ability (mainly in the case of group work), higher self-efficacy can be expected in the pupils of teachers who use predominantly the well-working pupil-centered pedagogies. A total of 1133 pupils in grade 5 from 36 schools in the Czech Republic were involved in the testing of their ability to solve mathematical problems and their mathematical self-efficacy as well. Participants were divided according to the above criteria as follows: (i) 73 from Montessori primary schools, (ii) 332 pupils educated in mathematics according to the Hejný method, (iii) 510 pupils from an ordinary primary school, and (iv) 218 pupils completing the Dalton teaching plan. In the field of mathematical problem-solving the pupils from the Montessori primary schools clearly outperformed pupils from the Dalton Plan schools ($p = 0.027$) as well as pupils attending ordinary primary schools ($p = 0.009$), whereas the difference between the Montessori schools and Hejný classes was not significant ($p = 0.764$). There is no statistically significant difference in the level of self-efficacy of pupils with respect to the preferred strategies for managing learning activities ($p = 0.781$). On the other hand, correlation between mathematical problem-solving and self-efficacy was confirmed in all the examined types of schools. However, the correlation coefficient was lower in the case of the pupils from the classes applying the Hejný method in comparison with the pupils attending the Montessori schools ($p = 0.073$), Dalton Plan schools ($p = 0.043$), and ordinary primary schools ($p = 0.002$). Even though the results in mathematical problem-solving are not consistent across the studies, the presented results confirm better performance of pupils in some constructivist settings, particularly in the case of individual constructivism in the Montessori primary schools. The factors influencing lower correlation of self-efficacy and performance in mathematical problem-solving ought to be subject to further investigation.

Keywords: alternative education; mathematical problem-solving; self-efficacy; correlation analysis

1. Introduction

Three main reasons why competences for sustainable development need to be addressed have been identified by the United Nations Economic Commission for Europe [1]. One of the weakest points in education for sustainable development is the way that teachers educate their pupils. Characteristic qualities of education for sustainable development include innovative and constructive features, which are inspired by the new paradigm of postmodern thinking [2]. Based on these facts we focus on the impact of educational approaches in mathematics on the mathematical performance and self-efficacy of primary school pupils.

Korbel and Paulus [3] mention that the Czech Republic is still one of the sad places or backward countries where the current teaching is largely based on the frontal transmissive teaching mode. This form of teaching has become a model used mechanically, not taking into account the needs of pupils and thus leading to the passive use of previously learned procedures [4–6]. Needless to say, these approaches are inappropriate for the conceptual understanding of mathematics as such [7]. This trend of mechanical learning in schools continues to prevail, despite the fact that the routine repetition of procedures leads, for example, to a reduction in interest [8] and to pupils consequently not understanding how to use or modify their knowledge [9]. Due to the currently rapidly changing technologies, it is necessary to solve mainly the non-routine problem phenomena accompanying convergent and divergent thinking, which requires a good portion of creativity in solving them consistently [10]. In connection to problem-solving, the necessity to get the pupil actively involved as a learning subject is becoming more and more common. In a constructivist mathematics education, mathematical learning is understood as an "active process of mental construction" [11] (p. 99). The issue of teacher beliefs has been much debated recently [5]. Lui and Bonner [12] note that there is a significant correlation between the quality of teachers' lesson plans and their conceptual knowledge of mathematical content, unlike procedural knowledge for which this relationship has not been confirmed yet. Daher and Saifi [13] believe that the constructivist approaches would increase democratic teaching practices that prepare today's pupils for their future lives, and thus are nowadays the essential aspects of learning [14]. These pedagogies (also known as constructivist approaches) are proposed as alternative teaching methods (see, for example, [15]).

Kirschner et al. [16] address the question of which types of educational practices are likely to support knowledge construction in terms of constructivist approaches. These theories emphasize the involvement of students in building their own knowledge [17]. Constructivist approaches are often based on problem-based learning. They have a positive effect on one's own educational process in terms of success [18]. It is necessary to note that the issue of constructivism is discussed in scientific literature both in terms of its contribution to education [19] and in terms of its negative effect [20,21]. There are several surveys confronting the traditional way of teaching based on the transmissive concept of teaching with other approaches, such as web-based learning [22], computer-assisted teaching [23,24], etc. However, it is rather complicated to find research that directly focuses on one specific approach (the scheme-oriented approach, the Dalton Plan, etc.). In our concept, for the learning management strategies we perceive and understand various branches of pedagogies that include (i) Montessori pedagogy, (ii) a scheme-oriented approach (the Hejný method), and (iii) an approach implementing the elements of the Dalton Plan.

We will focus primarily on the comparison of different preferred strategies for managing learning activities from the perspective of correlation between the success rate in mathematical problem-solving and mathematical self-efficacy. The basic differences between the chosen approaches (Montessori pedagogy, scheme-oriented approach, (i.e., the Hejný method), an approach implementing the elements of the Dalton Plan, and ordinary school) are summarized in Table 1.

The Hejný method in the field of mathematics education is based on a scheme-oriented education. Here, pupils themselves try to discover and understand mathematics through the independent creation and development of these schemes. The rationale of this approach is that no knowledge is anchored individually in the cognitive structure, but it is collected together in some meaningful functional units [25,26]. The Hejný approach to mathematics education is based on the construction of various schemes interconnecting the pupil's knowledge and skills [27]. Thus, it combines and creates a dynamic network of mathematical knowledge and skills. The scheme-oriented method can be used in various activities, such as summaries, discussions, etc. As it is well known, Hejný himself [28] specifies that the phrase "scheme-building orientation" originated because constructivism as such has several different interpretations in the fields of didactics of mathematics. This approach is in direct agreement with the Shapiro learning model, demonstrating the following percentage of memorization with respect to the chosen teaching method: lecture (5%), reading (10%), audiovisual methods (20%), demonstration (30%), group discussion (50%), practical exercises (70%), and teaching others (90%) (Shapiro in [29], p. 308).

Table 1. Comparison of the significant aspects of different conceptions.

Aspect	Montessori	Hejný	Dalton	Ordinary School
Role of the Teacher	guide	guide and facilitator	facilitator	source of information
Learning Theory	individual constructivism	social constructivism	social constructivism	transmissive approach with elements of constructivism
Way of Work	individual	individual/group	group	frontal
Organization of Education	trivia	only in mathematics	blocks	subjects
Age Groups	heterogeneous	homogeneous	heterogeneous	homogeneous
Main Idea	Help me do it myself.	Joy of learning	Freedom for cooperation and assignments.	Not stated

The active network of Dalton schools and Dalton specialists ("Dalton International") as a non-profit organization is based in the Netherlands nowadays. These schools often cooperate with each other and share methodological materials, which is a way to stimulate the innovation of Dalton education and bring it to a higher level. Within the Dalton Plan, freedom in the sense of choice is inextricably linked to the responsibility for that choice [30] (p. 21). Svobodová [31] (p. 173) further adds that "by transferring responsibility we also give children the feeling that their work makes sense." The principle of deferred attention is applied in Dalton school teaching [32], especially because the teacher does not have the opportunity to pay attention to all students at once. The activity of each of the pupils is based on the principle of independence, which is necessary in group work as such [33]. This approach to education consists mainly of using the Dalton blocks and Dalton tasks. It is based on the three following principles: (i) freedom, (ii) cooperation, and (iii) autonomy. Within these blocks, "emphasis is placed on searching and processing the information in one's own way (thus, individually, in a group, or with a teacher, according to a suitable pace), free choice of order of tasks, choice of other tasks." [34] (p. 118). The tasks differ in their difficulty and can last up to 14 days.

On the other hand, the Montessori approach is one of the most used approaches in alternative education worldwide [35]. This approach is primarily focused on children with special educational needs [36]. Such an approach, where the pupils learn what they want, has also led to the design of a large number of specific materials for the Montessori teaching environment. In essence, it is a gradual practice of self-created learning, which is based on a number of variables. For example, there is only one exemplar of each manipulative in the classroom and pupils are not forced into activities, but rather decide how to carry out the activities. There are more such differences. A characteristic feature of the Montessori method is, for example, its focus on the child in a predetermined environment that allows for independence, its focus on the importance of early childhood education, its offer of individual education, and its inclusion of programs involving families. This method emphasizes the concentration and focus of children in terms of polarization of attention, which can be defined as the key to pedagogy. This attention is not (and must not be) disturbed in any way by the teacher in the educational process [37] and is detached from the real world [38]. Dereli et al. [39] see the Montessori method as an educational approach that provides opportunities for self-education and freedom of individual study, while meeting cognitive development and adaptability to the social environment of children who use educational materials while developing their self-sufficiency skills. Thus, the child will be exposed to constant psychological risk if he or she is not prepared to face the risk. At the same time, this approach draws attention to the fact that students who are not confronted with mistakes will repeat them in adulthood.

1.1. Mathematical Problem-Solving

At the beginning of research into mathematical problem-solving, an attempt was made to categorize tasks using various variables and to express the difficulty of a task as a function of these variables [40]. However, today there is a general agreement that the complexity of the given problem depends mainly on the characteristics of the person solving the given problem [7]. Thus, successful problem-solving also depends on understanding when and how to use the relevant knowledge and on the ability to monitor and evaluate the use of a piece of knowledge during and after its use [41]. Recently, several researchers [42,43] have suggested that the use of problems resulting in or leading to multiple correct solutions can positively influence the pupils' attitudes towards mathematics and self-efficacy, and may contribute to the development of pupils' creativity. It is the teachers' responsibility to introduce adequate problems, providing the pupils with an appropriate challenge [44].

All the factors influencing the ability to solve mathematical problems can be divided into the three following groups: metacognitive, cognitive, and affective. It has been shown that higher metacognitive knowledge, i.e., the ability to monitor one's activity and regulate learning [45], may increase students' ability to solve mathematical problems [46–52]. In the affective area, a mutual effect is observed. The pupils' experience of solving a mathematical problem successfully may lead to a positive attitude towards mathematics. This also seems to hold true in reverse, i.e., students who have a positive attitude to mathematics are more successful at solving mathematical problems [53–57]. The results of several authors show that success in solving mathematical problems is influenced by students' procedural skills, including their ability to use (dominantly mathematical) tools productively and to choose an appropriate representation in the mathematization of problem situations [58–61]; their level of control of processes related to mathematical activity, such as reasoning, communication, generalization, or mathematical modeling [62–68]; and the level of their conceptual understanding of mathematical concepts [69–73].

As pointed out by Pehkonen et al. [74], "traditional teaching is well suited to the learning of facts, but the currently new methods—emphasizing, for example, pupils' self-regulated learning—are needed for learning procedures" (p. 12). On the other hand, when applying more student-oriented pedagogies, a change in the role of both the teachers and the students is required [75–77].

1.2. Mathematical Self-Efficacy

Several authors have already tried to define mathematical self-efficacy [78,79]. Burnham [79] defines it as "an individual's confidence in their own ability to perform successfully in mathematics." Betze and Hackett (1983 in [80], p. 300) add that it is "the belief of an individual about their abilities needed to solving specific mathematical problems, to fulfilling mathematical problems and to succeeding in mathematics-related courses." Hence, mathematical self-efficacy is divided separately from the teachers' perspective (mathematics teachers' self-efficacy [81]) and from the pupils' perspective (pupils' mathematics self-efficacy). In the case of pupils, authors often mention that those with a higher self-efficacy level can set higher and more challenging goals and, in addition, they often work harder to achieve them [82]. The fact that it is possible to predict pupils' specific academic achievements (especially in case of the achievements associated with solving mathematical problems) on the basis of their mathematical self-efficacy has already been described by several researchers [83]. As early as in 1983, Betz and Hackett [80] studied mathematics self-efficacy in terms of pupils' individual judgments about their capabilities to solve some specific mathematical problems and about their grade in mathematics. This is a domain that has been linked to a number of other factors, such as negative correlation with mathematical anxiety [57,84,85], or positive correlation with performance in mathematical problem-solving [86]. The higher the self-efficacy of an individual is, the more cognitively demanding problems the given respondent is willing to solve [87]. Hoffman [86], referring to other research (e.g., [88]), adds that the pupils with higher self-efficacy are more accurate in numerical activities because they do not have to use time-consuming activities to manage stress and anxiety, and, eventually, they are more able to calibrate and utilize their efforts. Many experts even consider the sole self-efficacy of an individual to be a limiting and crucial factor influencing a pupil's performance in mathematics. This relationship between mathematical anxiety and self-efficacy was portrayed in a regression model assuming work with lower-difficulty problems by Hoffman [86], who describes a moderate relationship between mathematical self-efficacy as such and mathematical anxiety on the other side. He further notes that mathematical anxiety increased along with an increase in task intensity, suggesting that self-efficacy was the predominant variable that logically compensated for anxiety. Some of the latest scholars focusing on this issue were Hufstader et al. [89] through the MSEAQ (Mathematics Self-Efficacy and Anxiety Questionnaire). Similar to Hoffman, their analysis was based on a regression model—in this case a multilinear regression analysis. As reported by Castellanos [90], the children attending Montessori classrooms have better pro-social behavior and higher general self-efficacy.

The main aim of this study is not only to investigate whether there is a relationship between pupils' self-efficacy and their performance levels in solving mathematical problems, as this relationship has already been reported by several authors [87,91–93]. Within the analysis, a partial variable enters the given issue, touching on the preferred strategies for managing learning activities in the sense of various educational activities run within different educational policies. We therefore focus on answering the question of how these two variables, i.e., the ability to solve mathematical problems and self-efficacy, differ in the four most prevalent types of schools with diverse preferred learning management strategies. Taking into account that there are many factors potentially influencing this relationship in particular, and including the age of the pupils, we need to focus on the pupils on the verge of primary and lower-secondary levels of education.

In the Czech Republic, pupils attending grade 5 still have only one teacher for all subjects (except special subjects). Therefore we anticipate that the influence of the teachers' pedagogies and preferred learning management strategies is most visible at this grade. Furthermore, an equal level of knowledge is expected at grade 5, as the pupils are not differentiated yet. Since self-efficacy is also closely related to the school success rate [94], the last of the research questions deals with this issue. The following three research questions were formulated:

- What is the relationship between the pupils' success in the didactic test in mathematics and the preferred learning management strategies?
- What is the relationship between the pupils' levels of their self-efficacy and preferred learning management strategies?
- What is the relationship between the success rate in the didactic test of mathematics and the pupils' self-efficacy with respect to the preferred learning management strategies?

The following hypotheses are also relevant and related to the research problems:

Hypothesis 1 (H1). *Pupils' performance in the didactic test in mathematics differs for pupils in the fifth grade in Montessori schools, pupils taught according to the Hejný method, pupils in ordinary primary schools, and pupils attending Dalton schools.*

Hypothesis 2 (H2). *The level of pupils' self-efficacy differs for the pupils in the fifth grade in Montessori schools, pupils taught according to the Hejný method, pupils in ordinary primary schools, and pupils attending Dalton schools.*

Hypothesis 3 (H3). *The higher the pupil's self-efficacy is, the more successful the pupil is in the didactic test in mathematics.*

2. Materials and Methods

Based on the research questions, these three variables were investigated in the study: (i) mathematical self-efficacy, (ii) mathematical problem-solving skills, and (iii) preferred strategies for managing learning activities, namely involving Montessori primary schools, schools following the Dalton Plan, schools with mathematics taught according to the Hejný method, and ordinary primary schools.

2.1. Research Sample

A total of 1133 respondents from 36 schools were involved in the testing, divided according to the above as follows: (i) 73 pupils (7 schools) from Montessori primary schools, (ii) 332 pupils (8 schools) educated according to the Hejný method, (iii) 510 pupils (15 schools) from an ordinary primary school, and (iv) 218 pupils (6 schools) completing the Dalton teaching plan.

Data were collected at ordinary primary schools, Montessori primary schools, primary schools where mathematics is taught according to the Hejný method, and primary schools implementing elements of the Dalton Plan. The sampling was not and could not be purely random for all of the mentioned types of schools, as it had to be managed according to certain predetermined criteria. We tried to respect as much as possible the proportionality view, social status, and equality of conditions for each respondent. These criteria included factors such as (i) the time aspect of when the data had to be collected (i.e., from Tuesday to Friday during the month of June), and (ii) the intensity per pupil. Data collection did not take place during the first lesson or the last lesson of the day. There was a standard lesson between the two parts of the data collection when pupils were not tested in any way. As the issue of data collection during the last lessons was discussed by various authors, the vast majority of schools collected data during the second and fourth lessons.

Only the schools where mathematics is taught according to the Hejný method were randomly selected. Knoke et al. [95] state that the only way to achieve representativeness is to perform a random selection of all the units in a population in a situation where all the units have the same probability of recovery. Due to the fact that the main data collection takes place through questionnaires and lasts approximately two hours for each pupil, it was necessary to choose the whole class groups as the basic unit. For each randomly chosen school using the Hejný method, one ordinary school with a corresponding number of pupils from the same city was selected in order to maximize the comparability of the environment of the pupils. In this sense the sampling was stratified or regional. According to the information on the website of the authors of the Hejný method (www.hmat.cz), 750 of the 4100 primary schools in the Czech Republic use this method. However, fewer than 120 schools implement the Hejný method throughout the whole primary level. We managed to get a total of nine schools, making up less than 8% of all primary schools where the Hejný-method mathematics is implemented. Although significantly more schools were contacted, we were not allowed to collect data there, despite the financial evaluation offered to teachers. Teachers in the Hejný schools are overloaded by requests for taking part in various surveys. Pupils from the Montessori and Dalton primary schools could not be considered a priority, especially for the following reasons: Teaching at a Montessori primary school is based on so-called trivia and there are usually only small numbers of pupils in the fifth grade.

All the primary schools from the list of primary schools were covered, except for the schools with a declared alternative concept of teaching. The selection was made using a random number generator, according to which the schools with the corresponding order on the list were always contacted. When it was possible to find the relevant teachers directly on the website of the primary school, the request to fill in the questionnaire was sent directly to them. When teacher contacts were not available, the request was sent to the school management. More than 50% of contacted schools took part in the study. In this way, the whole population of Montessori schools was addressed, based on a map located on the Montessori website.

The schools implementing elements of the Dalton Plan are primarily concentrated around the city of Brno. Therefore, the collection of data from other primary schools would also have to take place in the given locality. These schools belong to the "Czech Dalton" organization. Currently in the Czech Republic there are 16 primary schools and 1 homeschooled pupil implementing the Dalton Plan.

2.2. Tool for Assessing Mathematical Problem-Solving Skills

The evaluation of the tool (in our case an open-response test on mathematics) was based on content analysis aimed at compiling an evaluation vector, where each component describes a certain area, which can be divided into the following criteria: (i) arithmetic operations, (ii) word/modeling problems, (iii) geometry, (iv) chart reading, and (v) unit conversions. The test covered the compulsory topics given in the Czech primary mathematics curriculum. The tool was created by combining the two different tools tested in research of Czech Centre for assessing educational outcomes (CERMAT), namely the MA2ACZZ506DT test (test A) and M5PZD15C0T01 test (test B). The problems originally labeled as 2.1, 2.2, and 2.3 (the new 1.1, 1.2, and 1.3, respectively); 4.1, 4.2, and 4.3 (the same designation); 5–7 (the new 8.1–8.3, respectively); 8 (the new 5); 9 (the new 3); 10 (the new 2); and 12 (the new 9) were taken from test A. From test B, problems 6.1 and 6.2 (the same designation), 8.1 and 8.2 (the new 7.1 and 7.2, respectively), and 9 (the new 10) were used. To verify the content validity, the opinions of six experts in mathematics education were used. The experts were asked to assess the difficulty of the problems. The categorization of problems as having lower or higher cognitive intensity was based on the fact that at least four of the six experts agreed on the category. In total, the test is constructed to have more than 80% of the items corresponding to higher cognitive demands. Furthermore, the experts also agreed that the test is suitable for the target group, grade 5 pupils. There were only a few minor changes to the tool, which were discussed with the experts individually.

The answers to individual items are evaluated dichotomously, where 1 means that the pupil answered correctly and 0 refers to a wrong solution. NA was used to encode a blank response to the item. The answers were coded by six coders, primary school teacher trainees, according to a comprehensive manual. The coders first coded 10 tests and confronted their coding with the first author. Each test was coded by at least two coders. When the codes differed, the answers were checked and the final value was assigned according to the decision of the first author. The described method of coding allows the following interpretation of the results: The arithmetic mean of the measured values is a suitable point estimate of the parameter p of the alternative distribution, the probability that a randomly selected pupil will answer the question correctly. The difficulty index was calculated according to the relationship $p = \frac{x_s}{x} \cdot 100$, and the difficulty value was estimated as $q = 100 - p$. The difficulty of suitable tasks is the number in the interval. The problems with a value $p < 0.20$ or $p > 0.80$ are considered suspicious [96]. The instrument itself showed high reliability, tested on the basis of the Kuder–Richardson 21 formula (split half with division into the even and odd items: 0.771, and after correction by the Spearman–Brown formula: 0.871), whose values fell in the generally acceptable range of between 0.7 and 0.95 [97].

Next, the sensitivity coefficient was calculated. For this purpose, a point-biserial sensitivity coefficient (br_{bis}) was chosen among the possible variants of sensitivity determination. Its advantage is that it takes into consideration the difficulty of the given task directly in the calculation, while a disadvantage is the high complexity of its calculation. For all items, the value of the biserial sensitivity coefficient was higher than 0.2, which met the criterion described by Štěpánek [98] in that the point-biserial sensitivity coefficient should assume values higher than 0.20. In the didactic test, a pupil can obtain a maximum of 22 points.

2.3. Tool for Assesing Mathematical Self-Efficacy

To determine the level of self-efficacy of participating pupils, we used the tool for measuring mathematical self-efficacy developed by Smetáčková and Vozková [78]. The questionnaire is standardized and constructed according to the recommendations of Bandura [99] and has already been used in the Czech environment. In their study, the authors report a high degree of reliability (Cronbach's alpha = 0.9) and good psychometric properties [78].

The questionnaire, with a focus on mathematical self-efficacy, consists of 30 items. For individual items the pupil answers on a Likert scale (Likert, 1932) of 1–5, where the individual points are as follows: 1 = strongly agree, 2 = agree, 3 = do not know, 4 = disagree, 5 = strongly disagree. According to Chytrý and Kroufek [100], in many of the presented studies there is not coherence in opinions, especially in how to work with the given scales. It is not only an issue of the scope of the scale or the parity of items being discussed, but also the characteristics and subsequent statistical evaluation of the obtained data. Clason and Dormody [101] describe different types of scales, including those where the neutral values are omitted. Several items (at least four) were merged by summing to obtain the analyzed variables [102]. In this case, we proceed with the conclusions and the way of using the scale given by a number of authors (e.g., [103,104]) and consider the given variable as an interval. Moreover, the whole of the testing will also be based on non-parametric statistical methods. Within the mentioned tool, the pupils' responses obtain values ranging from 30 to 150. The lower the final score, the higher the level of mathematical self-efficacy [78]. Based on their survey, the authors themselves proved that "the self-efficacy questionnaire showed high reliability," as the reliability values were around 0.9. The reliability in our study was Cronbach's alpha $\alpha = 0.72$ for all respondents.

2.4. Statistical Analysis

All the statistical analyses were performed in Statistica 13.3 (StatSoft Inc., Tulsa, OK, USA). The normality testing was performed using the Shapiro–Wilk normality test [105]. Based on the results of the normality test, the appropriate parametric or non-parametric methods were selected. The Kruskal–Wallis test and subsequently pairwise Z-tests were calculated. The Spearman correlation coefficient ρ [106] was calculated to evaluate the strength of association between the performance in mathematical problem-solving and mathematical self-efficacy in the whole sample and in each of the investigated types of schools.

3. Results

In the first step, the difference in the level of self-efficacy of pupils with respect to the preferred strategies for managing learning activities was analyzed. The statistical characteristics given in Table 2 are in accordance with the results reported in the Czech literature [107]. Based on the analysis by the Kruskal–Wallis test, we reject the null hypothesis of an identical median at the one-percent level of significance ($H(3, n = 536) = 13.909, p = 0.003$) and we can proceed to the post hoc analysis, the results of which are shown in Table 3.

Table 2. Descriptive analysis of the results of mathematical problem-solving test according to the preferred learning management strategies at different types of schools.

Type of School	**Montessori**		**Hejný**		**Ordinary School**		**Dalton**	
Characteristic	**Score**	**%**	**Score**	**%**	**Score**	**%**	**Score**	**%**
average	14.62	0.66	13.28	0.60	12.05	0.55	11.73	0.53
median	15.00	0.68	14.00	0.64	12.00	0.55	12.00	0.55
mode	13.00	0.59	12.00	0.55	18.00	0.54	13.00	0.59
SD	4.16	0.19	4.29	0.19	5.86	0.26	4.99	0.23
max	21.00	0.95	23.00	1.00	22.00	1.00	22.00	1.00
min	5.00	0.23	1.00	0.05	0.00	0.00	1.00	0.05
SW *p*-level	0.109		0.223		<0.001		0.032	

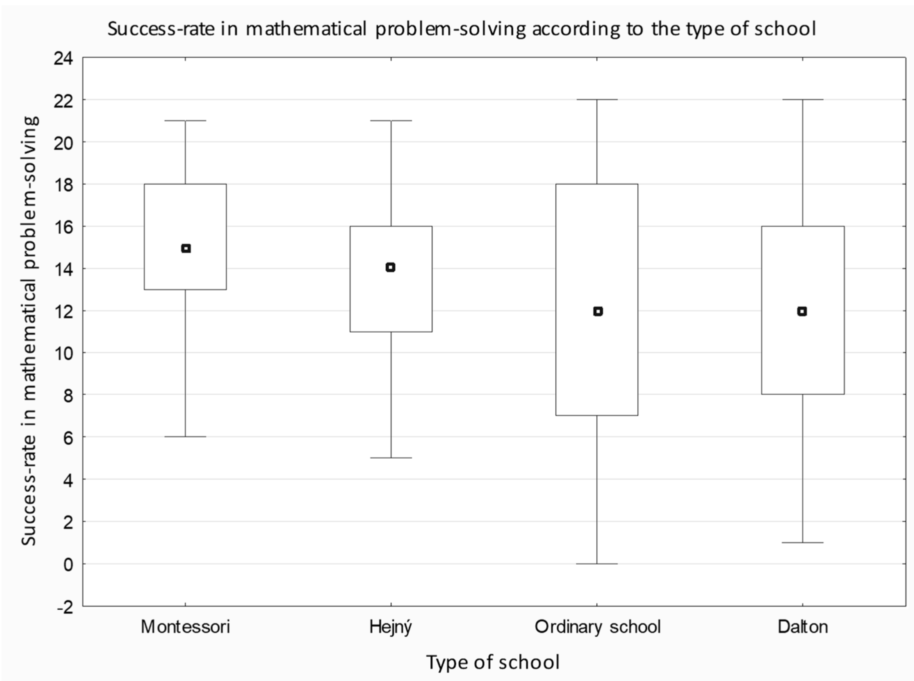
SD standard deviation, SW Shapiro–Wilk test.

Table 3. Post hoc analysis for the Kruskal–Wallis test of the results of mathematical problem-solving.

	Montessori	Hejný	Ordinary School	Dalton
Montessori	-	0.764	0.027	0.009
Hejný	0.764	-	0.328	0.099
Ordinary School	0.027	0.328	-	0.689
Dalton	0.009	0.099	0.689	-

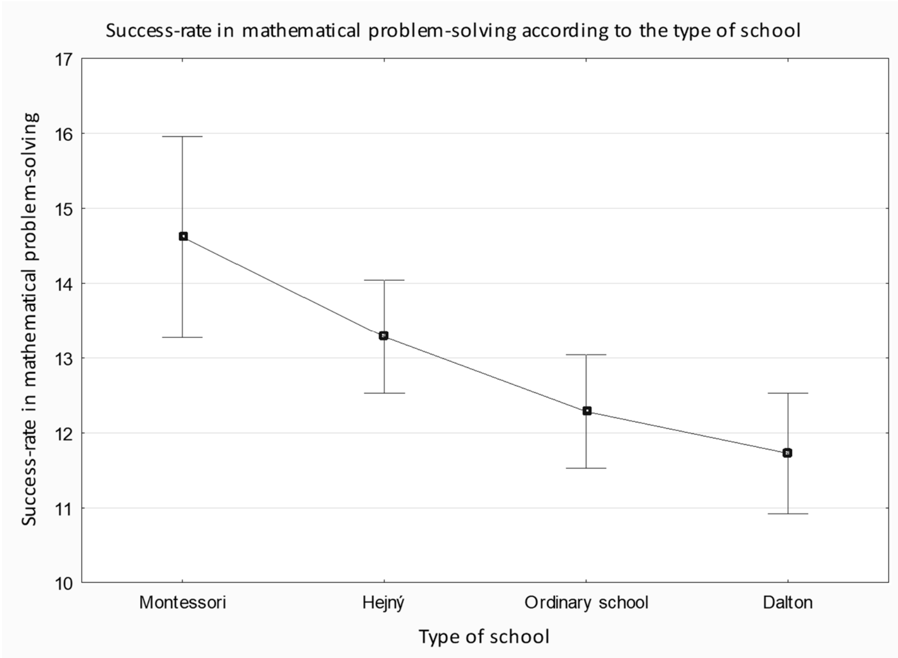
The pairwise comparison implies that the null hypothesis can be rejected in the pupils attending the Montessori primary schools and the pupils from other types of schools as well, with the exception of the schools teaching according to the Hejný method. In other words, the pupils from the Montessori primary schools significantly outscored the pupils from the schools following the Dalton Plan and ordinary schools. There are no significant differences between the pupils from all the other types of schools. If we consider the 10-percent level of significance, the difference will also be detected between the pupils of Dalton schools and the pupils taught by the Hejný method. The whole situation is shown more clearly in the following two graphs (Figure 1a,b). Hypothesis H1 is therefore confirmed.

Afterwards, the level of self-efficacy was compared according to preferred strategies for managing learning activities (Figure 2). Since the two cases rejected the null hypothesis of normality of the data (the data were also significantly skewed), the Kruskal–Wallis one-way analysis of variance [108] was used to compare the values of individual preferred strategies for managing learning activities. There is no statistically significant difference in the level of self-efficacy of pupils with respect to the preferred strategies for managing learning activities ($p = 0.781$). The differences in the individual distribution functions are clearly visible in the following quartile graphs. Outliers are included in the graph, as the medians are used, and these values do not significantly affect the analysis itself. From the descriptive analysis in Table 4 as well as from the following quartile graph (Figure 1), it is clear that the differences in self-efficacy for the individual preferred learning management strategies are only minor. Pupils attending the Montessori schools and the schools with the Hejný mathematics method have lower final scores, which indicates higher self-efficacy, but these differences are not significant.



(**a**)

Figure 1. *Cont.*



(**b**)

Figure 1. Quartile graph (**a**) and graph of averages (**b**) demonstrating differences in performance in mathematical problem-solving in different types of schools.

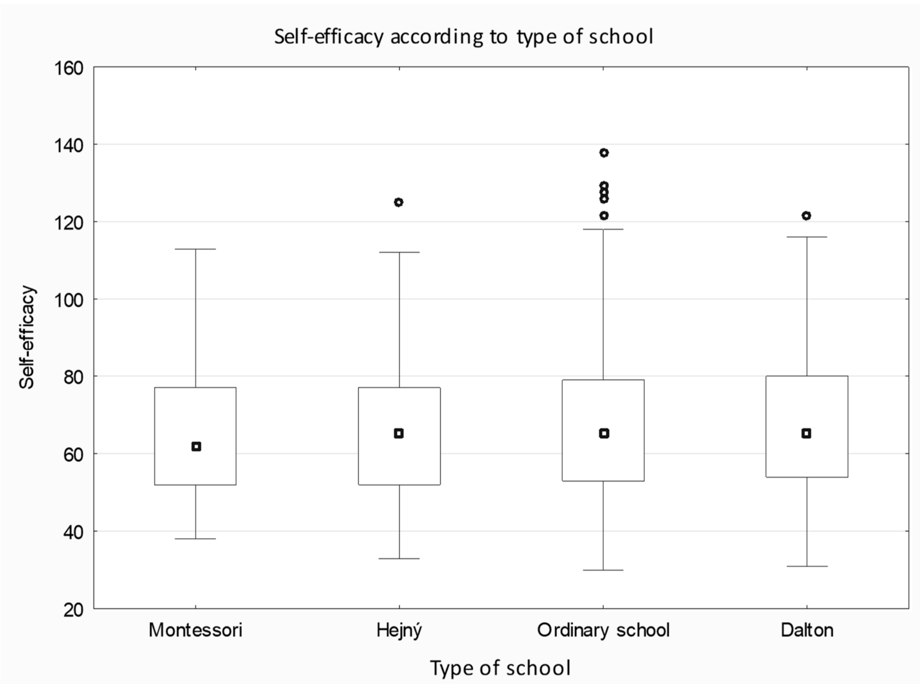
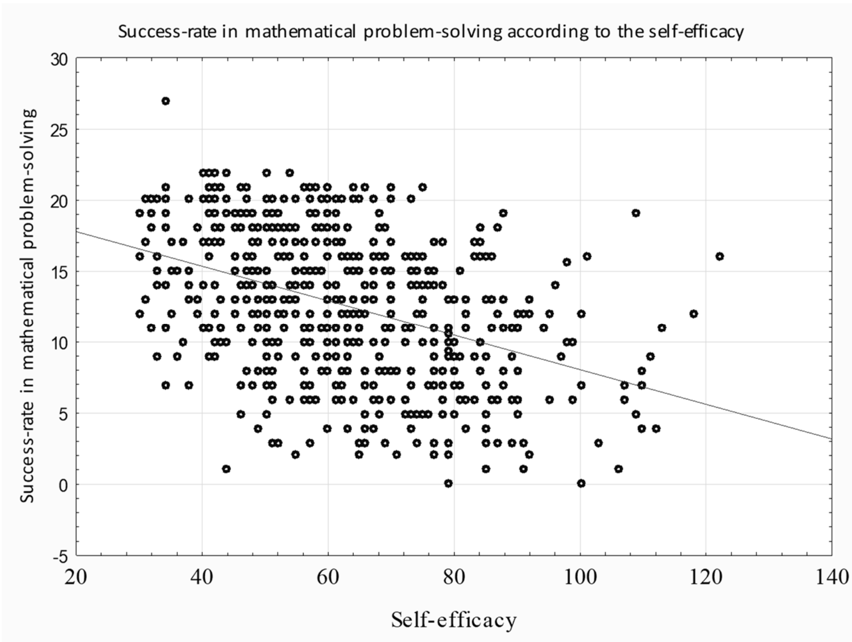
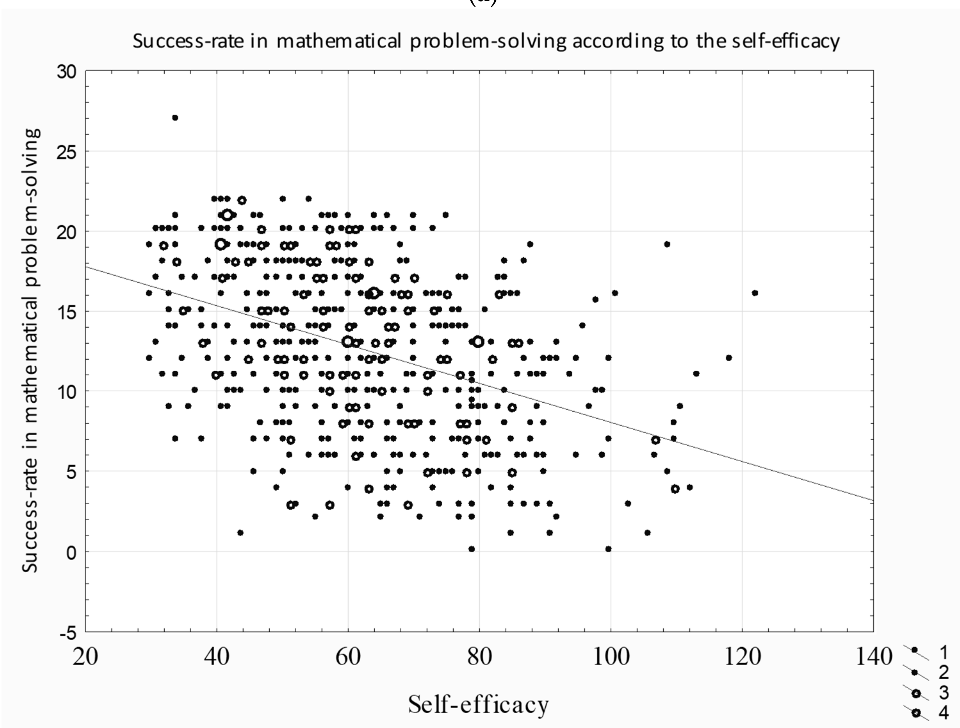


Figure 2. Comparison of self-efficacy for separate preferred learning management strategies at different types of schools.

In this case, it was not possible to confirm hypothesis H2, as there is no statistically significant difference between the separate preferred strategies for managing learning activities in terms of pupils' self-efficacy. Furthermore, while investigating the preferred strategies for managing learning activities, a negative correlation between self-efficacy and success rate in mathematical problem-solving was confirmed ($\rho = -0.418, t(n-2) = -10.88, p < 0.001$). Since both variables have different than normal distributions ($p < 0.001$ for the Shapiro–Wilk test in both cases), the Spearman correlation coefficient was used to estimate the degree of association. It is therefore possible to reject the null hypothesis of a zero correlation coefficient at the one-percent level of significance. From a factual point of view, we then talk about a moderate degree of association, as demonstrated by the following scatter plot (Figure 3). The standard scatter plot is also supplemented with a frequency graph to give a better idea of the actual data distribution.



(**a**)



(**b**)

Figure 3. Scatter plot (**a**) and frequency graph (**b**) between the self-efficacy and success rate in mathematical problem-solving.

Table 4. Descriptive analysis of the score of self-efficacy according to preferred learning management strategies at different types of schools.

Characteristic	Montessori	Hejný	Ordinary School	Dalton
average	64.24	65.07	66.34	66.75
median	62.00	63.50	64.00	64.00
mode	81.00	50.00	57.00	58.00
SD	16.87	17.44	19.62	18.97
max	113.00	125.00	138.00	122.00
min	38.00	33.00	30.00	31.00
SW *p*-level	0.108	<0.001	<0.001	0.011

The same analysis was further performed for each of the preferred learning management strategies (Table 3). In all cases, the Spearman correlation coefficient was used again.

As in the previous case, some interesting values of the coefficient of determination can be found, where each of them differs significantly in the individual groups. It is possible to monitor the whole situation in more detail using scatter plots (Figure 4).

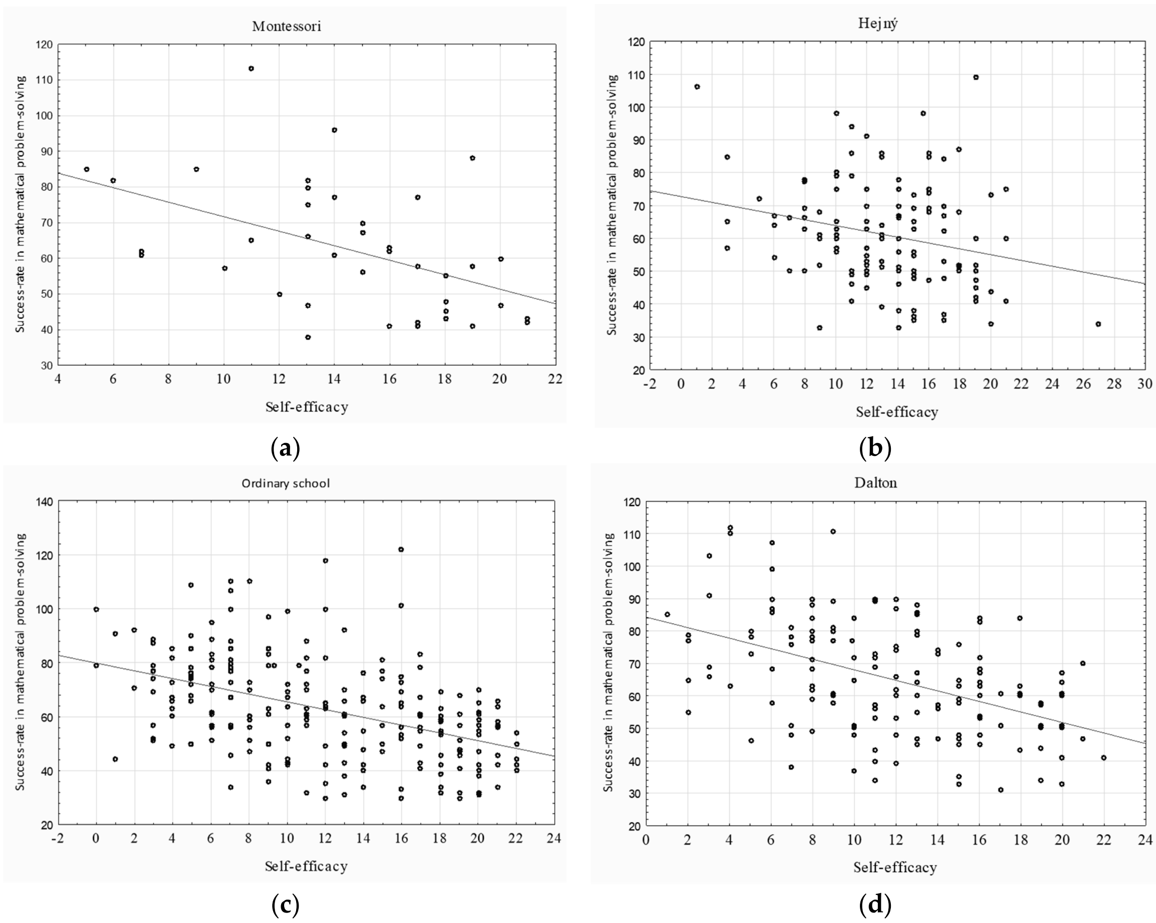


Figure 4. Scatter plot of self-efficacy and success rate on the didactic test in mathematics for different types of schools: Montessori primary schools (**a**), schools using Hejný's method (**b**), ordinary primary schools (**c**) and schools implementing Dalton plan (**d**).

It turns out that the degree of association between pupils attending the Montessori schools, ordinary primary schools, and the schools following the Dalton Plan is almost balanced. A slight difference occurs only in those schools where mathematics is taught according to the Hejný method, because the degree of association is significantly lower than in other preferred strategies for managing learning activities. In the last step, we discovered the difference between the values of correlation coefficients. The calculated *p*-values are displayed in the following table (Table 5) for the individual combinations.

Table 5. Significance of differences in the values of correlation coefficients.

	Montessori	Hejný	Ordinary School	Dalton
Montessori	NA	0.073	0.941	0.608
Hejný	0.073	NA	0.002	0.043
Ordinary School	0.941	0.002	NA	0.336
Dalton	0.608	0.043	0.336	NA

The table shows that the difference in the values of correlation coefficients relating to self-efficacy and the success rate on the didactic test in mathematics is only between the pupils taught according to the Hejný method, the pupils in mainstream schools, and the pupils in schools following the Dalton Plan. From the perspective of statistical significance, it is possible to confirm hypothesis H3. From a factual point of view, it can be stated that this dependence is moderately strong.

4. Data Interpretation and Discussion

The results of the study should be discussed on two levels. First, it is necessary to mention why we claim that the pupils of some "alternative" schools perform better than the pupils from ordinary primary schools. Second, we will focus on the question of why the results are inconsistent. For example, in the case when the pupils taught according to the Hejný method performed significantly better on tests during the Kalibro project in 2018 than the pupils from the ordinary primary schools and significantly worse in 2019. Another question concerns the pupils of schools implementing elements of the Dalton Plan in their program in comparison to the pupils from ordinary primary schools. According to the results of the Kalibro project in 2019, pupils of the Dalton Plan achieved better results than the pupils from ordinary primary schools, whereas based on the results of the above research, these results are comparable.

In the case of the first point, we could find a justification in the focus of the teaching, because quality teaching must be built on competencies, and the development of competencies specifically to solve problems is built on the principles of pedagogical constructivism [109]. Thus, the constructivist approaches also feature the most promising results in terms of the long-term knowledge acquisition [110,111]. Interestingly, Češková [109], with reference to Knecht et al. [112], further notes that in order to develop some key competencies it is necessary to build the mathematical problem on several principles: (a) The topic should concern the real life of pupils; (b) it cannot be solved by mere application of usual algorithms; (c) for the solution of the problem it is necessary to take into consideration the situational context; and (d) the solution should connect several closely related content areas as well. If we consider different strategies of managing learning activities compared to ordinary primary schools, they usually meet the basic definition of problem-oriented teaching, which can be [113,114] defined in several steps: (a) The pupil becomes a focus of the learning activity; (b) the subject matter must attract the pupils and make them think; (c) the given problem must be complex and exist outside of the pupil's classroom, therefore having an objective character; and (d) the teacher does not solve the problem, instead taking the role of a facilitator only. In case of the Montessori pedagogy, children work with the designed materials, so on the basis of direct manipulation of objects they can discover new knowledge that leads to the discovery of new problems [115]. This manipulation then directly leads to the fact that pupils solve problems practically with immediate control of possible mistakes and errors [116]. As Weirová [117] mentions, the Montessori materials or manipulators have a built-in self-correcting error-control element. Therefore, pupils here are able to work with a specific task with the material and, if necessary, they are able to recognize their own mistake(s) or more easily find out where they erred. In addition, the use of a practical manipulative approach in mathematics teaching, typical for both the Montessori concept and the Hejný method [118], results in a significant reduction in mathematical anxiety [119]. In addition, this approach in the Montessori pedagogy has proven to be suitable for problem-solving in other research as well [120]. In the ordinary primary school environment what still prevails and is preferred by teachers is the transmissive method of teaching based on a frontal organizational format [3], which may lead to the formalism regarded as the most serious didactic problem [121]. Within the Dalton Plan, the aim is to structure the tasks in the way that both individual and group teaching are used. Pupils are given some tasks to enhance the development of individual and group problem-solving skills in such a way that no further partial requirements for their fulfillment are needed [122]. Compared to Montessori schools, it is interesting that the pupils attending schools implementing the Dalton Plan do not differ significantly from the pupils attending ordinary primary schools when their ability to solve mathematical problems is tested. When considering the national high-stakes Kalibro surveys in 2018 and 2019, these pupils achieve significantly better results because the Dalton method does not replace classical teaching, but rather suitably complements it so that the advantages of both can be combined best. In these institutions we find the so-called Dalton blocks and Dalton tasks, where strong emphasis is placed on searching for and processing pieces of information in pupils' own way (individually, in a group, or with a teacher, at their own pace), with free choice of order [34]. The differences between the two tests may be related to the fact that these schools applied for Kalibro 2019 testing voluntarily. It can therefore be expected that these schools, expecting higher performance of their pupils, be involved in the research.

The second difference can be seen in the test of mathematical problem-solving used in this study. The tests used by Kalibro differ in some aspects from the test we described. For example, only the tasks are piloted, not the test as a whole. The six uses in the abovementioned survey were built in such a way that there were more demanding items compared to less demanding ones in a ratio of almost 2:1, as recommended for the construction of didactic tests by, e.g., [123]. It is therefore possible that it was the nature of the items that caused the higher scoring in the developed test. Similarly, the perceived difficulty of a given test can have an effect, too, as the pupils expecting a simpler test can perform better than the pupils who expect a more demanding test.

When implementing the Hejný method, some repetitions in environments often occur. The problems increase gradually in complexity. This then directly leads to the situation that knowledge is acquired through the understanding of the problem phenomenon. Interestingly, Hejný and Kuřina [124] are convinced that the basic task of any teacher is to motivate pupils, for example, by solving problem situations. These authors [124] further add that it is the inquiry itself that is an act of construction and the most important act of the cognition process in general. The question of comparing the gross score on the didactic test in mathematics for the pupils from ordinary primary schools with the pupils taught according to the Hejný method is very often discussed in the Czech Republic nowadays, both in political debates and among teachers and the general public as well. As with the other hypothesis, it should be noted that the pupils taught according to the Hejný method have a certain "disadvantage" compared to the Montessori and Dalton schools, due to the fact that in the observed schools only mathematics is taught by pupil-oriented pedagogies. For instance, in case of the pupils in the Dalton program or Montessori school pupils, the whole concept of teaching is considered alternatively across all subjects.

Interestingly, our other results imply that the pupils following the Hejný method usually accomplish better results than the pupils from the ordinary primary schools [125,126], or the same (Kalibro survey, 2019). This is most likely due to the fact that the pupils can combine and create a dynamic network of mathematical knowledge and skills in their learning process. It has already been indicated above that one of the important factors in competence-based teaching is real experience. Teaching according to the Hejný method is based on this experience, which leads to the contextualization of abstract knowledge, facilitating the consolidation and storage of new knowledge in the end (as an anticipated and desired result). We must critically note that there is a wide range of factors that can enter the research, as well as many variables that have not been investigated in this study. For example, it would be necessary to record lessons, monitor the interactions between the teacher and pupils and the use of pedagogies, map the afternoon program of the participants, assess socio-economic status, etc. At this point, however, the claims of some critics that "the Hejný children" lag in mathematics are likely refutable. This is proven by the results of our experiment focused on the given topic, where the data from the four largest data collections in the Czech Republic were used and processed. These pupils never scored significantly worse in comparison to the pupils from ordinary primary schools. Therefore, the Hejný pedagogies could be inspiring for other subjects in many ways, such as the active involvement of pupils, drawing on one's own experience, or working in environments that facilitate orientation. In addition, the method itself requires a facilitator approach, requiring a careful and comprehensive teacher training as well as internal motivation. We believe that this method cannot be applied "under duress" by school management, but that this activity must instead come from the teachers' beliefs, as the shift to the facilitator approach is very demanding. We believe that the teachers using the Hejný method for teaching mathematics can therefore better master some important elements of constructivism (this is not a rigorous conclusion based on vague research), which can then be implemented in other subjects as well.

The observed correlation coefficients between self-efficacy and the success rate in mathematical problem-solving classes are almost in line with the conclusions of the research conducted by [127], while their values ranged from 0.36 to 0.44. Williams and Williams [128] also addressed this issue in detail, testing the relationship across several countries. Hannula et al. [94] link self-efficacy with the school success rate, with the correlation coefficient being about r = 0.34. Thus, self-efficacy as such can be considered a predicting variable for performance in mathematical problem-solving [91]. Self-efficacy itself is perceived as a belief in one's own ability, which strongly influences the behavior of individuals in the sense of striving to achieve a goal. It is clear that self-efficacy is influenced by several factors, and one of the strongest is considered to be Bandura's so-called mastery experiences [129]. This means that if individuals are presented only with simple exercises, they get used to this activity and their success. Later on, they may not be able to cope with more complex problems. This would lead to the assumption of different self-efficacy categories with respect to the preferred learning management strategies as well as the individualization of teaching, resulting in and leading to the strengthening of self-efficacy itself. Given that the alternative teaching methods (in our case, all the preferred strategies for managing learning activities outside of the ordinary primary schools) are based on this approach together with some extent of group work, higher self-efficacy can be expected in the pupils of these schools. The relationship between self-efficacy and success rate in mathematical problem-solving is given by the particular second factor, namely, the vicarious (indirect) experience based on observing other people coping with difficult situations. Bandura [99] claims that if an individual tries harder and long enough to cope with a difficult situation, they can achieve the desired goal. When investigating the correlation between the self-efficacy of pupils and their success rate in mathematical problem-solving, Ayotola and Adedeji [130] came to the conclusion that the teacher should look for ways to improve mathematical self-efficacy in pupils. It may emphasize pupils' confidence in their ability to succeed in mathematics. Gómez-Chacón et al. [131] state that it is self-efficacy that interacts with and predicts performance in mathematics. More precisely, it can be stated that in testing, self-efficacy solves the question of one's own ability to perform required tasks, thus becoming a predictor of one's own success [132]. Therefore, it can be argued that the development of self-efficacy does not take place during frontal teaching, as it requires an individual approach to the pupil. Fonna and Mursalin [133] also report on the connection between self-efficacy and pupils' success in mathematics, but in relation to the ability to complete multiple mathematical representations. These authors claim that pupils have strong self-efficacy if they face tasks related to the ability to complete mathematical representation and are able to solve these tasks or problems accurately. This issue can be addressed especially in relation to the method of problem interpretation, and this is extensively applied in alternative educational programs.

The main aim of the present study is to compare the proclaimed curricula in terms of the preferred learning management strategies and confront them with the partial intervening variables that are the foci of the three research problems examined in this study: (i) What is the relationship between pupils' success rate in mathematical problem-solving and preferred management strategies of the learning activities? (ii) what is the relationship between pupils' levels of self-efficacy and their preferred learning management strategies? and (iii) what is the relationship between the success rate in mathematical problem-solving and pupils' self-efficacy with respect to the preferred learning management strategies? Within the didactic testing of mathematics, it is not possible to state that the obtained conclusions are coherent with respect to other research conducted in the Czech Republic (e.g., [125,126]), because not all the mentioned strategies were included in all the surveys. At the same time, there were also small differences in the sense that, for example, in 2018, the pupils taught according to the Hejný method performed better on the basis of Kalibro testing than the pupils from ordinary primary schools (where the results were significant), whereas in 2019 it was just the opposite (where the results were not significant).

Nicolaidou and Philippou suggest that "teachers should pay as much attention to students' perceptions of capability as to actual capability" [91] (p. 9). The recommendation to address students' self-efficacy is based on statements emphasizing the important role of emotional experience in the application of strategy, and this is also closely related to the development of students' metacognitive potential. Indeed, success itself naturally increases motivation for strategic behavior, automatically leading to and resulting in increased self-efficacy. Říčan and Chytrý [34] also mention that this ideally leads to student-attributed success in learning to their own efforts and the use of a proper learning strategy. Thus, the student finds out that the effort pays off and brings profit in the end, which is good and desirable. It is therefore necessary to create and then present adequately challenging tasks for pupils. While some challenging tasks can lead to the frustration stage, some simple tasks do not necessarily lead to the deployment of metacognitive strategies. We consider it necessary to mention that this scheme represents the hard line: Success–motivation–strategic behavior does not teach the student to work with a mistake and does not teach them a strategy of behavior in case of failure. Therefore, we consider it necessary to pay more attention to the issue of working with pupils' mistakes and errors.

Research Limitations

The sampling was not and could not be purely random for all the mentioned types of schools because it had to be managed according to certain predetermined criteria. The obtained sample contained 36 schools from all regions of the Czech Republic and may be considered representative. Thus, the largest limitations of the present study can be considered the absence of supplementary qualitative analysis where the maximum validity of the research would be achieved. Supplementing quantitative data with observations and interviews would allow the for research into real teachers' practice in different settings.

5. Conclusions

This study confirmed that it is necessary to address the issue of relationships between performance in mathematical problem-solving and mathematical self-efficacy within schools preferring different pedagogies, because it is the different approaches to teaching in the first stage of primary schools that have resulted in and led to different performance levels of pupils at the end of this part of the educational process. The recommendation to address pupils' self-efficacy is based on the important role of emotional experience in the application of strategy, which is also closely related to the development of pupils' metacognitive potential. In our earlier study [34], we also mentioned that this ideally leads to the pupils attributing success in learning to their own efforts and the use of a learning strategy. Thus, the pupils learn that the effort pays off and brings desired, sweet profit in the end. It is therefore necessary to create and then present adequately challenging mathematical problems to pupils. While certain challenging tasks can lead to high frustration, common simple tasks do not necessarily lead to the deployment of metacognitive strategies. Therefore, we consider it necessary to claim that this scheme, representing an apparent linkage between the three core stones, which are success, motivation, and strategic behavior, does not teach the pupils to work with a mistake and does not teach them a strategy of behavior if they experience failure. Therefore, we consider it necessary to pay more attention to the issue of working with errors and mistakes as such, since it is human to err in general in life, at school, at work, in privacy, or anywhere.

The diagnosis of self-efficacy using appropriate instruments is not difficult for teachers at all. An effort should be made in teacher education to train them in using the 30 well-known recommendations formulated by [80] in terms of the development of self-efficacy.

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