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# IMPACT OF LEARNING STRATEGIES INSTRUCTION ON STUDENTS' MATHEMATICAL TEXTS COMPREHENSION PERFORMANCE

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## *Abstract*

Negative attitudes towards mathematics appear early and correlate with difficulties to comprehend tasks. Can the learning strategies instruction help students to develop better skills for comprehending mathematical texts? The research question was to define the extent of the impact of the instruction of learning strategies on the performance of the third grade primary school students who were taught mathematical texts' comprehension. The purpose of this article was to establish the influence of the instruction of learning strategies on mathematical texts' comprehension of the third grade primary school students. The results whether two factors – students' cognitive abilities and their socio-economic status affected the performance of the mathematical texts' comprehension. An experimental project with pre-test and post-test measurements was created. The experimental group consisted of 46 girls and boys, and the control group consisted of 59 girls and boys (9–10 years). The data analysis methods were descriptive, probability and multidimensional statistics. Statistically significant differences were not found in the analysis of average mathematical texts comprehension performance in the experimental group in comparison to control group ($p < 0,05$). The results of study revealed that purposeful teaching of students to apply a learning strategy is a factor that has very small effect. The mathematical literacy previously acquired by the students, their learning achievements are much more influential factors for the students' further progress. Those with higher achievements continue to progress, those with lower achievements lag behind.

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**Keywords:** Learning strategies' instruction, mathematical texts comprehension.

## 1.  Introduction

In elementary school, children are provided with basic knowledge, which is crucial for their further achievement. The development of mathematical literacy skills is one of the main educational objectives of the European Union. Education documents in the European Union emphasize the importance of developing mathematical literacy skills as a key factor in the success of school education and in people's lives. The results of the TIMSS study indicate that a relatively small proportion of Lithuanian fourth-graders reach the highest international level of mathematics achievement (TIMSS Report, 2015). According to the results of standardized tests of Lithuanian fourth-grade students, until 2017 relatively good progress has been made in this area, reading is still one of the most problematic areas of primary education in Lithuania (NEC, 2017).

Negative attitudes towards mathematics appear early and correlate with difficulties to comprehend tasks. Mathematical text comprehension is related with reading comprehension and mathematics word problems as well. Mathematics word problems (further MWP) require the transfer of knowledge to novel situations, and this form of transfer can be difficult to effect especially for primary-grade children (Fuchs et. al., 2008).

Reading comprehension is a multifaceted and complex ability where multiple reading subsets and cognitive processes work together, such as: visual attention, processing speed, verbal decoding, lexical search, syntactic and contextual integration (Meixner, Warner, Lensing, Schiefele, & Elsner, 2019). Interactions between these subgroups require higher-level cognitive abilities, such as focusing, targeting, and suppressing inappropriate information. Recent research in neuroscience contributes to knowing how a person reads, what processes occur in the brain during reading. The ability to understand informational text is thought to rely on processes that help the reader create a consistent and accurate representation of the text, and processing speed, vocabulary, fluency, and decoding skills (e.g. Cutting, Materek, Cole, Levine, & Mahone. 2009). For successful comprehension, readers have to meaningfully integrate information into sentences in order to achieve a generally recognized level of text comprehension. As readers engage with the text, learning occurs by drawing conclusions and modifying readers' existing knowledge by adapting new concepts introduced in the text (Hooper, Rose, & Sperling, 2018). Therefore, recent studies have highlighted the influence of brain executive functions on the development of reading comprehension, particularly in the context of preschool and elementary education (Meixner et al., 2019).

The influence of learning strategies on the achievement of students of all ages is increasingly attracting the attention of researchers. Oxford has been the most consistent researcher on learning strategies for several decades and has provided a classification and concept of learning strategies (Oxford, 2016). Learning strategies were explored through the analysis aspects of foreign language learning. Self-management and motivation (e.g. Gerami & Baighlou, 2011; Rose, Briggs, Boggs, Sergio, & Ivanova-Slavianskaia, 2018; Lin, Zhang, & Zheng, 2017), the ability of students in grades 5-7 to apply learning strategies in mathematics lessons (Pennequin, Sorel, Nanty, & Fontaine, 2010; Sičiūnienė, 2015). Recently

researchers analysed the development of reading skills through reading strategies (Säälik, Nissinen, & Malin 2015; Toleikytė, 2014; Sičiūnienė & Toleikytė, 2017) and the application of meta-cognitive learning strategies (e.g. Veselinov & Nikolic, 2015). Baten, Praet and Desoete (2017) state that a meta-cognitive training model plays an important role to stimulate the development of reading skills in early childhood. Experiments have proven that reading strategies can improve the ability to understand the text being read (Toleikytė, 2014). Readers with good reading skills often find effective reading strategies themselves, can apply them consciously and unconsciously, but students with reading difficulties are unable to read strategically, and if they are not taught effective reading strategies in the teaching process, there is no way to bridge the gap between them and the strongest students (Faggella-Luby, Deshler, 2008; Li, Beecher, & Cho, 2018).

Teaching practices are the most significant factors in explaining students' academic outcomes (Caro, Lenkeit, & Kyriakides, 2016; Egloff, Förster, & Souvignier, 2019). Fuchs et al. (2008) revealed that the tutored students who received validated classroom instruction achieved better than the tutored students who received conventional classroom instruction. Tutoring, not validated classroom instruction reduced the prevalence of math difficulty. According to Raižienė, Stumbrienė, Ringienė, Dukynaitė and Jakaitienė (2019), the adaption of instruction significantly contributes to students' performance in all EU education systems. Students' need for competence is satisfied when teachers are perceived as adapting their instructions to students' diverse experience and cognitive preferences (Lau & Lam, 2017; Raižienė et al., 2019). The results of Raižienė et al. (2019) study reveal that students in all EU countries would benefit from adaptive instruction. The adaption of instruction is positively related and perceived feedback is negatively related to science performance. These patterns of associations are similar across all observed EU countries. Adaption of instruction refers to teachers' flexibility in constructing the lessons (OECD, 2016). Caro et al. (2016) findings show, that association between students' oriented learning strategies and mathematics performance are inconsistent across education systems according to 2012 year data from *Programme for International Student Assessment*.

Baten et al. (2017) propose to reinforce the meta-cognitive knowledge and skills of primary school students through modelling, pedagogical support, reflection, feedback, assessments, advice to the learner and observation. It is important to apply strategies that encompass a variety of thinking processes: cognitive, socio-emotional, and meta-cognitive (Toleikytė, 2014). Researchers stress that learning to read and learning other strategies should be systematic, coherent and challenging for students process, i.e. gradual transition from guided to autonomous learning, gradually increasing the degree of learning autonomy (Gibson, 2008, Tracy, Reid, & Graham, 2009; Toleikytė, 2014; Sičiūnienė & Toleikytė, 2017; De Smedt & Van Keer, 2018).

However, while research on the application of learning strategies is abundant and research has shown that learning strategies influence reading comprehension (Muijselaar et al., 2017), researchers note that their outcomes are not always transferable and adaptable to educational decisions (Chou, 2013). VanDerHeyden and Witt (2005) identified that nine practice sessions with feedback and reinforcement increase basic fact fluency. According to the other study, tutoring, not validated classroom instruction, and

reduced the prevalence of math difficulty (Fuchs et al., 2008). The majority of teachers do not use a carefully planned training material in the classroom (Chou, 2013; Star, Rittle-Johnson, & Durkin, 2016; De Smedt & Van Keer, 2018). Thus, teachers need didactic recommendations which, how and when the recommended training tools to use, that the learning strategies would become an inseparable part of the lesson. Raižienė et al (2019) estimated the positive statistically significant links between teacher support and science performance in 8 countries (Finland, Estonia, Lithuania, Sweden, UK, Latvia, Denmark, and Hungary).

Learning strategies in this study are explored using a constructivist learning model (Hattie, Donoghue, 2016), which consists of the following components: three sets of learning outcomes and three kinds of achievements, i.e. students' understanding of the criteria for success in the task, three stages of the learning process (superficial, deep and transferable learning), where superficial and deep learning involve each stage of knowledge acquisition and consolidation and the connecting component is the learning environment. As the teacher plays an important role in teaching learning strategies, the work is based on the model of teaching learning strategies and (according to Gibson, 2008, Tracy et al., 2009, De Smedt & Van Keer, 2018) it is emphasized that teacher mastery determines the correct application of strategy.

## 2.    Problem Statement

Negative attitudes towards mathematics appear early and correlate with difficulties to comprehend tasks. There is still a lack of research analysing the influence of learning strategies on the development of reading information texts in primary school. Analysing non-fiction text comprehension teaching in primary school and reader development strategies in Lithuanian textbooks (Salienė, 2010) it was found that not all Lithuanian textbooks have enough tasks related to reading a non-fiction text. There is a lack of research on how a teacher should teach learning strategies in lessons so that they can be effectively applied and students can discover them independently in the learning tools. Can the learning strategies instruction help students to develop better skills for comprehending mathematical texts?

## 3.    Research Questions

There are the following research questions: 1. How does the instruction of learning strategies affect the performance of the primary school students' mathematical texts comprehension? 2. To what extent are students' cognitive skills developed applying learning strategies?

## 4.    Purpose of the Study

The purpose of the present study, therefore, was to establish the efficiency of the instruction of learning strategies on mathematical texts' comprehension of the third grade primary school students' and to find out whether two factors – students' cognitive abilities and their socio-economic status affect  the performance of the mathematical texts' comprehension.

## 5.    Research Methods

### 5.1.  Methodological provisions

Experimental access to the research was selected for the research, combining quantitative and qualitative research methods. An educational experiment is the organization or reorganization of an educational process managed by a researcher, necessary and sufficient to "verify, substantiate or reveal the conditions of its application" (Rupšienė & Rutkienė, 2016, p. 20).

### 5.2.  Participants

An important feature of this experiment is that the study groups are not randomly selected. It is based on the recognition by researchers (Rupšienė & Rutkienė, 2016) that randomization in educational experiments is not necessary. As the student's population (the general population) is greater than 3000 cases, no simple or systematic, random sampling was used (Kardelis, 2007). 46 girls and boys were involved in the experimental group and 59 girls and boys were involved in the control group (aged 9–10 years). The participants of the experimental group were the 3rd grade students in a city school and in small town primary schools. The control group was formed in the same way.

### 5.3.  Data Collection

In this research, the independent variable was educational activity. The students' abilities and achievements were dependent variables. The educational experiment was conducted in the period of five months.

The first part of the process. At the beginning of the research, schools were asked for their consent to participate in the research. Having received the approval from the schools' authorities, the students' parents were contacted. The agreements to participate in the research were signed and collected. Then the researchers presented themselves to the students and explained the test tasks.

The second part of the process. The participants of the experimental and control groups carried out a diagnostic test (Lucid Recall, GB) and performed the task of mathematics word problem solving.

The third part of the process. The teaching program and the material were developed. A workshop on the concept, types and classification of learning strategies for teachers and teacher assistants in experimental classes was organized. The theory of the learning strategy and the stages of instruction how to use learning strategies were explained to the teachers as well.

The fourth part of the process. A plan for the insertion of learning strategies and their application in the experimental group were planned and aligned with the existing curricula. Together with the teachers it was discussed what learning strategies would be taught during the research period.

The fifth part of the process. The introduction of the methods to use learning strategy took place in real-life classes of experimental groups.

The sixth part of the process. The dependent variables were determined in all groups. The experimental and control groups performed a different version of the cognitive skills' diagnostic test (Lucid Recall, GB), and a new math task. Different didactic tasks for the research participants' ability to diagnose and tests of cognitive abilities were chosen.

The cognitive and neurocognitive research such as the Triple-Code Model of number processing (Dehaene & Cohen, 1997) relates spatial reasoning with the processing of numbers. So the spatial abilities are interconnected with the performance in mental arithmetic at the end of primary school, as Graß and Krammer (2018) hypothesize, and this relation is mediated by basic number processing. Computerized *Nonverbal Progressive Matrix Test* (*Lucid Recall*, GB, Lithuanian sample non-standardized) is a set of nonverbal tests investigating inductive thinking, working memory abilities and information processing speed based on Baddeley's theoretical model of working memory (St. Clair-Thompson, 2015). The test is suitable to assess non-verbal thinking functions of the persons aged 7–16: the ability to compare form, to think by analogy and to organize spatial information into a systemic whole. When solving tasks, the subject, having identified the relationship between the drawn stimuli represented by a matrix with $3 \times 3$ attributes, must identify and display the missing part of the drawing among the six alternative responses at the bottom of the drawing. The fact that tasks are arranged in an increasingly complex order allows them to be described as progressive (Gintilienė & Butkienė, 2005). The testing using software (*Lucid Recall*, GB) was conducted in the morning during lessons in the room designated by the school management. The test duration was 20-30 minutes. Respondents responses were programmatically analysed and compared by comparing study participants compliance with age-appropriate standards (according to the UK study, the test is not standardized in the Lithuanian sample).

Educational intervention followed a teaching model for learning strategies (according to Gibson, 2008; Tracy et al., 2009; De Smedt & Van Keer, 2018). The lessons of the experimental classes were monitored to ensure proper conditions for conducting the experiment. For example, in this study first mathematics lesson in the third class (an excerpt from the observation protocol) was organised by one of the teachers in experimental group in such a way:

*1. The teacher handed out the sheets with a black and white copy of the description of the strategy and asked the students to bend the sheet up till only the first paragraph was seen, as the first paragraph was the first step to learn. The teacher compared 5 steps of learning as 5 fingers. Students took turns reading aloud the unbent part and analysed the condition of the problem. After reading the task on the slide, they tried to find what was given in the condition, figured out what needed to be found and counted the units of measure.*

*2. The teacher announced that everyone would continue to read about the second step - anticipating the solution way, and that everyone should bend the sheet to the second paragraph, which describes the four ways to manage the solution way. The teacher led the students read the strategy description and underlined the verbs of the addition in red and the subtraction verbs in blue.*

*3. Students continued to read the questions and learn to anticipate what was to be found. The teacher told the students that often the second word after the question indicated what they would be looking for when solving the problem.*

*4. The teacher announced that they would continue reading about step three - the solution to the problem, and everyone had to bend to the third paragraph. The students in the second class already learnt the problem solving, so this part was the revision of their knowledge that the solution was written in terms of numbers and words.*

*5. The teacher announced that she would continue reading about step four - checking the solution, and everyone should bend to the fourth paragraph. The teacher advised to check if the solution did not contradict the condition by the reverse action: if we had to add - now subtract, if we had to subtract, now add up, if we had to multiply, now divide.*

*6. Students were invited to open the last paragraph - step five - writing the answer. This part was also a revision, as first class students learn how to write down their answer.*

*7. Students solved one problem independently looking at the handouts and the teacher helped some students. Students placed the handout behind the exercise-book cover folder for frequent viewing.*

Initial measurements were made in 2018, October. November marks the start of an intervention to teach students strategies for reading and mathematics word problems solving. Final measurements were made in 2019, March. Mathematics word problems solving tasks were selected from the 2016, 2017 standardized tests of grades 2 and 4. The mathematical word problem tasks were designed paying attention to what areas of cognitive competence the questions cover. The questions also cover all levels of learning: satisfactory, basic, advanced. Example of problem solving evaluation: *2 points for the task No.5:*

*1) $3 \times 10 = 30$ (sprouts); 2) $30 + 5 = 35$ (sprouts); Answer: 35 sprouts.* Alternatively: *$3 \times 10 + 5 = 35$ (sprouts); Answer: 35 sprouts.*

*2 points – for correct strategy and calculations without errors. If there is no naming, points are still awarded. If the strategy is correct but there are calculation errors, 1 point is given. If part of the solution is written ($30 + 5 = 35$), 1 point is given. If a correct answer is given without a solution - 1 point.*

Using the diagnostic standardized test evaluation methodology two experienced primary school teachers assessed the mathematical word problem tasks.

### 5.4. Data analysis

The collected data were analysed according to the experimental research scheme, comparing primary and final measurements in different groups. The quantitative data were analysed applying methods of descriptive statistics, multiple linear regression analysis, cluster analysis, correlation, and effect size calculations. The data were processed applying the IBM SPSS version 25.

### 5.5. Research ethics

The study adhered to the general ethical requirements of social research: legality of the study, clarity and disclosure of the study objectives, volunteering of the study, privacy and confidentiality of the study participants, avoiding deception and manipulation (Gaižauskaitė & Valavičienė, 2016).

In order to ensure the legitimacy of the study, the clarity of the research objectives and disclosure to participants and the principles of voluntary participation, schools were contacted with a request signed by the Dean of the KTU SHMM Faculty. Data were collected with the consent of the school management, student parents and students agreements.

## 6.   Findings

The difference between the pre- and post-test averages for the entire study sample ($n_1$) when comparing the intervention section and the comparison section indicates greater progress in the intervention section. However, the calculated effect size using a psychometric calculator shows that purposeful teaching of students to apply a learning strategy had virtually no effect. Next, a group of students was identified for whom the instruction and work with the learning strategy action algorithm might have influenced their progress. First of all, students who received the maximum possible assessment in the pre-test were eliminated from the entire sample. Next, the results of the *Lucid Recall*, GB test were used to eliminate a portion of the sample that was significantly distant from the typical cognitive abilities estimation (i.e., students with individual educational needs) and to form a redesigned study group - $n_2$. In this precise group, the effect size is weak but can be interpreted. In this group, the difference between the pre- and post-measurement averages indicates greater student progress in the intervention section.

**Table 01.** Descriptive statistics and effect size of study

| Column Heading | Intervention section | | M difference | Comparison section | | M difference | Effect Size Morris (2008) | Effect Size Klauer (2001) | Chi-square | p value |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | M(SD) | | n | M(SD) | | | | | |
| Pre-test (n1) | 42 | 0.60 (0.28) | 0,12↑ | 48 | 0.75 (0.27) | 0,07↑ | 0.159 | 0.138 | X2[df=7]= 11,484 | 0,12 |
| Post-test (n1) | 42 | 0.72 (0.25) | | 48 | 0.82 (0.27) | | | | X2[df=6]= 16,736 | 0,01 |
| Pre-test (n2) | 25 | 0,49 (0,25) | 0,23↑ | 22 | 0,64 (0,20) | 0,17 | 0,262 | 0,297 | X2[df=6]= 8,651 | 0,19 |
| Post-test (n2) | 25 | 0,72 (0,25) | | 22 | 0,81 (0,26) | | | | X2[df=6]= 8,599 | 0,20 |

$n_1$ – the entire study sample, $n_2$ – redesigned study group.

When it was found that the teaching of students to apply strategy in solving mathematics word problems had a weak effect, factors that are more powerful were searched. Multiple linear regression

analysis and correlation were applied to determine which factors influenced the progress of student achievement (see Table 02).

The results of multiple linear regression analysis and correlation confirm that purposeful teaching of students to apply a learning strategy is a factor that has very little effect. The mathematical literacy already acquired by the students, their learning achievements and their compliance with the typical assessment of cognitive abilities are much more influential.

**Table 02.** Data of regression analysis. Dependent variable – post-test measurement results (average of estimates)

| Predictors | $\beta$ | $t$ | $p$ | Pearson correlation coefficient | ANOVA | Adjusted $R^2$ |
|---|---|---|---|---|---|---|
| Pre-test measurement results (average of estimates) | 0,414 | 4,232 | 0,000 | 0,539** | | |
| Compliance with a typical cognitive aptitude estimate. | 0,276 | 2,876 | 0,005 | 0,433** | $F$ (3) =14,578 $p$=0.000 | 0,32 |
| Teaching to apply the learning strategy (Intervention) | 0,040 | 0,422 | 0,674 | 0,195 p=0.065 | | |

\*\**p*<0.01

K-means cluster analysis conducted to identify groupings of sample based on their pre-test and post-test results. The division of the respondent into three clusters is the most informative according to the dynamics (see Figure 01). The differences among groups (clusters) are statistically significant (ANOVA test, p = 0,000). Every cluster represents a group of students with its particular and different learning experience and changes during the period of the experiment. The whole sample was divided into clusters not differentiating into control or experimental groups (N=90; 26 cases (30 percent) were not involved). The differences among the determined types of students are contrasting enough.

Cluster 1 (N = 20 (22%; $N_I$: 13%; $N_C$: 9%) includes students with the lowest pre-test scores in the sample, but post-test scores show progress. Cluster 2 (N = 32 (36%; $N_I$: 18%; $N_C$: 18%)) includes students with relatively high pre-test scores but 6 months later progress has not been demonstrated.

Cluster 3 (N = 12 (22%; $N_I$: 8%; $N_C$: 6%)) includes students with lower post-test scores than pre-test ones. The even distribution of students from the intervention ($N_D$ and control ($N_C$) groups into clusters indicates that the presence or absence of progress cannot be directly attributed to the teaching of learning strategies or to the preparation of students to apply a strategy in solving mathematics word problems. This correlates with the results of regression analysis, which also showed that the learner's numeracy and correspondence with a typical level of cognitive ability had a strong influence on further learning.

Pennequin et al. (2010), Cornoldi, Carretti, Drusi and Tencati (2015) indicate that teaching metacognitive strategies is particularly influential to less successful students. Weaker learners acquire more

motivation to perceive the text better when a collaborative teaching and learning method is applied. Teaching reading strategies this way another important aspect of strategy teaching will be provided – a complex solution of the problems of reading motivation (Sičiūnienė & Toleikytė, 2017).
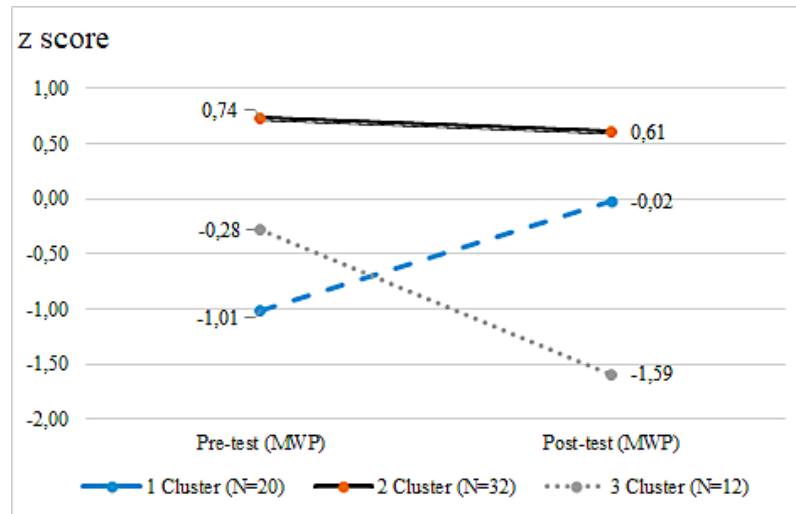


**Figure 01.** The graphical expression of K-means cluster analysis results

Researchers of this study agree with other studies findings (i.e. Star et al., 2016; Durkin, Star, & Rittle-Johnson, 2017), that the fact that study did not show significant improvement in student achievement shows that teachers need more didactic guidance. It is useful teaching students to solve math word problems strategies to compare multidimensional strategies. Next decision for our research would be to include into educational intervention such steps:

*(a) Regular and frequent comparisons of alternative strategies, in particular after some time when students succeeded in smoothly applying one initial strategy;*

*(b) Conscious choice of strategies and problems to compare;*

*(c) Carefully designed the visual presentation of multidimensional strategies;*

*(d) Using small group and whole class discussions to compare multiple strategies, focusing on approach similarities, differences, accessibility and limitations* (Durkin et al, 2017, p. 594).

Baten et al. (2017) state that meta-cognitive training stimulates children's early mathematical abilities. It considerably depends on the presentation of strategies, practical training in their application and constant discussion. In addition, the meta-cognitive knowledge and skills of primary school students should be enhanced through modelling, pedagogical support, reflection, suitable for the student feedback, assessments, advice and observation. Learning should progressively shift from guided to independent reading, increasing the degree of learning autonomy (Fuchs, et al., 2008; Sičiūnienė & Toleikytė, 2017).

This work has several limitations that are important to consider when interpreting the results. The fact that a teacher in one experimental class was a beginner and had less experience than an experienced educator in another might have influenced the results of the experiment. Experienced teachers are different

from beginners (Auerbach, Higgins, Brickman, & Andrews, 2018): experts are more likely to focus on student assessment and responsibility teaching, the students' difficulties with the subject matter, notice how students are asked to explain their understanding, how a teacher responds into students' reflections, on the scope for students to work independently and develop their own ideas.

## 7.   Conclusion

The results of the study revealed that purposeful teaching of students to apply a learning strategy is a factor that has very small effect. From the current study, we conclude that the different learning experiences and achievements of the students strongly influence the students' further progress. Those with higher achievements continue to progress, those with lower achievements lag behind. The research findings highlighted a group of students who, having mastered a typical learning strategy for solving a particular learning problem and / or to do a learning activity continued to do so independently and made progress.

The results of the research revealed three meaningful sample groups (clusters), which connect students with different learning experiences, achievements and learning opportunities. Each of these groups requires different teacher support, attention, and effort. A group that outperforms the sample, masters learning strategies faster, and is very likely to learn the strategies independently. This group requires more complex tasks and fewer typical tasks. That group does not add value to typical solution instructions and iterations. A group has emerged that needs more teacher support in learning and developing independent learning skills. This is the group that is harder to generate the possible solution on its own, the group that needs the coaching phase, for which it is very important to show the sequence of the learning strategy and monitor it until the learning strategy becomes a routine. This group, once mastered in learning strategies, is expected to achieve better learning results. The group that joins the smallest cluster is the group that needs the most pedagogical mastery and differentiated access. This group needs to be given extra time and individualized tasks to 'lead' it out of the wrong learning set and to progress.

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