The impact of the project-based learning method and the visual programming language Scratch on the achievements of preschool children in mastering arithmetic operations

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Abstract

The research aims to determine how the application of the project-based learning method affects the achievements of preschool children in mastering the arithmetic operations of addition and subtraction, as well as to determine the impact of the use of the visual programming language Scratch on the development of logical thinking and progress in learning. The experimental research was carried out with preschool children aged 6 years. In the research, 30 children participated. They were divided into two equal groups. The first group of children conventionally learned arithmetic operations, while the second group learned using the project-based method. After that, both groups

used the visual programming language Scratch to learn arithmetic operations. The Mann-Whitney U test was used to compare different methods of learning arithmetic operations and to determine the difference in achievement in mastering the arithmetic operations of addition and subtraction. The results show that the children of the experimental group, in which the project-based learning method was applied, showed a higher level of knowledge, especially after applying the visual programming language Scratch. Based on the obtained results, it can be concluded that the use of visual programming language in preschool education is an excellent supplement to the project-based learning method, as well as that it helps children to develop abilities such as creative and logical thinking and overall contributes to the progress of children in understanding arithmetic operations.
Keywords: addition; block-based programming; preschool education; project-based learning; subtraction.

Introduction

In the modern educational environment, the education of preschool children requires innovative and interactive methods to encourage their overall development. One such method is certainly the project-based learning method that allows children to explore and engage in meaningful situations, in which they creatively make connections between previous and new experiences. In the project, they explored together and learned from each other. Everyone contributes with their authentic experience. Different ways of children's participation in the project are valued as a valuable contribution to the learning community. All children, regardless of age, can participate in project-based learning. It gives them the power to learn and discover many things about themselves and the world around them. Children try to ask questions, make plans, and realize their ideas. Through project-based learning, they learn educational content and something much more important: they begin to understand themselves as human beings better. They connect with each other, with their preschool teachers and members of the broader community, in which they play an important role (Lev et al., 2022).

The project-based approach enables the creation of an atmosphere in which children's needs, wishes, and feelings are respected. Children feel comfortable and participate productively in the learning process. Positive emotions such as curiosity, enthusiasm, and joy encourage the learning process and make it more successful (Stojanović et al., 2021). A review of the literature dealing with the project-based

learning approach shows that this learning approach can be applied at all educational levels, including the preschool level (Katz & Chard, 2000; Rinaldi, 2006; Petrović & Hoti, 2020; Šarunić, 2023), and that it contributes to long-term academic and social development of children. When children learn through project-based activities, they remember content longer and better understand what they are learning (Beneke & Ostrosky, 2015; Harris-Helm & Katz, 2011).

The research results of one study (Rahman et al., 2010) showed that the project-based learning method is suitable for preschool age and can be applied at the beginning of the early childhood education program. At the beginning of the research, preschool teachers pointed out problems and challenges in implementing this approach. Their participation in the joint research project resulted in developing a more positive perception towards the use of the project-based approach and greater confidence in the implemented approach.

The authors (Farid & Rasyid, 2019) conducted research to investigate and evaluate the effect of using a project-based learning approach on improving the social development of children, as well as comparing this approach with a traditional approach. The results showed that project-based learning positively impacts children's social skills and improves cooperation among children. Based on the results of the project approach to learning, it was concluded that this is a meaningful approach for all educational levels because it provides an active process for children who work together and motivates them in the planned activity. Also, other studies highlight the benefits of project-based learning, such as the positive impact on the development of children's social skills, problem-solving, research, and interaction, and to promote cooperation among children (Beneke & Ostrosky, 2015; Sumarni et al., 2022).

As part of the research, the authors (Stojanović et al., 2023) examined the previous experiences and opinions of preschool teachers about the application of the project-based learning approach, with a special focus on the advantages and disadvantages in the process of realizing this model. The research was conducted in the central part of Republic of Serbia in preschool institutions in nine municipalities and cities. A total of 410 preschool teachers were surveyed. A questionnaire designed for the purposes of this research was used to collect data related to the opinion of preschool teachers on the implementation of the project-based learning approach. The findings showed that teachers in preschool institutions have a moderately positive attitude towards the benefits of project-based learning. Examinees agree with all statements from the questionnaire that refer to difficulties in implementing a project-based learning approach. Based on the obtained results, it can be concluded that it is necessary to continue working on improving the quality of the implementation

of the project-based learning approach, and this primarily refers to adequate training and motivation of preschool teachers for the application of this learning model.

Today, visual programming environments are a popular instrument for developing algorithmic and logical thinking. Visual programming languages are slowly but surely becoming a part of the educational system. They are the future of the educational process because of their positive characteristics that contribute to a better and more modern way of acquiring knowledge. The visual programming language most often used for educational purposes is Scratch. This visual programming language is increasingly the topic of research dealing with applying information and communication technologies (ICT) and programming languages in early education.

Examining the role of visual programming tools in the development of algorithmic thinking in six- and seven-year-old children is a research that aims to determine the attitude of children of preschool and younger school age towards programming using the two tools Scratch and Lightbot, taking into account the impact of programming on the development of algorithmic thinking. The general conclusion of this research shows that both groups of children had similar overall results and developed a positive attitude toward programming (Rose et al., 2017). Palmer (Palmer, 2017) researched the possibilities of applying programming in preschool education with a focus on learning mathematics. The research results indicate the exceptional potential of applying programming in teaching mathematics in educational work with children of preschool age (Palmer, 2017).

Based on the previously presented research results, it can be concluded that applying the project-based learning method, in most cases, positively affects achievements in early education. Therefore, it is necessary to conduct further research to encourage as many preschool institutions as possible to implement this approach in their educational work. For this purpose, the research within this paper aims to examine the impact of the application of the project-based learning method on the achievements of preschool children in mastering the arithmetic operations of addition and subtraction compared to the conventional method, as well as the impact of the application of the visual programming language Scratch on the development of logical thinking and children's progress in understanding arithmetic operations.

Research methods

At the beginning of the research, an initial test of children's knowledge of arithmetic operations, addition, and subtraction was conducted to determine their prior knowledge level. Based on the pre-test results, the children were divided into two equal groups with an equal level of knowledge, which ensured the conditions for the further performance of the pedagogical experiment. The first group was a control (I) group in which children learned arithmetic operations using a conventional learning method. The project-based learning method was applied in the experimental (II) group, based on the instructions from the Guide for Developing a Topic/project with Children: An Integrated Approach to Learning through Topics/projects following the Basics of the "Years of Ascension" program (Krnjaja & Pavlović Breneselović, 2022). After learning arithmetic operations using different learning methods, the visual programming language Scratch was applied in both groups. The research was conducted in the Preschool institution "Boško Buha" in Vrbas, Republic of Serbia. In the research, 30 children aged 6 years participated. There were 15 children in the control group and the same number in the experimental group. A research instrument was constructed for this research. It was used to check knowledge at the initial test. The pretest consists of 10 questions about adding numbers from 0 to 10, and 10 questions are used to check the knowledge of subtracting numbers from 0 to 10. The questions are designed to check the actual knowledge of arithmetic operations because they also include the feature of commutativity, as well as addition and subtraction with zero. The range of correct answers for each group of questions is from 0 to 10. After applying different learning methods, the same test was applied again to determine the children's achievements after learning arithmetic operations and to compare the effects of two different learning methods. After that, the visual programming language Scratch was used in both groups to determine the effect of visual programming language on the achievements of children who previously learned arithmetic operations by different learning methods. Given the sample size, the non-parametric Mann-Whitney U test was chosen to determine differences in children's achievement between the control and experimental groups. Differences were considered significant at $p<0.05$. The values of the achievements are presented in the form of median (25th percentile - 75th percentile).

Results and discussion

Table 1 gives descriptive statistics for the addition pre-test, and Table 2 shows descriptive statistics for the subtraction pre-test.

Table 1. Descriptive statistics for a pre-test of the addition operation

Group	N	Min	Max	Median
Control	15	0	7	1 (0−1)
Experimental	15	0	7	0 (0−1)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile−75-th percentile)

Table 2. Descriptive statistics for a pre-test of the subtraction operation

Group	N	Min	Max	Median
Control	15	0	2	0 (0−0)
Experimental	15	0	3	0 (0−0)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile−75-th percentile)

Table 3 shows the results of the Mann-Whitney U test. The results indicate that the obtained U values for the pre-test are not statistically significant at the $p<0.05$ level. Therefore, it can be concluded that there is no statistically significant difference in the results of the pre-test, i.e. the prior knowledge of arithmetic operations addition and subtraction between the group of children who will learn using the conventional (I) method and the group of children who will learn using the project-based (II) learning method.

Table 3. Results of Mann-Whitney U test for pre-test

	I		II		M-W U test	
	MR	N	MR	N	U	p
Addition	17.37	15	13.63	15	84.50	0.2543
Subtraction	14.93	15	16.07	15	104.00	0.7414

N-Number of children; MR-Mean Rank

The children were divided into two groups based on the pre-test results and the established prior knowledge. The first group learned arithmetic operations using the conventional learning method, while the second group learned using the project-based learning method. In each group, there were 15 children whose previous knowledge in the field of arithmetic operations was equal. Table 4 shows descriptive statistics for the test of addition. In Table 5, descriptive statistics for the test of subtraction are given.

Table 4. Descriptive statistics for the test of addition operation

Group	N	Min	Max	Median
Control	15	1	8	3 (1.5–4)
Experimental	15	3	8	5 (4–6)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile–75-th percentile)

Table 5. Descriptive statistics for the test of the subtraction operation

Group	N	Min	Max	Median
Control	15	0	3	1 (0–1)
Experimental	15	1	5	2 (1–3)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile–75-th percentile)

The Mann-Whitney U test was used to compare two different learning methods and determine the difference in achievement in mastering the arithmetic operations of addition and subtraction. The measure of success of preschool children in mastering addition and subtraction operations was the number of correct answers to the questions. The Mann-Whitney U test was performed using the SPSS software package. Below is the null hypothesis in the Mann-Whitney U test for the different tasks and groups being compared:

1. There is no statistically significant difference in achievement when applying the conventional (I) and project-based (II) methods of learning the arithmetic operation addition before using the visual programming language Scratch;

2. There is no statistically significant difference in achievement when applying the conventional (I) and project-based (II) methods of learning the arithmetic operation subtraction before using the visual programming language Scratch;
3. There is no statistically significant difference in achievement when applying the conventional (I) and project-based (II) methods of learning the arithmetic operation addition after using the visual programming language Scratch;
4. There is no statistically significant difference in achievement when applying the conventional (I) and project-based (II) methods of learning the arithmetic operation subtraction after using the visual programming language Scratch.

The Mann-Whitney U test was used to compare the effects of conventional (I) and project-based (II) methods on mastering the arithmetic operations of addition and subtraction before using the visual programming language Scratch. Table 6 shows the results of the Mann-Whitney U test obtained by comparing the conventional (I) and project-based (II) methods of learning arithmetic operations addition and subtraction. The values of the obtained U tests are statistically significant and indicate that the project-based (II) learning method has better effects (MR=19.63) compared to the conventional method (MR=11.37) on mastering the arithmetic operation addition ($U=50.50$, $p<0.05$). Also, it was shown that the values of the obtained U tests are statistically significant for the subtraction operation and indicate that the project-based (II) learning method has better effects (MR=20.20) compared to the conventional method (MR=10.80) on mastering the subtraction operation ($U=42.00$, $p<0.01$). Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted for both arithmetic operations.

Table 6. Results of Mann-Whitney U test before applying visual programming language Scratch

	I		II		M-W U test	
	MR	N	MR	N	U	p
Addition	11.37	15	19.63	15	50.50	0.0108
Subtraction	10.80	15	20.20	15	42.00	0.0037

N-Number of children; MR-Mean Rank

Table 7 gives descriptive statistics for the test of addition operation after using the visual programming language Scratch. Table 8 shows descriptive statistics for the test of subtraction operation after using the visual programming language Scratch.

Table 7. Descriptive statistics for the test of addition operation after using the visual programming language Scratch

Group	N	Min	Max	Median
Control	15	1	10	4 (3−6)
Experimental	15	15	10	6 (5−8.5)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile−75-th percentile)

Table 8. Descriptive statistics for the test of subtraction operation after using the visual programming language Scratch

Group	N	Min	Max	Median
Control	15	0	5	1 (0−2)
Experimental	15	2	10	4 (3−7)

N-Number of children; Min-Minimal number of correct answers;
Max-Maximal number of correct answers;
Median (25-th percentile−75-th percentile)

After using the visual programming language Scratch, the Mann-Whitney U test was also performed to compare the effects of the conventional (I) and project-based (II) learning methods on mastering the arithmetic operations of addition and subtraction. The results of the Mann-Whitney U test obtained by comparing the conventional (I) and project-based (II) methods of learning arithmetic operations addition and subtraction are shown in Table 9. The values of the obtained U tests are statistically significant and indicate that the project-based (II) learning method has better effects (MR=19.70) than the conventional method (MR=11.30) on mastering the arithmetic operation of addition ($U=49.50$, $p<0.01$). Also, it was shown that the values of the obtained U tests are statistically significant for the subtraction operation and indicate that the project-based (II) learning method has better effects (MR=21.57) compared to the conventional method (MR=9.43) on mastering the subtraction operation ($U=21.50$, $p<0.01$). Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted for both arithmetic operations.

Table 9. Results of Mann-Whitney U test after applying visual programming language Scratch

	I		II		M-W U test	
	MR	N	MR	N	U	p
Addition	11.30	15	19.70	15	49.50	0.0090
Subtraction	9.43	15	21.57	15	21.50	0.0002

N-Number of children; MR-Mean Rank

The visual programming language Scratch was used to determine the impact of visual programming languages on the achievements in mastering arithmetic operations, the development of logical thinking of children in both groups and the progress of children in understanding arithmetic operations. A Mann-Whitney U test was also performed to determine if there was a statistically significant difference in children's progress in mastering arithmetic operations after using the visual programming language Scratch in both groups. Below is the null hypothesis in the Mann-Whitney U test for the different tasks and groups being compared:

1. There is no statistically significant difference in the progress of children in mastering the arithmetic operation of addition after the use of the visual programming language Scratch in the group of children who previously learned using the conventional learning method;
2. There is no statistically significant difference in children's progress in mastering the arithmetic operation subtraction after the use of the visual programming language Scratch in the group of children who previously learned using the conventional learning method;
3. There is no statistically significant difference in children's progress in mastering the arithmetic operation addition after the use of the visual programming language Scratch in the group of children who previously learned using the project-based learning method;
4. There is no statistically significant difference in children's progress in mastering the arithmetic operation subtraction after using the visual programming language Scratch in the children who previously learned using the project-based learning method.

Table 10 shows the results of the Mann-Whitney U test obtained by comparing the research results before and after using the visual programming language Scratch in a group of children who previously learned arithmetic operations addition and subtraction using the conventional method. The results shown in Table 10 indicate

that the obtained U values are not statistically significant at the $p<0.05$ level. Therefore, it can be concluded that there is no statistically significant difference in children's progress after using the visual programming language Scratch. Therefore, the null hypothesis is accepted for both arithmetic operations.

Table 10. Results of Mann-Whitney U test before and after using the visual programming language Scratch (conventional method)

	I		II		M-W U test	
	MR	N	MR	N	U	p
Addition	12.87	15	18.13	15	73.00	0.1052
Subtraction	13.83	15	17.17	15	104.00	0.3077

N-Number of children; MR-Mean Rank

The results of the Mann-Whitney U test obtained by comparing the research results before and after the use of visual programming language Scratch in the group of children who previously learned arithmetic operations addition and subtraction using the project-based method are shown in Table 11. The values of the obtained U tests are statistically significant and indicate that the visual programming language Scratch affects children's progress in mastering the arithmetic operation addition ($U=49.00$, $p<0.01$) in the children who previously learned using the project-based method. Also, it was shown that the values of the obtained U tests are statistically significant for the subtraction operation ($U=39.50$, $p<0.01$). Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted for both arithmetic operations.

Table 11. Mann-Whitney U test before and after applying the visual programming language Scratch (project-based method)

	I		II		M-W U test	
	MR	N	MR	N	U	p
Addition	11.27	15	19.73	15	49.00	0.0091
Subtraction	10.63	15	20.37	15	39.50	0.0026

N-Number of children; MR-Mean Rank

In order to determine the practical significance of the obtained results, Cohen's coefficient d and Glass's coefficient δ were determined for both arithmetic operations. Table 12 shows the results obtained for both groups after using the visual pro-

gramming language Scratch, which shows that there is a practical significance of the established better effect of the project-based (II) method compared to the conventional (I) method on mastering the arithmetic operations of addition and subtraction.

Table 12. Cohen's and Glass's coefficient after using the visual programming language Scratch

	I		II			
	M	SD	M	SD	δ	d
Addition	4.67	2.41	6.93	1.91	0.94	1.04
Subtraction	1.47	1.41	5.07	2.74	2.55	1.65

M-Mean, SD-Standard deviation, δ - Glass's coefficient, d - Cohen's coefficient

Table 13. Cohen's and Glass's coefficient before and after using the visual programming language Scratch (project-based method)

	Before		After			
	M	SD	M	SD	δ	d
Addition	5.07	1.29	6.93	1.91	1.44	1.14
Subtraction	2.27	1.29	5.07	2.74	2.17	1.31

M-Mean, SD-Standard deviation, δ - Glass's coefficient, d - Cohen's coefficient

The results shown in Table 13 indicate that there is a practical importance of using the visual programming language Scratch to the progress of children in mastering the arithmetic operations of addition and subtraction and the development of logical thinking in the group of children who learned using the project-based method.

Conclusion

The obtained values of the U tests are statistically significant and indicate that the children from the experimental group in which the project-based learning method was applied showed better results, especially after applying the visual programming language Scratch. It was also shown that the results obtained were statistically and practically significant. Based on the obtained results, it can be concluded that applying the visual programming language Scratch in preschool educational work represents an exceptional supplement to the project-based learning method, as it helps children develop abilities such as creative and logical thinking, problem-solving, and continuous learning. Having in mind the positive effects of the application

of the project-based learning method, as well as the visual programming language on achievements in mastering arithmetic operations in early education, it is necessary to conduct further research and examine the impact of their application on the acquisition of knowledge from other fields, all to encourage the application of new methods and new technologies in the teaching process of an increasing number of preschool institutions.

References

Beneke, S. & Ostrosky, M. M. (2015). Effects of the project approach on preschoolers with diverse abilities. *Infants & Young Children*, *28*(4), 355-369.

Farida, N. & Rasyid, H. (2019). The effectiveness of project-based learning approach to social development of early childhood. *Proceedings of the Conference on Special and Inclusive Education (ICSIE 2018)* (pp. 369-372). Atlantis Press.

Harris-Helm, J. & Katz, L. (2011). *Young investigators the project approach in the early years* (2nd ed.). New York: Teachers College Press.

Katz, L. G. & Chard, S. C. (2000). *Engaging children's minds: The project approach*. Greenwood Publishing Group.

Lev, S., Klark, A. & Starki, E. (2022). *Projektno učenje za predškolski i mlađi školski uzrast [Implementing Project Based Learning in Early Childhood – Overcoming Misconceptions and Reaching Succes]*. Beograd: Clio; Jagodina: Fakultet pedagoških nauka Univerziteta u Kragujevcu.

Palmér, H. (2017). Programming in preschool – with a focus on learning mathematics. *International Research in Early Childhood Education*, *8*(1), 75-87.

Petrović, M. & Hoti, D. (2020). *Priručnik za projektnu nastavu i nastavu na daljinu*. Beograd: Zavod za unapređivanje vaspitanja i obrazovanja.

Rahman, S., Yasin, R. M. & Yassin, S. F. M. (2011). The implementation of project-based approach at preschool education program. *Procedia-Social and Behavioral Sciences*, 18, 476-480.

Rinaldi, C. (2006). *Reggio Emilia: Listening, researching and learning*. London: Routledge.

Rose, S., Habgood, J. & Jay, T. (2017). An Exploration of the Role of Visual Programming Tools in the Development of Young Children`s Computational Thinking. *Electronic Journal of e-Learning*, 15(4), 297-309.

Stojanović, B, Cirković-Miladinović, I. & Milovanović, R. (2021). The quality of communication in teaching and students' emotional reactions in the classroom. *Technium Social Sciences Journal*, 19, 55-66.

Stojanović, B., Ristanović, D., Živković, P. & Džaferović, M. (2023). Project-Based Learning in Early Childhood Education in Serbia: First Experiences of Preschool Teachers. *International Journal of Cognitive Research in Science, Engineering and Education*, *11*(2), 213-220.

Sumarni, S., Ilma, R. & Andika, W. D. (2022). Project-Based Learning (PBL) Based Lesson Study for Learning Community (LSLC) in Kindergarten. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, 6(2), 989-996.

Šarunić; D., Burić, M. & Milas, G. (2023). Evaluating the effects of project-based history learning on the interests, affinities, and knowledge of elementary school students. *Napredak*, *164*(3-4), 309-328.

Utjecaj projektne metode učenja i vizualnog programskog jezika Scratch na postignuća djece predškolske dobi u svladavanju računskih operacija

Sažetak

Cilj je istraživanja utvrditi kako primjena metode projektnog učenja utječe na postignuća djece predškolske dobi u svladavanju računskih operacija zbrajanja i oduzimanja, kao i utvrditi utjecaj korištenja vizualnog programskog jezika Scratch na razvoj logičkog mišljenja i napredak u učenju. Eksperimentalno istraživanje provedeno je s djecom predškolske dobi od 6 godina. U istraživanju je sudjelovalo 30 djece. Bili su podijeljeni u dvije jednake grupe. Prva skupina djece učila je računske operacije na konvencionalan način, dok je druga skupina djece učila projektno. Nakon toga obje su skupine koristile vizualni programski jezik Scratch za učenje aritmetičkih operacija. Mann-Whitneyjevim U testom uspoređene su različite metode učenja računskih operacija i utvrđena je razlika u postignućima u svladavanju računskih operacija zbrajanja i oduzimanja. Dobiveni rezultati pokazuju da su djeca eksperimentalne skupine, u kojoj je primijenjena projektna metoda učenja, pokazala višu razinu znanja, posebice nakon primjene vizualnog programskog jezika Scratch. Na temelju dobivenih rezultata može se zaključiti da je uporaba vizualnog programskog jezika u predškolskom odgoju i obrazovanju izvrsna nadopuna projektnoj metodi učenja, kao i da pomaže djeci u razvoju sposobnosti kao što su kreativno i logičko razmišljanje te općenito pridonosi napredovanju djece u razumijevanju računskih operacija.

Ključne riječi: blokovsko programiranje; oduzimanje; predškolski odgoj; projektno učenje; zbrajanje.