International Electronic Journal of Mathematics Education
2024, 19(3), em0779
e-ISSN: 1306-3030
https://www.iejme.com

MODESTUM

Research Article

OPEN ACCESS

The impact of early childhood education and mathematical abilities on student achievement: Analysis of TIMSS 2019

Naida Bikić [1*], Nevzudin Buzađija [2], Anela Hrnjičić [1]

[1] Department of Mathematics and Computer Science, Faculty of Philosophy, University of Zenica, Zenica, BOSNIA & HERZEGOVINA
[2] Department of Software engineering, Polytehnic Faculty, University of Zenica, Zenica, BOSNIA & HERZEGOVINA
***Corresponding Author:** naida.bikic@unze.ba

Citation: Bikić, N., Buzađija, N., & Hrnjičić, A. (2024). The impact of early childhood education and mathematical abilities on student achievement: Analysis of TIMSS 2019. *International Electronic Journal of Mathematics Education, 19*(3), em0779. https://doi.org/10.29333/iejme/14599

ARTICLE INFO

Received: 22 Dec. 2023

Accepted: 24 Apr. 2024

ABSTRACT

This paper is based on the analysis of the relationship between early education, mathematical skills, and student achievement in Bosnia & Herzegovina, using data from the trends in international mathematics and science study (TIMSS) 2019. The study involves 5,628 fourth-grade students whose average age was 10.1 years. The research specifically focuses on factors such as the age of students at the beginning of schooling, attendance at preschool institutions, and their mathematical skills before starting school. Through the application of SPSS analysis, insights into the statistical relationships and trends between these factors are provided, emphasizing the importance of early educational experiences to improve the quality of education in Bosnia & Herzegovina. The analysis results show that the length of stay in preschool institutions, attendance in preschool programs, and the early acquisition of mathematical skills (counting skills, recognition of numeral representations, numeral writing, simple addition, and subtraction) impact later mathematical achievements of students.

Keywords: mathematical achievements, mathematical skills, early education, TIMSS 2019, beginning of schooling, preschool programs

INTRODUCTION

Competencies in mathematics and science are crucial for economic and individual success, as they predict a country's competitiveness in socially and economically prestigious occupations. Therefore, it is important to examine the factors influencing the development of these competencies from preschool age onwards. Examining mathematical knowledge, skills, and achievements is a complex process as it requires reliable and valid measurement tools. In this regard, well-designed assessment tools approved by leading international education research organizations play a crucial role. The trends in international mathematics and science study (TIMSS) are an international assessment program for students' mathematics and science knowledge. It monitors trends in student achievements and teaching in fourth and eighth grade primary schools. TIMSS 2019 study is the seventh cycle of the international student assessment, organized by the International Association for the Evaluation of Educational Achievement (IEA). IEA and Organization for Economic Co-operation and Development (OECD) conduct research in participating countries. The survey also includes questionnaires for students, parents, teachers, and school principals, aiming to improve student achievement.

The performance of students in mathematics in Bosnia & Herzegovina is poor and concerning. The Agency for Pre-Primary, Primary, and Secondary Education in Bosnia & Herzegovina (APOSO) is involved in international studies in education. Bosnia & Herzegovina first participated in TIMSS study in 2007, conducted by APOSO during which it did not achieve high results. In the 2007 study, 4,300 students from 150 final-grade schools participated. According to the results, Bosnia & Herzegovina ranked 27th out of a total of 50 countries, with the average score lower than the international average.

APOSO (2015, 2020) continues to participate in international studies, such as TIMSS 2019 study, to improve education in the country. TIMSS 2019 survey for the fourth grade included 56 nations and 6 benchmarking participants, including Bosnia & Herzegovina. All Western Balkan countries have taken part. The results have shown that the country falls short of OECD average of 500 in mathematical achievements, with a score of 452 in TIMSS 2019 test, which falls between the intermediate international level (475 points) and the basic level (400 points). Compared to other countries in the Western Balkans, Bosnia & Herzegovina ranks at the lower end of the scale. Croatia achieved the best results in mathematics in the region with 509.50 points, which is significantly above the average for Bosnia & Herzegovina. Serbia also achieved a high score of 507.88 points, while Montenegro and North Macedonia scored 452.78 and 471.72 points, respectively, which is very close to the average score for Bosnia &

Herzegovina. These highlights need for further education system improvement to achieve competitiveness and compliance with international norms.

Numerous studies have confirmed that participation in quality early childhood education and care institutions positively influences students' achievements as well as various other areas of development (Lowe Vandell et al., 2010; Schweinhart et al., 2005; Sylva et al., 2008). Mullis and Martin (2017) also highlight a positive correlation between students' achievements and the duration of attendance in early childhood education and care programs, which is supported by a series of previous TIMSS cycles. Students' achievements in mathematics at the international level are higher the longer they have attended early childhood education and care (Mullis et al., 2020). Additionally, students' achievements in mathematics at the international level are higher when students more frequently engage in early literacy and mathematical literacy activities with their parents (Mullis et al., 2020).

One of the important recommendations of APOSO after analyzing TIMSS 2019 is the need to increase the coverage of preschool care and education at early ages, with a particular focus on the age of three years. In this regard, the aim of this study is to investigate how different early education factors affect mathematics attainment among students using findings from TIMSS 2019. This research includes factors such as age at school start, attendance at preschool establishments, and specific mathematical skills and demonstrate their impact on students' mathematics achievements. The goal is to find any links between these factors and mathematics results, and to determine which traits have the biggest effect on academic success.

It is critical to underline that test findings not only reflect the current state of affairs, but also provide suggestions for improvement. Bosnia & Herzegovina can improve its education system and students' mathematics skills by evaluating factors that influence performance and following best practices from other nations. Newer cycles of large-scale assessment studies, such as IEA studies, have demonstrated that early learning activities can help lay the groundwork for positive educational outcomes in the future (Meinck et al., 2018). TIMSS 2011 study for European Union (EU) countries found that early mathematical competencies are linked to later success in mathematics (Soto-Calvo & Sánchez-Barrioluengo, 2016).

THEORETICAL BACKGROUND

About Preschool Education in Bosnia & Herzegovina

Bosnia & Herzegovina's educational system is inextricably linked to the state's organizational framework, as described in its constitutions. The education sector coordinates with 14 ministries of education distributed across various levels of governance, including entity levels (Federation of Bosnia & Herzegovina/FB&H and Republic of Srpska/RS), Brčko District, cantons within FB&H, and the Ministry of Civil Affairs at the state level.

In Bosnia & Herzegovina, compulsory primary education lasts nine years, with certain districts including mandatory preschool education in the year preceding grade 1. Children often begin elementary school at the age of six.

Strategic directions for the development of preschool education (Ministry of Civil Affairs of Bosnia & Herzegovina, 2004) in Bosnia & Herzegovina were agreed by the Bosnia & Herzegovina Council of Ministers in 2005, with the implementation deadline set for the end of 2010. During its 16th session of the House of Representatives on October 11 and 30, 2007, and its 9th session of the House of Peoples on October 29, 2007, the Parliamentary Assembly strengthened the educational framework by supporting the Framework Law on Preschool Education in Bosnia & Herzegovina. This act, which includes Article 16[1], specifies the mandatory enrollment term for preschool education (Parliamentary Assembly of Bosnia & Herzegovina, 2007).

Platform for the development of preschool education (Ministry of Civil Affairs of Bosnia & Herzegovina, 2016) was crafted by a working group comprising representatives from the Ministry of Civil Affairs of Bosnia & Herzegovina, entity and cantonal ministries of education, the relevant department of the Government of the Brčko District, and APOSO. This strategic document on the development of preschool education serves as a guide for the competent educational authorities, aligning their policies with the objectives of EU and the United Nations in this domain. It not only reflects the aspiration for EU integration but, more importantly, serves as a foundational basis for formulating local strategies, plans, and other measures aimed at fostering the development of preschool education, ensuring optimal conditions for self-driven progress.

Given that Bosnia & Herzegovina achieve below-average results in international assessments, it is important to examine whether attending preschool education has an impact on student achievement. For Bosnia & Herzegovina, it is crucial to observe the influence of early childhood education on the achievements of students of the same age as in neighboring countries, which have similar school education programs. An analysis of TIMSS 2019 by the National Center for External Evaluation of Education for the Republic of Croatia shows that students who attended early childhood education programs achieve better results, with a trend of increasing achievements the longer they attended such programs. It was found that the highest achievements in mathematics (509) are attained by students who attended early childhood education for three or more years, followed by students who attended for two years (495), and one year or less (483) (National Center for External Evaluation of Education, 2019). The lowest achievements in mathematics (464) are recorded by students who did not attend any early childhood education programs at all. In TIMSS 2019 analysis for Serbia (Institute for Educational Research, 2021), it was shown that the better students mastered tasks related to language and numerical literacy before starting school, and the longer they attended preschool education, the higher their mathematics achievement was.

[1]Article 16 (Mandatory Enrollment Time for Children in Preschool Education) (1) In the year prior to enrollment in elementary school, preschool education is mandatory for all children of preschool age. (2) The conditions and methods of financing, programs, and the duration of preschool education are regulated by the competent educational authorities through the relevant law.

Table 1. Research hypothesis

Hypothesis	Null hypothesis (H_0)	Alternative hypothesis (H_i)
Total variation	Total variation in students' achievement is not statistically significantly associated with analyzed variables.	Total variation in students' achievement is statistically significantly associated with analyzed variables.
Individual variables	None of analyzed variables has a statistically significant impact on student achievement.	At least one of analyzed variables has a statistically significant impact on student achievement.

Early Childhood Education & Mathematical Skills

The National Association for the Education of Young Children (NAEYC) deems the early childhood education stage crucial in fostering the early development of mathematical competencies, particularly for students facing potential challenges (Cebolla Boado, 2011, 2012; Garrido & Cebolla Boado, 2010; Hindman, 2013). Early childhood mathematics education refers to the education of children aged three to six years (NAEYC, 2010), which is significant for children (Clements et al., 2013). The experiences of a child at an early age are crucial as they can contribute to the development of a formal sense of number, counting, and fundamental arithmetic operations (Sharma, 2001).

Pre-mathematical and mathematical experiences and knowledge begin to be acquired from a very early age. According to the curriculum for early and preschool education (B&H, 2021), early age encompasses children from birth to the end of the third year and by the age of six, it is preschool education. In this curriculum, defined areas with learning and development outcomes, along with corresponding indicators, are included. These domains are designed to cultivate essential competencies for lifelong learning. Early mathematical literacy constitutes a component of the "world around us" domain, focusing on logical-mathematical knowledge associated with recognizing quantitative relationships in the immediate environment and fostering foundational mathematical concepts. It encompasses mathematical areas such as simple manipulation of objects, logical operations on concrete items, set operations, perception and proper naming of space and spatial orientation, observation and differentiation of geometric shapes and object properties, and the formation of the concept of number and measurement activities.

Several sources have examined the correlation between attendance in early childhood education and subsequent performance in later stages (Arteaga et al., 2014; Hindman, 2013; Lehrl et al., 2016; Sylva et al., 2013; Temple & Reynolds, 2015). Some writers link struggles with mathematical competencies to the pre-acquisition of early numeracy skills (Jordan et al., 2010). Early proficiency in mathematical skills is also regarded as a strong predictor of later performance in mathematics (Grissmer et al., 2013; Jordan et al., 2010; Mazzocco & Thompson, 2005; Taskin & Tugrul, 2014). Additionally, previous research has shown that early academic skills and socio-emotional behavior are linked to later academic achievement as they provide a foundation for positive adaptation in the classroom (Cunha et al., 2006; Entwisle et al., 2005). La Paro and Pianta (2000) discovered moderate correlations in cognitive and academic skills, with coefficients of .43 during the transition from preschool to kindergarten and .48 during the transition from kindergarten to first or second grade. An early educational intervention has been shown to lead to lasting decreases in the utilization of special education services, grade retention, and an improvement in educational achievement over the long term. (Campbell et al., 2002; Lazar et al., 1982; Reynolds & Temple, 1998). According to the developmental theory, children's informal, intuitive understanding of early language and mathematical concepts significantly contributes to the acquisition of more advanced skills formally taught during elementary school (Adams et al., 1998; Baroody, 2003; Griffin et al., 1995; Tunmer & Nesdale, 1985).

In previous TIMSS research cycles, a strong positive correlation has been found between early literacy and mathematical literacy activities with parents or other household members before starting school and students' mathematics achievement (Mullis & Martin, 2017; Mullis et al., 2012a, 2012b, 2016a, 2016b).

METHODOLOGY

Research Design

The following are the research objectives.

1. **Identifying achievement discrepancies:** Determine whether there are substantial variations in mathematical achievement between students who began school earlier and those who began later.
2. **Investigating the effects of preschool education:** Determine if students who attended preschool institutions performed better in mathematics than those who did not and discover particular benefits of preschool attendance for subsequent mathematics achievement.
3. **Identifying essential mathematical talents:** Determine which of the listed mathematical skills is most associated with mathematical achievement and whether these abilities can predict future mathematical outcomes of students.
4. Investigating how the combination of factors, such as students' age at school entry, attendance at preschool institutions, and specific mathematical abilities, influences mathematics achievement and identify potential interactions between these factors that further impact mathematics achievement.

From these goals and research tasks, the hypotheses are derived and presented in **Table 1**.

In this paper, we have formulated several sub-hypotheses for the variables under analysis. These sub-hypotheses are crucial for establishing clear frameworks that facilitate the analysis and interpretation of our research results, and they are presented in **Table 2**.

Table 2. Research sub-hypothesis

Variable	Null hypothesis (H_0)	Alternative hypothesis (H_i)
Skills/count by him/herself	Ability to count by oneself does not have a statistically significant impact on student achievement.	Ability to count by oneself has a statistically significant impact on student achievement.
Skills/recognition written numeral	Recognition of written numerals does not have a statistically significant impact on student achievement.	Recognition of written numerals has a statistically significant impact on student achievement.
Skills/write numbers	Writing numbers does not have a statistically significant impact on student achievement.	Writing numbers has a statistically significant impact on student achievement.
Skills/simple addition	Knowledge of simple addition does not have a statistically significant impact on student achievement.	Knowledge of simple addition has a statistically significant impact on student achievement.
Skills/simple subtraction	Knowledge of simple subtraction does not have a statistically significant impact on student achievement.	Knowledge of simple subtraction has a statistically significant impact on student achievement.
Attended/early childhood education	Attendance in early childhood education does not have a statistically significant impact on student achievement.	Attendance in early childhood education has a statistically significant impact on student achievement.
Attended/pre-primary education	Attendance in pre-primary education does not have a statistically significant impact on student achievement.	Attendance in pre-primary education has a statistically significant impact on student achievement.
Age of child beginning school	Age of the child at beginning of school does not have a statistically significant impact on student achievement.	Age of the child at beginning of school has a statistically significant impact on student achievement.

Table 3. Variables form ELS used to describe students' education skills

Variable code	Variable description		
ASBH04AA	Did your child attend an early childhood educational program or center for children under age 3 before first grade? (yes & no)		
ASBH04AB	Did your child attend pre-primary educational program for children aged 3 or older, including kindergarten? (yes & no)		
ASBH04B	Approximately, how long was your child in these programs altogether? (did not attend, less than 1 year, 1 year, 2 years, 3 years, & 4 years or more)		
ASBH05	How old was your child when he/she began the first grade of primary/elementary school? (5 years old or younger, 6 years old, 7 years old, & 8 years old or older)		
ASBH07A	Could your child do following when he/she began first grade of primary/elementary school?	Count by himself/herself	Not at all, up to 10, up to 20, & up to 100 & higher
ASBH07B		Recognize written numbers	
ASBH07C		Write numbers	
ASBH07D		Do simple addition	Yes & no
ASBH07E		Do simple subtraction	

Participants

In TIMSS 2019 cycle, 5,628 fourth-grade students from primary schools participated (2,876 boys, 51.00%, and 2,752 girls, 49.00%), with an average age ranging from 9.5 to 10.5 years, from 336 classrooms in 178 primary schools in Bosnia & Herzegovina. The average age of the students was 10.1 years. Students with more severe developmental difficulties who could not independently respond to questions were not included in the study. Each school received instructions for their educational services to assess which students could not meet the testing requirements and, accordingly, inform parents. Parents of all participating students signed statements confirming their awareness of TIMSS 2019 research and agreeing to the use of their child's data for the specified study. Data obtained through responses from school directors, teachers, parents, or legal guardians of students participating in TIMSS are collected and stored in a pre-regulated manner. This information cannot be used to identify individual respondents by name, and TIMSS data are secure and inaccessible to any external individuals or systems.

Instruments

TIMSS 2019 survey took place in Bosnia & Herzegovina from May 20 to June 13, 2019. Two types of instruments were used in TIMSS 2019 research: questionnaires and 14 test booklets containing questions from mathematics and science. Each task examines one of three cognitive domains: factual knowledge, application of knowledge, or reasoning (synthesis and evaluation). The test booklets and all TIMSS materials for the research process were translated into all three official languages in Bosnia & Herzegovina. Students completed the test booklets and questionnaires in the language of instruction and curriculum in their respective environments. All international standards were adhered to, and all procedures were conducted within the specified time intervals. In addition to the test booklets, TIMSS research also applies questionnaires for students, parents, teachers, and school directors. For the purposes of this study, we utilized the early learning survey (ELS) questionnaire. ELS was filled out by the parents of the children who took part. The survey sought information about the kid's early learning experiences, as well as insights into the activities shared between the child and the parent, as well as comments about various aspects of the child's school. It was made clear that there were no right or wrong answers, emphasizing the importance of the information gathered in understanding the learning processes of young infants.

Variables of Investigation

The following variables from the questionnaire ELS were considered, presented in **Table 3**.

The variables listed in **Table 3** are independent variables, and the dependent variable consists of students' achievements in mathematics, represented by plausible values from one to five.

Table 4. Years of attendance of preschool institution

Number of years	Percentage (number of cases)	Mathematics achievement (mean)
Not attended	18.63	445.59
Less than one year	37.51	447.09
One year	13.03	447.60
Two years	7.64	463.61
Three years	12.34	477.99
Four years or more	10.86	467.40

Table 5. Attendance of preschool education programs

Preschool program	Attended	Percentage (number of cases)	Mathematics achievement (mean)
Early childhood education	YES	21.24	459.11
	NO	78.76	454.87
Pre-primary education	YES	81.28	455.60
	NO	18.72	447.06

Table 6. Mathematical skills before starting school

Answer	Counting by him/herself		Recognized written numeral		Write numbers	
	Percentage	Mathematics achievement	Percentage	Mathematics achievement	Percentage	Mathematics achievement
Not at all	4.29	416.15	8.01	430.44	8.73	429.92
Up to 10	25.78	426.80	33.81	437.79	37.46	442.60
Up to 20	40.88	452.11	36.54	455.74	34.95	457.49
Up to 100+	29.05	481.42	21.64	484.13	18.86	479.68

Table 7. Simple addition & subtraction before starting school

Operation	Attended	Percentage (number of cases)	Mathematics achievement (mean)
Simple addition	YES	72.27	462.31
	NO	27.73	427.93
Simple subtraction	YES	63.84	464.00
	NO	36.16	434.87

RESULTS

We used SPSS 25 software and IDB Analyzer for data processing. In this research, special attention is dedicated to analyzing responses related to the duration of children's participation in preschool education before formal education in Bosnia & Herzegovina. Through an examination of these dynamics, we also explore the prevalence of children attending preschool institutions in this region. Our aim is to assess the impact of this practice on their academic achievements, particularly in the field of mathematics. The results of this comprehensive analysis, including an exploration of the frequency of enrolment in preschool institutions in Bosnia & Herzegovina, are clearly presented in **Table 4**, as well as the average mathematics achievements across these categories.

It is surprising to find that more than 50.00% of students in Bosnia & Herzegovina either did not attend preschool institutions or did so for less than a year. What is not surprising is that these students achieved lower results in mathematics.

We investigated the impact of attending early childhood education programs and preschool programs on mathematical achievements. The results presented in **Table 5** indicate that students who attended preschool education programs achieve, on average, higher results in mathematics compared to those who did not participate in such programs.

The continuation of the analysis will involve a deeper examination of the data to enhance our understanding of the dynamics of the impact of preschool programs on various aspects of student achievements. A focus in this study is placed on analyzing students' mathematical abilities before they start first grade of school. This specifically pertains to their counting skills, recognition of numeral representations, and numeral writing, as illustrated in **Table 6**.

From **Table 6**, it can be inferred that there is a positive correlation between the increase in children's mathematical skills and their mathematical performance. For instance, as children progress in their counting, recognizing written numerals, and writing numbers from "not at all" to "up to 100+", a gradual improvement in mathematics achievements is observed.

We also aimed to examine the extent to which the tested students possessed the skills to perform the simplest addition and subtraction operations before starting school. Additionally, we investigated whether these abilities had an impact on their later achievements. These results have been comprehensively presented in **Table 7**.

It can be concluded from **Table 7** that children who could perform simple addition and simple subtraction before starting school achieve, on average, better results in mathematics compared to children who did not possess these skills.

Table 8 illustrates the distribution of students across different age groups at the commencement of their schooling. Many children (80.82%) start school at the age of six, with an associated mean mathematics achievement score of 453.04. A smaller percentage begins school at ages five or younger (3.98%), seven years (14.95%), and a minimal percentage starts at eight years or older (0.25%), with varying mean mathematics achievement scores for each group.

Table 8. Age of child beginning school

Age	Percentage (number of cases)	Mathematics achievement (mean)
Five years or younger	3.98	447.21
Six years	80.82	453.04
Seven years	14.95	451.09
Eight years or older	0.25	351.22

Table 9. Model summary

Model	R	R square	Adjusted R square	Standard error of estimate
1	.397[a]	.158	.155	64.260

Note. [a]Predictors: (Constant); GEN\SKILLS\SIMPLE SUBTRACTION; GEN\AGE OF CHILD BEGINNING SCHOOL; GEN\ATTEND\EARLY CHILDHOOD EDUCATION; GEN\ATTEND\PRE PRIMARY EDUCATION; GEN\SKILLS\COUNT BY HIM/HERSELF; GEN\SKILLS\WRITE NUMBERS; GEN\SKILLS\SIMPLE ADDITION; GEN\HOW LONG ATTENDED PROGRAMS; & GEN\SKILLS\RECOG WRITTEN NUMERAL

Table 10. Fisher's test

Model		Sum of squares	df	Mean square	F	Significance
1	Regression	2,356,516.19	9	261,835.13	63.410	0.000[b]
	Residual	12,582,271.99	3,047	4,129.40		
	Total	14,938,788.18	3,056			

Note. [a]Dependent variable: Mathematics achievement & [b]Predictors: (Constant); GEN\SKILLS\SIMPLE SUBTRACTION; GEN\AGE OF CHILD BEGINNING SCHOOL; GEN\ATTEND\EARLY CHILDHOOD EDUCATION; GEN\ATTEND\PRE PRIMARY EDUCATION; GEN\SKILLS\COUNT BY HIM/HERSELF; GEN\SKILLS\WRITE NUMBERS; GEN\SKILLS\SIMPLE ADDITION; GEN\HOW LONG ATTENDED PROGRAMS; & GEN\SKILLS\RECOG WRITTEN NUMERAL

To substantiate the first hypothesis, we used regression analysis to investigate the potential correlation between selected independent variables and the dependent variable, with the goal of quantifying the role of these factors in explaining the variability in students' mathematics achievement. We used regression analysis to look at all independent variables listed in **Table 3** to see how well our model predicts changes in the dependent variable.

The regression model identifies the factors that explain the collective significance of the observed variables on the achieved outcomes. The results of the regression analysis show that the value of the regression factor is R=39.70%, and the R square shows that the treated variables explain 15.80% of the impact on the total mathematics results from the first to the fifth plausible values. From a global perspective, it is evident that an explanation of 15.80% of the impact is not negligible, serving as a robust indicator that results could be improved through a proper approach to defining early education. **Table 9** shows model summary.

To investigate the impact of the analyzed variables on student achievement, we conducted an ANOVA analysis, utilizing the Fisher's test (**Table 10**). The results of this analysis clearly indicate a statistically significant influence of the analyzed factors on student mathematics achievement (p-value<0.05). F-value of 63.408 further confirms the statistical significance of the impact, suggesting that the differences between groups are not due to chance but rather to systematically relevant factors associated with student achievement.

In the continuation of the study, we aimed to identify which of the analyzed variables had a statistically significant impact on student achievement, i.e., which could be considered predictors of academic success.

In **Table 11** are results of multiple regression analysis designed to identify potential predictors or factors that may significantly impact the dependent variable, in this case, student mathematical achievement (dependent variable: mathematics achievement). Each variable listed in the model represents a potential predictor, and the corresponding coefficients indicate the strength and direction of their influence on student success in math. These variables are described in **Table 3**.

The results in **Table 11** provide information about the beta coefficient, i.e., the standardized regression coefficient, whose magnitude indicates the extent to which each of the predictor variables determines the criterion or dependent variable. For variables ASBH04AA, ASBH04AB, ASBH04B, ASBH07A, ASBH07B, ASBH07C, ASBH07D, Sig.<0.05, indicating that they have a statistically significant impact on the achieved results in mathematics. Variables ASBH05 and ASBH07E have Sig.>0.05, indicating that these predictor variables do not have a statistically significant impact on the achieved results. The practical significance of regression analysis lies in identifying the key factors that account for 15.80% of the variability in the achieved results. The key factors are "age of child beginning school" and "simple subtraction." These two pivotal factors should be utilized in future early education development strategies to enhance the quality of early education and to reach as many children as possible, encouraging them to engage in logical thinking when solving basic mathematical problems.

DISCUSSION

Given the crucial role that preschool institutions (kindergartens) play in the development of a child's pre-mathematical skills, we explored whether the duration of a child's attendance in preschool institutions influences their achievements in mathematics. The results indicated that students who attended preschool for more than one year achieved better results than those who either did not attend preschool at all or attended it for less than a year. Thus, a positive correlation has been confirmed between

Table 11. Standardized regression coefficients

Model		Unstandardized coefficients		Standardized coefficients	T	Significance
		B	Standard error	Beta		
1	(Constant)	363.282	15.217		23.873	0.000
	GEN\ATTEND\PRE PRIMARY EDUCATION	8.473	3.522	0.053	2.406	0.016
	GEN\ATTEND\EARLY CHILDHOOD EDUCATION	16.612	4.025	0.095	4.127	0.000
	GEN\HOW LONG ATTENDED PROGRAMS	9.338	1.124	0.237	8.307	0.000
	GEN\AGE OF CHILD BEGINNING SCHOOL	-2.111	2.770	-0.013	-0.762	**0.446**
	GEN\SKILLS\COUNT BY HIM-/HERSELF	18.629	2.035	0.221	9.156	0.000
	GEN\SKILLS\RECOG WRITTEN NUMERAL	9.216	2.516	0.118	3.663	0.000
	GEN\SKILLS\WRITE NUMBERS	-5.610	2.436	-0.072	-2.303	0.021
	GEN\SKILLS\SIMPLE ADDITION	-24.054	4.353	-0.156	-5.525	0.000
	GEN\SKILLS\SIMPLE SUBTRACTION	-0.710	4.079	-0.005	-0.174	**0.862**

Note. [a]Dependent variable: Mathematics achievement

students' achievements and the duration of attendance in early childhood education and care programs, as well as across a series of previous TIMSS cycles (Mullis et al., 2012a, 2012b, 2016a, 2016b).

Regarding preschool education programs, we differentiate between early childhood education and pre-primary education. Our results show that the difference in achievements among children from early childhood programs proved to be smaller compared to programs involving older children, aged three and above. Children who attended these programs achieved better results than those who did not.

As previous studies (Grissmer et al., 2013; Jordan et al., 2010; Mazzocco & Thompson, 2005; Taskin & Tugrul, 2014) have shown that early acquisition of mathematical skills is considered a strong predictor of later achievements in mathematics, we examined whether developed abilities such as counting skills, recognition of numeral representations, and numeral writing have an impact on achievements. Children who can count independently, recognize written numerals, and write numbers tend to achieve better results in mathematics compared to those who lack or have less developed these skills. The obtained data are consistent with previous TIMSS research cycles, where a strong positive correlation was found between the success in performing early mathematical literacy tasks at the beginning of the first grade of primary school and students' mathematics achievement (Mullis & Martin, 2017; Mullis et al., 2012a, 2012b, 2016a, 2016b).When it comes to mathematical abilities like simple addition and subtraction, we observed that students who had developed these skills achieved better results. However, simple subtraction does not have a statistically significant impact on the outcomes. Since subtraction is the inverse operation of addition, children may use addition as the primary method for solving subtraction problems. This could result in the performance of subtraction not showing a significant influence, as the same mental processes are applied through the addition operation.

Regarding the age at which children start school in Bosnia & Herzegovina, the majority of children (80.82%) begin school at the age of 6. Based on the test achievements, we see that these students achieved the best results, with a mean mathematics achievement score of 453.04. Therefore, we can conclude that our analysis justifies children starting school at the age of 6 and that it has a positive impact on their mathematics achievements.

Based on regression analysis presented in **Table 9**, in relation to the number of variables included in TIMSS testing, the first hypothesis was confirmed. The total variation in students' achievement is statistically significantly associated with the analyzed variables. Based on the ANOVA analysis, our findings support our second hypothesis, asserting that some of the analyzed variables have a statistically significant impact on student achievement.

The results presented in **Table 11** show that a child attending an early childhood educational program or center before the first grade has a statistically significant impact on the achieved results in mathematics. Another variable with a statistically significant impact on the outcomes is whether the child attended a pre-primary educational program, including Kindergarten, at the age of three or older. These considerations indicate that many of the observed dependent variables influence students' mathematical achievements.

Thus, our results are consistent with previous TIMSS research cycles and TIMSS analyses of neighboring countries, where a strong positive correlation was found between attending early childhood education and care programs and students' mathematics achievement.

CONCLUSIONS

This research provides a deeper insight into the educational landscape of the region, emphasizing the significance of preschool education in the context of children's subsequent mathematical success. The analysis suggests the possibility of a positive impact of preschool programs on achievements. The results show that students who attended a preschool institution for more than one year, at the age of less than three and more than three years, and who developed the ability through preschool programs: independent counting, recognition of numeral representations, and numeral writing, as well as simple addition and subtraction, achieved better results in TIMSS. Therefore, early childhood education and developed mathematical skills influence the mathematical achievements of students in Bosnia & Herzegovina. It is important to emphasize that the length of stay in preschool institutions has an impact on students' achievements because they are exposed for a longer period to the expert presentation of mathematical concepts through the early childhood education curriculum.

Our analysis highlights the importance of early education and attendance in preschool institutions, regardless of the student's age, as they acquire fundamental mathematical skills and stimulate the desire to learn. Our results support the recommendation of APOSO, which suggests an increase in the number of children covered by early childhood care and education, with a focus on children from the age of three. These findings encourage further reflection on the importance of integrating preschool programs into the educational process, with a particular emphasis on the early years of a child's development and their preparation for later academic challenges.

The results of this research are important because they reveal significant predictors of mathematical achievements of the 4th grade elementary school students. Efforts invested in improving the factors that influence students' mathematical achievements provide an opportunity to achieve competitiveness and compliance with international standards.

Future research could emphasize the changes that have occurred in early childhood education improvement from 2019 to the present. By collecting data on reforms being implemented in similar educational systems and identifying key factors that differ from more successful educational systems, this information could be used to improve Bosnia & Herzegovina's results in international assessments.

Limitations of Study

The limitations of this study originate primarily from the inherent nature of the variables used within the framework of TIMSS and other large-scale studies. In these studies, data on the relationship between early cognitive competencies and later academic achievements are frequently covered superficially with a small number of questions, limiting the depth and precision of the analysis.

Gathering information from parents or guardians about their children's mathematical development presents an additional methodological challenge. Parents and guardians frequently lack confidence in categorizing and quantifying their children's mathematical competencies in comparison to their peers, particularly when identifying advanced mathematical skills, such as those related to numerical manipulation.

Due to the inconsistency in the legal regulations regarding preschool programs at the state level and the inconsistency in the mandatory attendance of these programs across the cantons of Bosnia & Herzegovina, it cannot be claimed that all respondents attended a uniform preschool program under the same standards and conditions.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgements: The authors would like to thank the US Embassy & the Education Center for Democracy and Human Rights CIVITAS in Bosnia & Herzegovina.

Ethical statement: The authors stated that ethical approval was not needed as this study was on publicly available TIMSS 2019 data: https://www.iea.nl/data-tools/repository/timss.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Adams, M. J., Treiman, R., & Pressley, M. (1998). Reading, writing and literacy. In I. Sigel, & A. Renninger (Eds.), *Handbook of child psychology: Child psychology and practic*e (pp. 275-355). Wiley.

APOSO. (2015). Zajednička jezgra nastavnih planova i programa za matematičko područje definisana na ishodima učenja [The common core mathematics curriculum based on learning outcomes]. *Agency for Pre-Primary, Primary and Secondary Education, Bosnia & Herzegovina, Council of Ministers*. https://aposo.gov.ba/sadrzaj/uploads/ZJNPP-matemati%C4%8Dko-podru%C4%8Dje-BOSANSKI.pdf

APOSO. (2020). TIMSS 2019 izvješće za Bosnu i Hercegovinu [TIMSS 2019 report for Bosnia & Herzegovina]. *Agency for Pre-Primary, Primary and Secondary Education, Bosnia & Herzegovina*. https://aposo.gov.ba/hr/objavljeno-timss-2019-izvjesce-za-bosnu-i-hercegovinu/

Arteaga, I., Humpage, S., Reynolds, A. J., & Temple, J. A. (2014). One year of preschool or two–Is it important for adult outcomes? Results from the Chicago longitudinal study of the child-parentcenters. *Economics of Education Review, 40*, 221-237. https://doi.org/10.1016/j.econedurev.2013.07.009

B&H. (2021). *Kurikulum za rani i predškolski odgoj i obrazovanje* [*Curriculum for early and preschool education*]. https://kurikulum.ks.gov.ba/sites/default/files/2023-09/Kurikulum%20za%20rani%20i%20predskolski%20odgoj%20i%20obrazovanje%20FINAL.pdf

Baroody, A. J. (2003). The development of adaptive expertise and flexibility: The integration of conceptual and procedural knowledge. In A. J. Baroody, & A. Dowker (Eds.), *The development of arithmetic concepts and skills: Constructing adaptive expertise studies* (pp. 1-34). Erlbaum.

Campbell, F. A., Ramey, C., Pungello, E. P., Sparling, J. J., & MillerJohnson, S. (2002). Early childhood education: Young adult outcomes from the Abecedarian Project. *Applied Developmental Science, 6*, 42-57. https://doi.org/10.1207/S1532480XADS0601_05

Cebolla Boado, H. (2011). Primary and secondary effects in the expla-nation of immigrants' educational disadvantage. *British Journal of Sociology, 32*, 407-430. https://doi.org/10.1080/01425692.2011.559341

Cebolla Boado, H. (2012). *La incorporación escolar de la población deorigen inmigrante y el impacto de la concentración de inmigrantesen las escuelas Navarras* [*The school incorporation of the population of immigrant origin and the impact of the concentration of immigrants in Navarrese schools*]. https://www.observatoriorealidadsocial.es/es/estudios/la-incorporacion-escolar-de-la-poblacion-de-origen-inmigrante-y-el-impacto-de-la-concentracion-de-inmigrantes-en-las-escuelas-navarras/es-529274/

Clements, D. H., Baroody, A. J., & Sarama, J. (2013). Background research on early mathematics. *National Governor's Association*. http://www.nga.org/files/live/sites/NGA/files/pdf/2013/1311SEME-Background.pdf

Cunha, F., Heckman, J., Lochner, L., & Masterov, D. (2006). Interpreting the evidence on life cycle skill formation. In E. Hanushek, & F. Welch (Eds.), *Handbook of the economics of education* (pp. 307-451). Elsevier. https://doi.org/10.1016/S1574-0692(06)01012-9

Entwisle, D. R., Alexander, K. L., & Olson, L. S. (2005). First grade and educational attainment by age 22: A new story. *American Journal of Sociology, 110*, 1458-1502. https://doi.org/10.1086/428444

Garrido, L., & Cebolla Boado, H. (2010). Rendimiento académicoy concentración de inmigrantes en las escuelas espa˜nolas: PISA2006 [Academic performance and concentration of immigrants in Spanish schools: PISA2006]. *Presupuesto y Gasto Público, 61*, 159-176.

Griffin, S., Case, R., & Capodilupo, A. (1995). Teaching for understanding: The importance of the central conceptual structure in the elementary mathematics curriculum. In A. McKeough, J. Lupart, & A. Marini (Eds.), *Teaching for transfer* (pp. 123-151). Erlbaum.

Grissmer, D. W., Mashburn, A. J., Cottone, E., Chen, W. B., Brock, L. L., Murrah, W. M., & Cameron, C. (2013). *Play-based after-school curriculum improves measures of executive function, visuo spatial andmath skills, and classroom behavior for high risk K-1 children* [Paper presentation]. The Meeting of the Society for Research in Child Development.

Hindman, A. H. (2013). Mathematics instruction in head start: Nature, extent, and contributions to children's learning. *Journal of Applied Developmental Psychology, 34*, 230-240. https://doi.org/10.1016/j.appdev.2013.04.003

Institute for Educational Research. (2021). *TIMSS 2019 u Srbiji. Rezultati međunarodnog istraživanja postignuća učenika četvrtog razreda osnovne škole iz matematike i prirodnih nauka* [*TIMSS 2019 in Serbia. Results of the international study of achievement of fourth-grade primary school students in mathematics and natural sciences*]. https://www.iea.nl/sites/default/files/2021-11/TIMSS%202019%20in%20Serbia%20-%20Results%20Of%20the%20International%20Achievement%20Survey%20Fourth%20Grade%20Students.pdf

Jordan, N. C., Glutting, J., & Ramineni, C. (2010). The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences, 20*(2), 82-88. https://doi.org/10.1016%2Fj.lindif.2009.07.004

La Paro, K. M., & Pianta, R. C. (2000). Predicting children's competence in the early school years. A meta-analytic review. *Review of Educational Research, 70*, 443-484. https://doi.org/10.3102/00346543070004443

Lazar, I., Darlington, R. B., Murray, H., Royce, J., Snipper, A., & Ramey, C. T. (1982). Lasting effects of early education: A report from the consortium for longitudinal studies. *Monographs of the Society for Research in Child Development, 47*(2-3). https://doi.org/10.2307/1165938

Lehrl, S., Kluczniok, K., & Rossbachba, H. G. (2016). Longer-term associations of preschool education: The predictive role of preschool quality for the development of mathematical skillsthrough elementary school. *Early Childhood Research Quarterly, 36*, 475-488. https://doi.org/10.1016/j.ecresq.2016.01.013

Lowe Vandell, D., Belsky, J., Burchinal, M., Steinberg, L., Vandergrift, N., & NICHD Early Child Care Research Network. (2010). Do effects of early child care extend to age 15 years? Results from the NICHD study of early child care and youth development. *Child Development, 81*(3), 737-756. https://doi.org/10.1111/j.1467-8624.2010.01431.x

Mazzocco, M., & Thompson, R. (2005). Kindergarten predictors of math learning disability. *Learning Disabilities Research and Practice, 20*, 142-155. https://doi.org/10.1111/j.1540-5826.2005.00129.x

Meinck, S., Stancel-Piatak, A., & Verdisco, A. (2018). Preparing the ground: The importance of early learning activities at home for fourth grade student achievement. *International Association for the Evaluation of Educational Achievement*. https://www.iea.nl/publications/series-journals/iea-compass-briefs-education-series/september-2018-preparing-ground

Ministry of Civil Affairs of Bosnia & Herzegovina. (2004). *Strateški pravci razvoja predškolskog odgoja i obrazovanja u Bosni i Hercegovini* [*Strategic guidelines for education development in Bosnia & Herzegovina*]. https://aposo.gov.ba/sadrzaj/uploads/Strateski-pravci-razvoja-pred%C5%A1kolskog-odgoja-i-obrazovanja.pdf

Ministry of Civil Affairs of Bosnia & Herzegovina. (2016). *Platforma za razvoj predškolskog odgoja i obrazovanja u Bosni i Hercegovini za period 2017-2022* [*Platform for the development of preschool education in Bosnia & Herzegovina for the period 2017-2022*]. http://www.mcp.gov.ba/attachments/bs_Migrirani_dokumenti/Sektori/Obrazovanje/Obrazovanje-strate%C5%A1ki/Platforma_za_razvoj_pred%C5%A1kolskog_odgoja_i_obrazovanja_u_Bosni_i_Hercegovini_za_period_2017._do_2022._bos..pdf

Mullis, I. V. S., & Martin, M. O. (2017). TIMSS 2019 assessment frameworks. *TIMSS & PIRLS International Study Center*. http://timssandpirls.bc.edu/timss2019/frameworks/

Mullis, I. V. S., Martin, M. O., Foy, P., & Arora, A. (2012a). TIMSS 2011 international results in mathematics. *TIMSS & PIRLS International Study Center*. https://timssandpirls.bc.edu/timss2011/international-results-mathematics.html

Mullis, I. V. S., Martin, M. O., Foy, P., & Arora, A. (2012b). TIMSS 2011 international results in science. *TIMSS & PIRLS International Study Center*. https://timssandpirls.bc.edu/timss2011/international-results-science.html

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016a). TIMSS 2015 international results in mathematics. *TIMSS & PIRLS International Study Center*. http://timssandpirls.bc.edu/timss2015/international-results/

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016b). TIMSS 2015 international results in science. *TIMSS & PIRLS International Study Center*. http://timssandpirls.bc.edu/timss2015/international-results/

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). TIMSS 2019 international results in mathematics and science. *TIMSS & PIRLS International Study Center*. https://timssandpirls.bc.edu/timss2019/international-results/

NAEYC. (2010). NAEYC position statement: Early childhood mathematics promoting good beginnings. *National Association for the Education of Young Children*. https://www.naeyc.org/files/naeyc/file/positions/psmath.pdf

National Center for External Evaluation of Education. (2019). *Results of TIMSS 2019–International study of trends in mathematics and science*. https://www.ncvvo.hr/wp-content/uploads/2022/03/TIMSS-Nacionalni-izvjestaj-finale.pdf

Parliamentary Assembly of Bosnia & Herzegovina. (2007). Okvirni zakon o predškolskom odgoju i obrazovanju u Bosni i Hercegovini [The framework law on preschool education in Bosnia & Herzegovina]. *Official Gazette/Službeni Glasnik BiH* 88/07. https://www.propisi.ks.gov.ba/sites/propisi.ks.gov.ba/files/Okvirni_Zakon_o_predskolskom_obrazovanju_u_bih.pdf

Reynolds, A., & Temple, J. A. (1998). Extended early childhood intervention and school achievement: Age thirteen findings from the Chicago longitudinal study. *Child Development, 69*, 231-246. https://doi.org/10.2307/1132082

Schweinhart, L. J., Montie, J., Xiang, Z., Barnett, W. S., Belfield, C. R., & Nores, M. (2005). Lifetime effects: The high/scope perry preschool study through age 40. *High/Scope Educational Research Foundation*. https://highscope.org/wp-content/uploads/2018/11/perry-preschool-summary-40.pdf

Sharma, M. C. (2001). *Matematika bez suza* [*Mathematics without tears*]. Ostvarenje.

Soto-Calvo, E., & Sánchez-Barrioluengo, M. (2016). The influence of early literacy competences on later mathematical attainment: Evidence from TIMSS & PIRLS 2011. *Publications Office of the European Commission*. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC102210/lbna28010enn.pdf

Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford I., Taggart, B., Hunt, S., Jelicic, H., Barreau, S., Grabbe, Y., Smees, R., & Welcomme, W. (2008). *Effective preschool and primary education 3-11 project*. DfE.

Sylva, K., Sammons, P., Chan, L. L. S., Melhuish, E., Siraj, I., & Taggart, B. (2013). The effects of early experiences at home and pre-school on gains in English and mathematics in primary school: A multilevel study in England. *Zeitschrift für Erziehungswissenschaft* [*Journal for Educational Science*]*, 16*, 277-301. https://doi.org/10.1007/s11618-013-0364-6

Taskin, N., & Tugrul, B. (2014). Investigation preschool teachercandidates' mathematics literacy self-sufficiency beliefs in various variables. *Procedia-Social and Behavioral Sciences, 116*, 3067-3071. https://doi.org/10.1016/j.sbspro.2014.01.708

Temple, J. A., & Reynolds, A. J. (2015). Using cost-benefit analysis to scale up early childhood programs through pay for success financing. *Journal of Benefit-Cost Analysis, 6*, 628-653. https://doi.org/10.1017/bca.2015.54

Tunmer, W. E., & Nesdale, A. R. (1985). Phonemic segmentation skill and beginning reading. *Journal of Educational Psychology, 77,* 417-427. https://doi.org/10.1037/0022-0663.77.4.417