Children educated in heterogeneous and homogeneous kindergarten classes: Comparing their results in early years mathematics

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Our study presents the results of research aimed at comparing the results of children educated in homogeneous and heterogeneous classes in the last year of preschool education. The research was prepared with the support of findings from research mapping the influence of the age structure of classes on education in kindergartens. The test determined the level of children's pre-numerical ideas and spatial orientation as an important part of their school maturity. A total of 378 children from 16 kindergarten classes were tested with a test standardized for the Czech Republic. No statistically significant difference was found between the performance of children from age-homogeneous and heterogeneous preschool classes. The different age composition of the class was not reflected in the results of the children in our sample.

Keywords: Pre-primary education, heterogeneous and homogeneous classes, pre-numerical ideas, spatial orientation.

Introduction

In preschool years, when the foundations for later high-quality and effective mathematics learning are being formed, early years mathematics has an irreplaceable role in the development of the whole child's personality. Developing the prerequisites for mathematics in the Czech Republic belongs now and has always belonged to the educational programmes for kindergartens (Nováková, 2022; MŠMT ČR, 2021). Kindergarten teachers consider the area of geometric ideas (orientation in space and in the plane) and pre-numerical ideas (perception of quantity, determining the number of objects) to be the most important for children's cognitive development. This is convincingly confirmed by the results of our previous research (Nováková & Novák, 2019).

Tasks, included in our test, diagnose the level of spatial orientation and the concept of quantity in children educated in different kindergarten environments: in homogeneous as well as heterogeneous classes.

In a homogeneous class, children of approximately the same age are educated together, while a heterogeneous class is composed of children of different ages (three to seven years) and stages of development together. It is the diversity of children's abilities and knowledge within the group that is used for effective learning (Rathbone, 1993, p. 64). The term heterogeneous is sometimes replaced by the terms mixed-age, multi-age or non-graded classroom.

Reflection of education in homogeneous and heterogeneous kindergarten classes in research

Evidence from relevant research highlights the main effects of classroom age composition and how these translate into children's performance when they enter primary education. The

discussion about the advantages and disadvantages of homogeneous or heterogeneous classroom arrangements has a long history. It is most often associated with arguments that homogeneous grouping of children according to one criterion (age) does not produce groups that are also homogeneous in other criteria (children's dispositions, interests, experiences, needs, family background) relevant to education (Goodlad & Anderson, 1987). The heterogeneous arrangement develops in older children a sense of helping the younger and weaker ones, the younger children are more easily integrated into the collective. Children develop social sensitivity, relationships and consideration, and in natural situations they strengthen their cultural, hygienic and social habits. The approach to children in these classes is based on an appreciation of the diversity of the group, and on the fact that children are not compared, but attention is focused on their individual progress. Sharing experiences with each other and creating an individual structure of knowledge is considered important. In homogeneous classrooms, they argue, the focus is primarily on the development of cognitive skills (Politano & Davies, 1994; Rice & Shortland-Jones, 1999).

However, the research findings are not unequivocal. Ansari (2017) found that the development of language and pre-math notions was given less attention in a heterogeneous classroom than in a homogeneous classroom. The children performed worse in pre-math literacy and reading, language and grammar development, executive functions, and externalizing behaviours. She attributed this to the fact that children were given fewer teacher-directed tasks.

To answer the question of the nature of teaching and learning mathematics in a heterogeneous classroom, Wood and Frid (2005) used a qualitative research approach. The development of mathematical ideas was embedded in the curriculum, using examples and situations familiar to the children from everyday life. Children shared their ideas during the tasks, which enabled them to learn from other children's ideas. If more experienced and mature children appeared in the group, they took over the role of leader or tutor. Learning was based on intersubjectivity, that is, their shared understanding of the activity and its purpose, with the older children helping the younger children. The authors point out that children help each other even in homogeneous classrooms, but in heterogeneous classrooms there are far greater differences between children, hence the greater effectiveness of sharing between older and younger children.

In Lanphear's and Vandermaas-Peeler's (2016) study, an inquiry-based guidance method was applied, based on the use of open-ended questions, developing children's curiosity and leading to problem solving (Ermeling, 2010; Gerde et al., 2013). Teachers interfered less in discovery activities, creating more space for children to communicate with each other. This often happened in age-mixed groups in which older children took the lead and also showed more advanced levels of inquiry.

Cascio and Whitmore Schanzenbach (2007) found that younger children who were in class with older children showed later better performance in mathematics in primary school. Findings from other research suggest that the more time children spent on teacher-directed, high-quality didactic activities with teacher-child interactions, the better their performance (e.g., Barnett, 2011; Pianta et al., 2008; Guo et al., 2014).

We identified the strengths and weaknesses of both ways of age arrangement in the research findings in a review study by Syslová et al. (2021). No conclusions can be drawn that clearly

favour one of the possible classroom arrangements in terms of the development of mathematical ideas. It depends on the authors' specific, explicitly stated research objectives and the interpretation of their findings in the context of a broader framework of general pedagogical, social, economic and political issues. The findings inspired us to prepare and implement our research in the Czech educational environment.

Methods

The aim of the research was to compare the results of children in the last year of preschool education in the area of pre-numerical ideas and spatial orientation. Children were educated in heterogeneous and homogeneous kindergarten classrooms.

In relation to the research aim, the research question and hypothesis were formulated:

RQ: Does the age structure of the classroom manifest into the children's results in mathematical (pre-calculus) ideas and spatial orientation?

H: There is a statistically significant difference between the overall results of children from homogeneous and heterogeneous classes.

A total of 378 children in the Czech Republic were tested in the last year of their preschool education, aged six to seven years. Of the total, 223 children were from 9 heterogeneous classes and 155 children from 7 homogeneous classes. All children were educated in a given type of age-class arrangement throughout their stay in kindergarten.

As a research tool, we used a diagnostic test that has been standardized in the Czech environment (Pekárková & Švandová, 2020). The content validity of the method is based on an explicit agreement among experts and teachers that the tasks included in the test are relevant in terms of children's school maturity.

The test was supplemented by an answer sheet, methodological handbook for administrators, and test guide which included additional instructions for test distribution and evaluation and information on permitted support of children. The test was administered by a group of trained female students from the Faculty of Education, Masaryk University, specialization Teacher training for kindergartens.

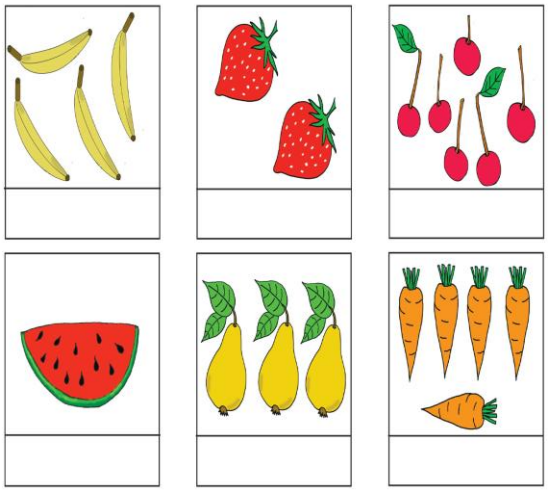
The testing took place at the end of the school year, which was the last year of the children's pre-school education. The children solved the problems individually based on the instructions of the administrators. The children were given 30 minutes to complete the test. The answers were written in printed answer sheets, then transferred to electronic form and evaluated quantitatively using statistical methods.

A. Pre-numerical ideas – examples of test problems:

- comparing the number of elements in the set of up to 8 elements (less-more) – to decide which card has more/less dots,
- sorting 2D shapes according to two properties – to select elements from a set of geometric shapes (DLB) that meet the required characteristics: small yellow squares, large green circles,
- determining the number of objects – determine how many objects are in the picture.

B. Spatial orientation – examples of test problems:

- assembling a figure from individual parts according to the template – to create a picture of a house, oval and trapezoid from available parts, while some parts do not fit,
- creating the desired picture of a specific object (rooster) from the individual pieces of the puzzle,
- describing location of the objects in the picture – to describe what is placed in the shelf at the bottom centre, top left, next to the shelf on the right, in front of the shelf.



A.

B.

Figure 1: Examples of test problems

A. New goods have been brought into the shop. Help the shop assistant to count how many items are in the boxes. Draw commas according to the number of pieces and write the correct number if you can.

B. Describe what can you see in the kitchen on the table: Where is the glass? Where is the flower? Where is the pear? Where is the carrot? Instead of pointing (here), the child should use a description of the position and location of the object.

Research results

In order to make the obtained data for each test area clearer, the average results obtained in both groups can be seen in Tables 1 and 2. Maximum point gain in pre-numerical ideas is 18, in spatial orientation is 13. Subsequently, statistical hypotheses were tested to help us answer the research question.

Table 1: Numerical characteristics of variables in homogeneous classes in individual areas of the test

	Homogeneous classes (N_1 = 155)		
	Mean result (in brackets %)	Max. reached (in brackets %)	Min. reached (in brackets %)
Pre-numerical ideas	14,7 (81,7)	18 (100)	2 (11,1)
Spatial orientation	7,4 (56,9)	13 (100)	1 (9,1)
In total	22,1 (70,9)	31 (100)	3 (9,7)

Table 2: Numerical characteristics of variables in heterogeneous classes in individual areas of the test

	Heterogeneous classes (N_2 = 223)		
	Mean result (in brackets %)	Max. reached (in brackets %)	Min. reached (in brackets %)
Pre-numerical ideas	15,1 (83,9)	18 (100)	6 (33,3)
Spatial orientation	7,1 (54,6)	13 (100)	0 (0)
In total	22,2 (71,6)	31 (100)	6 (19,4)

Table 1 and Table 2 show that both the overall mean scores and the mean scores of children in homogeneous and heterogeneous classes are very evenly distributed across test areas, with minimal differences. However, Table 1 and Table 2 show considerable variation in the results of individual children: columns maximum and minimum. The range of total scores obtained is from 31 (100 %) to 3 (9,7 %) in the homogeneous classes, and from 31 (100 %) to 6 (19,4 %) in the heterogeneous classes.

Hypothesis testing was performed at the 0.05 significance level. All variables, i.e. the scores obtained in the two test domains, have a somewhat different distribution from normal in both groups, but due to the large ranges of the groups, a two-sample Student's t-test for agreement of means could be used together with an F-test for agreement of variances. The t-test is one of the most well-known statistical tests of significance for metric data, used to compare two data sets. We use this test to test the null hypothesis that both sets come from a distribution with the same mean. In order to use the t-test, both sets must come from a normal distribution with unknown but equal variance. We verify the agreement of the variances using the F test (StatSoft, Inc., 2013).

The null hypothesis H_0 was tested, against which the two-sided alternative hypothesis H_A was contrasted.

H_0: There is no statistically significant difference in the overall results between children from homogeneous and heterogeneous classes. Belonging to a homogeneous or heterogeneous class and overall test score are independent.

H_A: There is a statistically significant difference in the overall results between children from homogeneous and heterogeneous classes. Belonging to a homogeneous or heterogeneous class and overall test score are not independent.

Table 3: The results of the two-sample Student's t-test together with the results of the F-test

Results of t-test and F-test group 1: homogeneous class, group 2: heterogeneous class											
The area of the test	Mean group 1	Mean group 2	t	df	p-value	N group 1	N group 2	St. dev. group 1	St. dev. group 2	F	p-value
Pre-numerical ideas	14.7	15.1	1.209	376	0.2274	155	223	2.51	2.47	1.035	0.8114
Spatial orientation	7.4	7.1	0.704	376	0.4819	155	223	3.11	3.06	1.031	0.8294

As can be seen in Table 3, all p-values are greater than the 0.05 significance level, i.e., two-sample t-tests and F-tests did not show statistically significant differences between the means and variances of the results of children from homogeneous and heterogeneous classes at the 0.05 significance level. We do not reject the null hypothesis at the 0.05 level of significance. The age distribution of the class does not affect the outcome of the children in our sample.

Discussion, limitations and conclusions

The aim of the study was to investigate which age arrangement of kindergarten classes brings a higher effect on children's cognitive development (pre-numerical ideas and spatial orientation) before entering systematic school education. Research has shown:

- that differences in results achieved by children educated in classes with different age arrangement are not statistically significant in our sample,
- that, given conditions for optimal development of cognitive functions in pre-school children, neither of the age arrangements shall be preferred.

We are aware of the limitations of the research. Solving the test tasks helped us to diagnose the current level of pre-numerical ideas and spatial orientation of children educated in homogeneous and heterogeneous kindergarten classes, but it does not provide a more comprehensive view related to the influence of age arrangement in the perspective of children's, academic success.

In our research, we did not monitor the influence of teachers on the cognitive and socio-emotional development of the child, related to the personal characteristics, assumptions and competences of the teachers (their age, professional education and academic qualifications, readiness for the specifics of work in a certain type of age structure of the class, relationship to mathematics and other). Other aspects that can be assumed to interfere with children's performance in the test were also not monitored: for example, their general intellectual ability, level of language and communication skills, more or less stimulating family environment.

Some authors, such as Guo at al. (2014), mention that positive consequences of age arrangement may help in cognitive development of children if and only if they are combined with high quality interactions between children and teachers. The influence of teachers' professional qualities for the development of children is suggested also by studies aimed at finding teacher opinions on suitability of homogeneous or heterogeneous arrangement as environments for efficiency of educational activities (Broome, 2009; Hitz et al., 2011).

In the Czech Republic, research focused on comparing the results of children educated in homogeneous and heterogeneous classes is completely unique and has not yet been recorded in the research field. This has not been studied even in a widely designed research conducted in the Czech Republic in 2015 (Greger et al., 2015). The level of children's mathematical skills before entering primary education was examined in relation to the level of visual perception and other general skills important for the development of mathematical ideas (graphomotor skills, perception of time and time sequence, speech, vision, hearing, rhythm, concentration, memory).

Neither in other research examining, for example, the ability to make non-symbolic (non-verbal) quantity comparisons (Stock et al., 2009) or the level of spatial orientation (Levenson et al., 2011), the age arrangement factor of kindergarten classes was not studied.

We consider our research as a partial contribution to a more objective mapping of the current state of considerations and discussions about the appropriateness of education in homogeneous and heterogeneous kindergarten classes.

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