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HOW PRIMARY STUDENTS UNDERSTAND THE CONCEPT OF MAGNETISM

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Abstract: Magnets are a part of students' daily experience, whether within technical devices, souvenirs, toys or included in various school experiments. The aim of this research was to gain insight into the way primary students understand magnetism and to estimate the effect of teaching to the development of concepts about magnetism. For the purpose of this research, a diagnostic knowledge test was designed which includes teaching content about the concept of magnets, their properties, interaction and application. A total of 160 of second, third and fourth grade students attending elementary schools „Siniša Glavašević" and „Nikola Andrić" from Vukovar and „Bijelo Brdo" from Bijelo Brdo, Republic of Croatia, were included in the study. The results showed that there were no statistically significant differences in knowledge test scores among girls and boys. The knowledge test achievements according to age (second, third and fourth grade) were statistically significant between second and third grade, as well as second and fourth. The difference in test scores between third and fourth grade students was observed, but it was not statistically significant. The analysis of students' responses according to each test question confirmed the absence of differences according to gender but significant differences according to age, as well as the persistence of some typical misconceptions. The overall level of knowledge test achievement was rather low throughout the sample, indicating that primary students lack sufficient knowledge and that the majority of students fail to completely and accurately answer the questions about magnetic phenomena. Based on the results of this study it could be concluded that the process of developing concepts about magnetism within the course Nature and Society from the second to the fourth grade is insufficiently effective. We recommend that the contents about magnetism should be studied from the very beginning of primary school education. Furthermore, it is necessary to apply innovative teaching methods, strategies and models, while connecting these contents with students' everyday experiences.

Keywords: magnetism, development of scientific concepts, primary education, subject Nature and Society.
Field: Social sciences

1. INTRODUCTION

Early science teaching has great importance for logical and critical thinking as well as several competencies and skills needed for 21st century (Samara & Kotsis, 2023). Knowledge and skills acquired by students enable them to understand technologies and their impact to everyday activities and environment. Before starting school, in order to explain themselves the world that surrounds them, children create logically unpredictable explanations which are often inconsistent with science-based concepts (Pine et al., 2011; Smolleck & Hershberger, 2011). Such personally created preconceptions become deeply rooted and, if not discovered and corrected in time, can make school learning difficult or even impossible. In order to prevent these educational scenarios, it is necessary to enable students to independently observe, describe and draw conclusions about natural phenomena through inquiry-based activities, thus developing and changing their own preconceptions (Harlen, 2021).

The complexity of various scientific concepts shouldn't be the reason for their absence or scarce representation in educational programs in lower grades of primary school. On the contrary, it should be quite opposite, since the proper adoption of complex scientific concepts needs time, continuity in learning and adequate teaching approaches. Regardless to the intricate physical mechanisms behind them, magnets and magnetic phenomena are a part of children's daily experiences, so they must understand them properly in order to avoid development of misconceptions (Farrow, 2006). At that age, it is appropriate for children to observe, reliably describe and elucidate causative relationships of magnetic phenomena, adopting scientific terminology at the same time (Grigorovitch & Nertivich, 2017). A high-quality foundation created in this way can greatly facilitate the later study of sciences in subject teaching by applying inquiry-based teaching models (Minner et al., 2010).

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2. MATERIALS AND METHODS

Research studies of children's understanding of physical concepts at early school age are still scarce in the region of Balkan, especially in the field of more complex phenomena such as magnetism. Despite numerous innovations in teaching in past few decades, recent studies showed the continued presence of preconceptions and misconceptions at all levels of education, even among adults (Özdemir & Coramik, 2018; Lemmer at al., 2020; Ürek & Çoramık, 2021; Samara & Kotsis, 2023). The problem of this research was the adoption of concepts about magnetic phenomena in the primary science teaching. The dependent variable was the quality of knowledge about the concepts adopted, expressed by the scores on each individual task and on the entire test. This variable was quantitative and continuous, while independent variables of grade and gender of students were categorical. In order to estimate the impact of teaching in the subject Nature and Society, the achievements of the second, third and fourth grade students were checked through a diagnostic test that included ten tasks on the concept of magnets, their properties, interaction and application. Since in the first and second grade magnetism was not included in curricula, the second grade students' achievements were interpreted as preconceptions. An overview of terms and requirements for each task in the knowledge test is shown in Table 1.

Table 1. An overview of concepts, requirements and points on the knowledge test about magnetism

Task	Concept	Requirement	Points
1.	Shape of magnets and magnetic poles	Recognize and name the magnets on the picture (bar-shaped and horseshoe-shaped). To explain why they are colored in two colors – red and blue.	3
2.	Magnetic pole labels	Connect the name of the magnetic pole (north and south) with the corresponding label.	1
3.	Interactions between two magnets	The picture shows three pairs of magnets oriented so that the first pair has different poles next to each other (S - N), and the second and third pair have the same poles next to each other (S - S and N - N). Circle the appropriate type of interaction (attract / repel) and explain the answer.	5
4.	Interactions between magnet and objects of different materials	The picture shows magnets and paper, steel paperclips and wooden toothpicks. Name the objects (materials) which will be attracted by magnet and explain the answer.	3
5.	Application of magnets	Give examples where magnets can be used.	3
6.	Effect of magnets (magnetic field)	The picture shows a sheet of paper sprinkled with iron filings that were arranged around a bar magnet. Explain why the iron filings are arranged as shown in the picture. Based on the arrangement of the filings, how can it be concluded on which part of the magnet its effect is strongest?	5
7.	Property of inseparability of magnetic poles	The picture shows a halved bar-shaped magnet without magnetic pole labels. Answer whether these parts of magnet have one or both poles and mark them in the picture.	5
8.	Application of magnets	The picture shows a mixture of sand and iron filings on a table. Explain the easiest way to separate the components of that mixture.	4
9.	Application of magnets	The picture shows a compass. State which part of it is made of magnetic material and what is the purpose of this device.	4
10.	Electromagnet	Draw and explain how a magnet can be made using the following objects: copper wire, iron nail and battery.	7

A total of 160 second, third and fourth grade students (84 girls and 76 boys) attending three elementary schools in the Republic of Croatia (OŠ „Siniša Glavašević“ and „Nikola Andrić“ from Vukovar and OŠ „Bijelo Brdo“ from Bijelo Brdo) were included in the study. The overall test scores of all participants were presented by a scale that measures level of achievements by point intervals. Based on the total test score, another dependent variable was derived - the percentage of correct answers. This variable is categorical with five levels, that is, the scale was divided into five categories based on percentages of correct answers (Table 2). It was possible to obtain a total of 40 points on the test, and the students solved it within one school hour (45 minutes).

Table 2. Test scoring scale

Points	The percentage (%) of correct answers and categories
0 - 8	0 – 20 (1)
9 -16	21 – 40 (2)
17 - 24	41 – 60 (3)
25 - 32	61 - 80 (4)
33 - 40	81 -100 (5)

The following statistical procedures were used when processing the test results: analysis of contingency tables (chi-square test), analysis of variance (ANOVA) and t-test.

3. RESULTS

The correlation of students' grade and the categories of achievement is shown in Table 3 through frequencies and percentages of correct answers on the knowledge test.

Table 3. The correlation of students' grade and categories of achievement on the knowledge test

			Grade			Total	χ^2	p
			second	third	fourth			
Categories of achievement	category 1	frequencies	14	5	8	27	15.8	0.04
		%	51.9	18.5	29.6	100		
	category 2	frequencies	16	13	15	44		
		%	36.4	29.5	34.1	100		
	category 3	frequencies	22	17	20	59		
		%	37.3	28.8	33.9	100		
	category 4	frequencies	3	11	14	28		
		%	10.7	39.3	50	100		
	category 5	frequencies	0	2	0	2		
		%	0	100	0	100		
Total		frequencies	55	48	57	100		
		%	34.3	30	35.6	100		

As shown above, the value of the χ^2 test is 15.8 ($p < 0.05$), which means that the differences in achievements according to grade are statistically significant. However, since the previous analysis does not show between which specific groups there are statistically significant differences, the unifactorial analysis of variance (ANOVA) of the differences in the test results for the three grade categories follows (Table 4).

Table 4. Unifactorial analysis of variance of the differences in the test results for the three grade categories

		Number of students	Arithmetic mean (M)	SD	F test	p
Grade	second	55	7.54	4.09	6.52	0.02
	third	48	10.22	4.29		
	fourth	57	9.89	4.12		
Total		160	9.18	4.31		

Based on the arithmetic mean values (Table 4) it can be seen that the highest test scores are achieved by the students of the third grade and the lowest test scores were among second graders, with statistically significant differences between these two age categories ($p = 0.02$). The post hoc test revealed that the differences in the achievements between second and third graders, as well as second and fourth graders were statistically significant.

The results of unifactorial analysis of variance for each of nine questions (none of the participants gave the answer to the 10th question) follow the trend observed in the analysis of overall test results: statistically significant differences in achievements were found in several tasks between second and third graders (tasks 4, 5, 6 and 7), as well as between second and fourth graders (tasks 1, 4, 5 and 8), while between third and fourth graders statistically significant difference was discovered only in task 6. Based on these results, it can be concluded that there are significant differences in the quality of the adoption of concepts of magnetic phenomena between second graders on one side and third and fourth graders on the other side. The t-test analysis of achievements showed that there were no statistically significant differences between boys and girls on any question nor on the whole test, i.e. that the quality of the adoption of concepts about magnetic phenomena does not depend on gender.

The data on the frequencies of correct answers on knowledge test along with the qualitative analysis of the parts of answers to the open-ended questions provided a deeper insight into students' understanding of magnetic phenomena, as well as the structure of their misconceptions. The majority of students of all grades successfully recognized and named the types of magnets in the 1st task, but the difficulties and differences between their answers were in the second part of that task when they tried to explain the way the magnets were colored. The second graders explained that the magnets are colored for more attractive appearance, to make it colorful, and that red color represents hot and blue represents cold, probably by analogy to the water faucet markings. The third graders thought that the magnet can be of any color, that one side repels and the other attracts and that the different colored sides are attracted by each other, which were partially correct answers. About half of the second graders and about one third of the third and fourth graders didn't answer that part of the question. Approximately half of the second graders, two thirds of the third graders and one third of the fourth graders gave incorrect explanations of the colors of magnets, while only one third of the fourth graders gave the correct answer. In the 2nd task almost half of the students of all grades correctly attributed the labels to the corresponding pole (N and S), bearing in mind that there was a possibility of random association. When it comes to mutual interactions of the magnetic poles (3rd task), one third of all students correctly determined the type of interaction (attract/repel), two fifths did it partially correctly or incorrectly, while one fifth did not even try to solve the task. Approximately equal proportion of students in each grade solved this problem incorrectly. As many as four fifths of students of all grades were able to correctly predict which objects/materials (iron paperclip, papers and wooden toothpicks) will be attracted by the magnet or not (4th task), while one fifth of the students didn't solve the task or did it erroneously. In that task the proportion of correct answers raised with grade, and the number of students which failed to solve it decreased. When asked to name some examples of application of magnets (5th task), the students' answers of all grades were similar. The majority of students associated magnets with travel souvenirs (fridge magnets) and the ones used on school boards, while a few participants mentioned collecting small objects, toys that contain magnets and powerful electromagnets for transporting shipping containers, cars, etc. About two fifths of students of all grades correctly explained why iron filings were arranged around magnet as shown in picture, as well as in which areas magnetic effect was the strongest (6th task), but one third of the students gave erroneous explanations or didn't answer the question. The most of the third graders tried to solve this task and gave the highest proportion of correct and wrong answers. While answering the question whether the parts of magnet cut in half have both poles (7th task), about two fifths of the third and fourth graders and one fifth of the second graders gave the correct answer, and the proportion of incorrect answers decreased with grade. It should be noted that in this task there was also a possibility of random guess (yes/no). None of the students explained his answer, nor labeled the poles on the newly created magnets. More than a half of students of all grades proportionally correctly proposed that the mixture of iron filings and sand can be separated to components by using magnet (8th task), but, unexpectedly, as many as two fifths of participants didn't try to solve the problem. It is interesting to mention the erroneous suggestion of five second grade students that the mixture could be separated by pouring water into it, which is probably an association with the similar experiment which involves other mixtures (sawdust/sand or sawdust/iron filings). In this task there were no differences in achievements according to grade. When identifying the part of the compass that is made of magnetic material (9th task), two fifths of all students answered correctly that it is a needle, one third didn't answer the question, and a slightly smaller proportion of the students answered erroneously (compass rim, case or letters/symbols). Contrary to the most of previous tasks, in this task the achievements of the third graders were the lowest, the second graders are better and the fourth grade students were the most successful.

4. DISCUSSION

The achievements on diagnostic test about magnetism indicate specific deficiencies in knowledge and understanding of the examined concepts among all students. The analysis of students' answers to the questions revealed that the significant proportion of students wasn't capable to provide scientifically correct answers, and an even bigger proportion wasn't able to explain them correctly, similar to the results of another study (Ningsih et al., 2019). Namely, the mean value of points scored among the second graders was less than 20% of the maximum number of points, while that value for the third and fourth graders was close to 25% of the maximum number of points on the knowledge test.

The second grade students predominantly provided answers that derive from their daily experience. Such answers are prominent in questions related to observations or experiences with the magnets, such as their use and the property of attracting or repelling certain objects. Given that the third and fourth graders were exposed to contents about magnetism, they were able to provide certain answers based on the knowledge they have acquired during the Nature and Society classes. It is most obvious in case of the questions where they were asked to label magnetic poles and determine the type of interaction (attract/repel), or explain why the iron filings were grouped at the ends of magnet, or to recognize the part of a compass made of magnetic material.

The fact that each question was left unanswered by a certain number of students leads to a conclusion that they don't possess the knowledge about the examined concepts. For instance, in the 1st task the students didn't have a problem to recognize magnets on the picture, but they were unable to explain why the same magnets were colored in two colors. Likewise, the students concluded that the parts of halved magnet have magnetic poles, but they didn't mark them, nor provide explanation for that phenomenon. The results of this study imply that some innovations in the primary science teaching should be recommended. Namely, when teaching complex concepts, such as magnetism, it is desirable to apply games and activities in which students will independently experiment, or even better, play the roles of magnets, magnetic poles, and imitate the ways of their interactions, as well as interactions with other objects - materials (Krišková, 2016).

When it comes to the differences in the achievements of students of different grades, it was determined that they are not statistically significant only in the case of comparing the third and fourth grades. The best results were achieved by the third grade students, and, expectedly, the worst were the second graders. In this study, similar to our previous study (Balać et al., 2022), it was found that the fourth graders have lower achievements comparing to the third graders. That could be explained by the significantly smaller volume of content on magnetism in the fourth grade curriculum, as well as the insufficient durability of the knowledge acquired in the previous year. As expected, there were no statistically significant differences in the achievements of boys and girls among students of all grades.

5. CONCLUSIONS

The results of our research showed a low level of adoption of scientific concepts about magnetism, both among third and fourth graders who studied these phenomena in the classes of Nature and Society, and among second graders who had not yet encountered them at school. Based on the insight into the students' answers to individual questions it can be concluded that they don't possess sufficient knowledge about magnets, their properties and applications, to be capable to provide the explanations for the given answers, or suggest solutions within problem tasks. The more detailed analysis revealed that there were significant differences in the quality of adoption of concepts about magnetic phenomena between the second grade students on one side and the third and fourth grade students on the other side, while gender related differences don't exist. By looking at the achievements of students on individual tasks, the most dominant misconceptions about magnetic phenomena were recognized, such as those about the reasons for coloring magnets in two colors, the dependence of the type of interaction on the orientation of the poles and the type of material, about the parts of the magnet where its effect is strongest, the inseparability of the poles as well as certain application of magnets. The identified examples of students' misconceptions in our study completely match the findings of some previous studies (Allen, 2011; Smolleck & Hershberger, 2011). All the abovementioned leads to a conclusion that the process of adoption of concepts about magnetism under the influence of teaching within the subject Nature and Society in elementary school

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is insufficiently effective. In order to overcome the shortcomings of school learning about magnetic phenomena, and based on some earlier research (Bošnjak et al., 2016; Grigorovitch & Nertivich, 2017; Ürek & Çoramık, 2021), the introduction of innovative teaching methods, strategies and models, as well as connecting the teaching contents with the daily experiences of students is highly recommended. Moreover, these phenomena should be studied from the very beginning of primary school education, and even earlier.

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