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Attitudes of high school students towards visualization of mathematical content

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ABSTRACT

Teaching is a process for which its plan should contain reflection onto previous experience. With that in mind, teaching situations should be continuously researched and improved in accordance with the research results. Led by this thought and the fact that students are uncritically using visualization to solve mathematical problems, we defined the aim of this research–determine the attitude of students about the visualization of mathematical content (VMC). The subject of this research are the attitudes of students towards VMC. By analyzing our research subject, we have discovered the research problem–students use visual aid to solve problems uncritically. Based on this problem, we have set the aim of our research. Our aim was to determine the students' attitudes (and their opinions) about VMC. Based on the aim of our research, we have set four research tasks. Based on these research tasks, we have established the main (leading) research question–What is the attitude of high school students towards the application of VMC? We divided the main research question into five questions: Do high school students consider that they understand the term 'VMC'? Who considers they use more methods of solving mathematical problems using visual aid–high school male students or female students? Students of which grades consider that they use solving problems using visual aid more? What is the attitude of high school students about the relationship between the substantiality of the picture (the amount of data it encompasses) and the difficulty of solving the problem? What is the attitude of students about the use of software to solve mathematical problems? The research has been conducted with 1,240 high school students from Sarajevo, Bosnia & Herzegovina. For the purposes of this article, we employed a survey, questionnaire-based research. The research was created as part of a larger study conducted in the context of preparing a doctoral dissertation related to VMC. It is one fundamental research. An essential aspect of this research involves students' attitudes toward VMC. After obtaining all necessary approvals from relevant institutions and parents, students proceeded to testing and surveying in their school classrooms, under the supervision of designated individuals who facilitated the conduct of the research. The distribution of the data was not normal, so we used the Pearson Chi-square, likelihood ratio Chi-square, and linear-by-linear association test to examine the association between student attitudes and categorical variables (gender and grade). In addition, we used frequencies and percentages. It has been concluded that the students are mostly positive towards applying visualization in their process of solving mathematical problems and these should be used in the direction of improving the students' success, their confidence and their level of contentment in their mathematics class, as well as in other life situations that encompass mathematical content. In future research, it could be examined why students expressed such attitudes about the presented situations. Additionally, it would be significant to explore why students do not consider themselves successful in applying VMC, despite claiming to understand the term. The analysis could extend to the content presented in textbooks or instructional materials students use–how visualized the content is or whether students are required to visualize it themselves. It would also be worthwhile to investigate the extent to which teachers encourage students to visualize specific tasks or do so on their behalf. Given the fluctuation in results (we observe affirmative answers–partially or completely) observed across grades–initial decrease, subsequent increase, followed by another decrease–it might be explored whether this is related to the curriculum taught in each grade (such as content, volume, number of class hours, etc.). Regarding images leading to incorrect conclusions, it would be interesting to investigate the types of images students have in mind, how frequently they encounter such situations, where they use these images, who creates them, and similar aspects. These are just some questions for future research.

Keywords: gender, grade, high school students, student attitudes, survey research, teaching process, visualization of mathematical content

INTRODUCTION

Teaching mathematics certainly represents a big challenge because students should be introduced to various and enriched experiences that will motivate them to look forward to what is ahead of them (Aires & Catarino, 2019). With a closer look at the early years and early education, one may notice that the mathematical activities are among children's favorites. That trend continues in the early years of primary school, only to find these kinds of activities at the other end of the same scale of favorite school activities for young students. Considering the importance of mathematical education, it is intolerable to simply ignore these statements. It is vital to continuously look for causes and take all necessary steps to eliminate them. If these causes are eliminated in the early years, there is an undoubtedly good chance that better results will be achieved later. Something that can often be heard when discussing mathematics are statements such as "why do I need this, when will I ever apply this in real life." It is often forgotten that the application is actually the highest form of what should be achieved. In their research, Nesimović and Pjanić (2019) have conclude that teachers do not understand teaching and learning as a united process. They see their teaching as a separate process from the students' learning. The most important change that should happen is the shift of the educational process from the transmissive "teach-learn" process to a more active learning process that requires further engagement from both ends (Pocsova et al., 2022). However, without fundamental knowledge, it is very difficult to achieve even the lowest level of learning (reproduction). STEM classes have risen in popularity in the recent years. However, it may be noticed how usually one of the four disciplines (science, technology, engineering, and mathematics) dominates these classes, and not all four. This further implies that STEM should be represented as a concept from which each one of these disciplines is represented separately. However, that should not happen (Lasa et al., 2020). To obtain actual insight into the way of students' thinking and their knowledge, the process of marking should be analyzed in a more detailed way. It is not recommended to use multiple-choice questions for problems at the intermediate cognitive level (Baranović & Antunović-Piton, 2021). This is why mathematics should be studied in a way that allows students to discover both the horizontal and vertical connection of mathematical knowledge and to strengthen their interest for mathematics (Yanhui, 2018).

The research described in this article is part of a larger research (fundamental research). It presents students attitudes on the visualization of mathematical content (VMC). The attitudes of students are influenced by teaching methods (Akinsola & Olowojaiye, 2008; Mensah et al., 2013) and teacher attitudes (Beswick, 2006), and students' attitudes and their achievements are interconnected, prompting recommendations for investigating students' attitudes towards mathematics (Ajayi et al., 2013; Mata et al., 2012; Mohamed & Waheed, 2011). There is a connection between solving mathematical problems and students' success (Gahi et al., 2023). As teachers perceive teaching as a separate process from student learning (Nesimović & Pjanić, 2019), it is crucial not only to examine students' attitudes but also to make such research accessible to teachers. Teachers can facilitate learning in the classroom (Attard, 2012; Kele & Sharma, 2014), so it is important for them to be aware of student attitudes. It's essential to note that caution is needed when interpreting student attitudes, as they may not always align with the actual situation. In our case, these results will be verified through student testing.

THEORETICAL FRAMEWORK

Hwang and Son (2021) identified four profiles of attitudes towards mathematics, namely: very negative (5.44%), negative (41.38%), neutral (38.77%), and positive (14.41%). Their research showed that students who like to study mathematics and engage in mathematical activities, and those who believe that learning mathematics will result in a positive outcome (e.g., success in school and job opportunities), as well as those who believe in their mathematical abilities, they have high achievements in mathematics. Consequently, they recommend that teachers examine students' attitudes towards mathematics and provide them with appropriate support to stimulate the development of positive attitudes towards mathematics. Ajayi et al. (2013) concluded that students' attitude to mathematics and self-concept have significant joint effect on mathematics achievements. Among the students' factors, attitude is regarded by many researchers as a key contributor to higher or lower performance in mathematics (Mata et al., 2012; Mohamed & Waheed, 2011). Abate at al. (2022) have stated

> "The instructional approaches visualization techniques as well as visualization techniques-assisted problem-based learning approach were significantly contributing towards increasing attitude except for engagement. Hence, it is useful to employ visualization techniques and visualization techniques-assisted problem-based learning approach with amendments to encompass engagement."

Sanchal and Sharma (2017) claim that when students learn in a sports context, their confidence, understanding of the importance of mathematics and engagement increases. Factors that influence students' attitudes towards learning mathematics are the students themselves, the school, teachers' beliefs and attitudes (Beswick, 2006), and teaching methods (Akinsola & Olowojaiye, 2008; Mensah et al., 2013). Teachers can facilitate learning in the classroom, and increase confidence in learning mathematics (Attard, 2012; Kele & Sharma, 2014), and can encourage students to engage in learning mathematics (Sullivan & McDonough, 2007), by embedding teaching content in context real life (Kacerja, 2012). The use of textbooks is a very complex and dynamic process that includes various parameters, not only students and teachers (Jukić-Matić & Glasnović-Gracin, 2020). Makamuro and Jojo (2020) have concluded that the conceptual and figural aspects are not coordinated within most questions, which could represent the lack of visual and spatial reasoning. This is why it is recommended to focus onto the aspect of figural concept of problems in coordinate geometry in order to demonstrate spatial skills in solving geometry problems. It is necessary to conceptually understand the properties of figures, their position in space, their connection etc. Sketches and diagrams are often

used to describe various types of mathematical content (a picture changes a thousand words). In order to achieve wanted results, it is possible to combine different techniques, both visual and formal. One sketch can create multiple conclusions, as well as discover something completely new (Veljan & Marušić, 2009). In Kamber Hamzić et al. (2022), no statistically significant difference was found between those who studied online and those who studied in the classroom, except in the case of an advanced level according to the standards for student achievement in mathematics. Spatial thinking allows an individual to use space for modelling the world (both real and theoretical), to structure problems, find answers and express their solutions (National Research Council, 2006). Gahi et al. (2023) proved that there is a significant relationship between the style of solving mathematical problems and students' performance, and students approach textual mathematical tasks in a thoughtful and analytical way. The mathematics instructor and equipment dimensions have a significant effect on student attitudes among students taking advanced mathematics courses (Moussa & Saali, 2022). Some of the previous studies have shown a strong correlation between spatial skills and mathematical learning and achievements (Atit et al., 2020; Kok, 2021; Mix et al., 2017). This is a point when students understand this more clearly because they can visualize what they are being taught. Geometry represents a challenge in this domain. Tools such as graphs, sketches, diagrams, pictures and models enable and support spatial thinking (National Research Council, 2006). Unfortunately, the images used to study geometry often are not simple or obvious. In these situations, sketching represents an additional difficulty. Besides sketches, using 'mathematical language' may represent another obstacle because oftentimes students are not familiar with some terms or mathematical laws. The focus of mathematics lessons is the development of mathematical thinking, although some authors suggest that special attention should be drawn to the language used in the classroom because the language used to teach significantly impacts its outcomes (Fernández et al., 2022). In an attempt to reduce the number of such situations, we have done a research to understand the attitudes of students regarding VMC. We considered that such data is very significant as preparation for the creation of a doctoral thesis by one of the authors related to VMC. The use of information technologies and systems encompasses the digitalization of classwork. This is expected to transform the concentrated form to distributed form. In this case, learning can occur at different times and at a different pace. Furthermore, the learning process can be divided into several intervals to be suited to individual needs and skills of the student (Pocsova et al., 2022). In their article, Perri et al. (2021) have stated that their aim was to provide students with an environment in which they can focus onto what they are learning. They have directed their research towards immersive learning, especially the use of applications that enable the user to immerse themselves into a virtual world, in order to increase the stimulation of brain during the learning process. Alsina and Nielsen (2006) have presented an interesting way to visualize mathematics using pictures, as well as other examples of visualization in the classroom. It is recommended to simplify the mathematical content in order to make it more comprehensible to students. Making content easier to understand leads to more success among students because it has been proven that the students' self-esteem and confidence are quite low. Furthermore, it is recommended to compliment and encourage the students' work. The use and further development of mathematical mobile applications (MALMath: Mobile application for learning mathematics) is encouraged too, considering that the use of these applications improves the students' self-efficiency (De Asis & Ucang, 2022). The impact of multimedia onto the learning process has been positively received, having in mind that the present generations of students are very familiar with information technologies (Novalić et al., 2021). Within the research framework that has been conducted with university students studying to be teachers, it has been proven that they consider themselves ready for work that includes the highest technological level, which somehow shows that the educational model is purposeful in the segment of information technologies (Brčić, 2020). Psychologist Alan Richardson has conducted a sports experiment, and he has used it to prove that the most efficient visualization happens when the subject feels and sees what they are doing (https://psihologijanovisad.rs/pocetna/vizuelizacija/). Mihajlov-Carević et al. (2020) recommend that the further research should be directed towards assessing the education software that produces visual-logic access to learning mathematics and solving mathematical problems. Studies of Akinsola and Olowojaiye (2008), Beswick (2006), Mensah et al. (2013), and Syyeda (2016) suggest that students' attitude is associated with visualization techniques and problem-based learning approach and their integrated practices. Visualization techniques, problem-based learning approaches and visualization techniques-assisted problem-based learning approaches enhance students' attitude to learn mathematics and retention of subject matters of mathematics (Akinsola & Animashun, 2007; Rabab'h & Veloo, 2015; Ruhan, 2007; Walker & Lofton, 2003).

RESEARCH METHODS

Population & Research Sample

The population of this research consists of high school students (gymnasium) in the Sarajevo Canton in Bosnia and Herzegovina. As it is necessary to obtain the consent of the competent ministry and the school principal, as well as the consent of the parents for each student to allow the child to participate in the research, the sample consisted of students who were present at the time of the research and for whom we had the required permissions. Students were given a survey during their class. The sample consists of 1,240 students. The sample is representative because the margin of error is two. Of that, 20.32% students are from the first gymnasium (prva gimnazija), 8.71% are from the second gymnasium (druga gimnazija), 29.92% from the third gymnasium (treća gimnazija), 22.66% from the fourth gymnasium (četvrta gimnazija), and 18.39% are from the First Bosniak High School (Prva Bošnjačka Gimnazija). When it comes to the distribution of students the grade they are in, 24.03% of students are in first grade, 25.65% are in second grade, 21.45% are in third grade and 28.87% are in fourth grade. It may be noticed that the students are approximately equally distributed by grade (the difference is up to 5.00%). According to their gender, 38.15% of students are male and 61.85% are female, which means that there was a much greater number of female students surveyed for this research (see **Figure 1**).

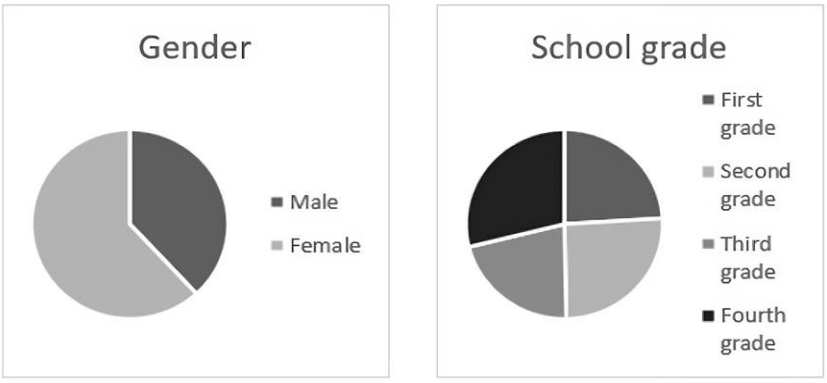

Figure 1. Research sample according to gender & school grade (Source: Authors' own elaboration)

It should be noted that there is a greater number of female students in all schools of the Sarajevo Canton (data taken from the Annual Federal Statistical Office), therefore the sample may be considered representative of a greater number of students.

Research Methods & Instruments

The research method used in this study is surveying. The purpose of the survey was to determine and confirm the distribution of students' attitudes and opinion about certain questions regarding VMC. The instrument of this research has been specially constructed for its single purpose. That is a survey consisting of 10 questions. The distribution of the data was not normal, so we used the Pearson Chi-square, likelihood ratio Chi-square, and linear-by-linear association test to examine the association between student attitudes and categorical variables (gender and grade). In addition, we used frequencies and percentages.

Subject, Problem, & Aims of Research

The subject of this research are the attitudes of students towards VMC. By analyzing our research subject, we have discovered the research problem–students use visual aid to solve problems uncritically. Based on this problem, we have set the aim of our research. Our aim was to determine the students' attitudes (and their opinions) about VMC. The results of the research will be used in the preparation of a doctoral thesis entitled "visual representations in mathematics teaching".

Research Tasks

Based on the aim of our research, we have set a number of research tasks. The tasks are, as follows:

1. Examine and determine the students' attitudes about the understanding of term 'VMC'.
2. Examine and determine the students' attitudes towards solving mathematical problems using images or sketches.
3. Examine and determine the students' attitudes towards the function of a more substantial image in the difficulty of solving problems.
4. Examine and determine the students' attitudes towards using software to solve certain mathematical problems.

Main Research Question

Based on these research tasks, we have established the main (leading) research question. The main research question is, as follows:

1. What is the attitude of high school students towards the application of VMC?

Research Questions

There are several research questions based on the main research question:

1. Do high school students consider that they understand the term 'VMC'?
2. a. Who considers they use more methods of solving mathematical problems using visual aid - high school male students or female students?
   b. Students of which grades consider that they use solving problems using visual aid more?
3. What is the attitude of high school students about the relationship between the substantiality of the picture (the amount of data it encompasses) and the difficulty of solving the problem?
4. What is the attitude of students about the use of software to solve mathematical problems?

RESEARCH RESULTS

First Research Question

Our first research task has been defined as: *Examine and determine the students' understanding the term 'VMC'.* As the result of this task, our first research question has been further defined: *Do high school students consider that they understand the term 'VMC'?*

Table 1. Attitudes of students regarding term 'VMC' (Do you understand term VMC?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Yes	423	34.10	34.10	34.10
Partially	565	45.60	45.60	79.70
No	100	8.10	8.10	87.70
I am not sure	151	12.20	12.20	99.90
No answer	1	.10	.10	100
Total	1,240	100	100	

Table 2. Attitudes of students regarding understanding term 'VMC' according to grade & gender (Do you understand term VMC?)

Gender			Grade				Total
			1st grade of high school	2nd grade of high school	3rd grade of high school	4th grade of high school	
Male	Do you understand term VMC?	Yes	42	38	29	52	161
		Partially	39	57	50	56	202
		No	8	16	10	21	55
		I am not sure	18	12	11	13	54
		No answer	0	0	0	1	1
	Total		107	123	100	143	473
Female	Do you understand term VMC?	Yes	54	63	64	81	262
		Partially	93	97	70	103	363
		No	17	13	2	13	45
		I am not sure	27	22	30	18	97
	Total		191	195	166	215	767
Total	Do you understand term VMC?	Yes	96	101	93	133	423
		Partially	132	154	120	159	565
		No	25	29	12	34	100
		I am not sure	45	34	41	31	151
		No answer	0	0	0	1	1
	Total		298	318	266	358	1,240

The students were asked whether they understand the term 'VMC'. 79.68% of students have stated that they understand the term to some extent (yes and partially), while 20.24% students have disagreed (no and unsure) (see **Table 1**).

To analyze these results by the school grade, it may be noticed that the differences between responses vary up to 5.05% regarding positive responses (yes and partially). To be more precise, 81.56% of fourth-grade students have expressed a certain level of agreeing to the given statement, as well as 80.19% of second-grade students, 80.08% of third-grade students and 76.51% of first-grade students. By applying the Pearson Chi-square test, we obtained that $p=0.063>0.05$, so we also applied the likelihood ratio ($p=0.049$), and linear-by-linear association ($p=0.044$), which indicates a statistically significant linear relationship.

If these responses are analyzed by gender, the situation is, as follows: male students that have responded positively are 79.00% of third-grade students, 77.24% of second-grade students, 75.70% of first-grade students, as well as 75.52% of fourth-grade students. When it comes to female students, the percentages are following: 85.58% of fourth-grade students, 82.05% of second-grade students, 80.72% of third-grade students, 76.96% of first-grade students. It may be noticed that the deviation by grades in the case of boys is up to 3.48%, and for girls it is 8.62% (see **Table 2**). Application of the Pearson Chi-square test ($p=0.003$) and likelihood ratio ($p=0.004$) indicates statistically significant differences.

To summarize, it may be noticed that there have not been any huge oscillations by any variable when it comes to the students' responses (neither by grade nor by gender). Almost 80.00% of high school students declared that they fully or partially understood the term 'VMC'. Deviations from that result are up to 5.00% when we analyze according to grade or gender. Students really do consider that they understand the term 'VMC'.

Our next point of research was the students' opinion regarding the success rate of the application of visualization in mathematics classes. 41.80% of students believe that they successfully visualize various types of mathematical content in order to solve problems to a certain extent. 28.30% of students have disagreed, while 29.90% of students had no opinion on this matter. This question has been analyzed from the gender aspect as well. 45.24% of male students agree with the statement to a certain extent, as well as 39.63% of female students. 26.43% of male students and 29.47% of female students had no clear opinion regarding this question. Application of Pearson Chi-square test ($p=0.401$), likelihood ratio ($p=0.403$), and linear-by-linear association ($p=0.067$) indicates that there is no statistical significance. The same question has been analyzed according to the grade of students. 47.32% of first-students have partially agreed with the statement, as well as 38.99% of second-grade students. Furthermore, 43.23% of third-grade and 38.55% of fourth-grade students have partially agreed to understand the term correctly. On the other side, 26.17% of first-grade and 30.82% of second-grade students have disagreed with the given statement, as well as 27.07% of third-grade and 28.77% of fourth-grade students. The remaining percentage of students have an unclear opinion on this matter. Application of Pearson Chi-square test ($p=0.595$), likelihood ratio ($p=0.588$), and linear-by-linear association ($p=0.171$) indicates that there is no statistical significance. Let's note that regardless of the obtained p-values that indicate no statistical significance, this does not mean that in real life there is absolutely no such significance. There can be many reasons for this.

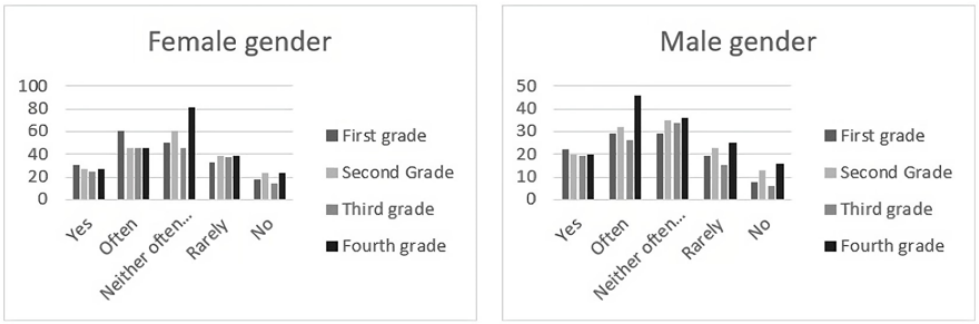

Figure 2. Attitudes of students regarding successfulness of application of VMC in classroom according to gender school & grade (Source: Authors' own elaboration)

Table 3. Attitudes of students regarding using visual aid to solve mathematical problems (Do you use visual aid [pictures, sketches, & diagrams] to solve mathematical problems?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Always	52	4.20	4.20	4.20
Sometimes	625	50.40	50.40	54.60
Not often nor rarely	192	15.50	15.50	70.10
Rarely	297	24.00	24.00	94.00
Never	74	6.00	6.00	100
Total	1,240	100	100	

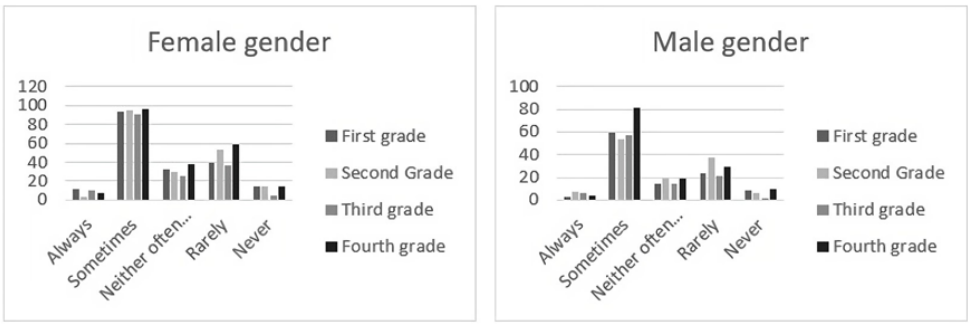

Figure 3. Attitudes of students regarding solving problems using visual aid according to gender & school grade (Source: Authors' own elaboration)

It may be noted that approximately 80% students consider that they do understand the term of 'VMC'. However, when it comes to the successfulness of the application of it, that percentage drops significantly (see **Figure 2**). This means that the term is correctly understood, but that the students are not successful in its application.

Second Research Question

Our second research task has been defined as: *Examine and determine the students' attitudes towards solving mathematical problems using images or sketches*. This research has given us our second research question that has been further divided into two questions: *Who considers they use more methods of solving mathematical problems using visual aid - high school male students or female students?* and *Students of which grades consider that they use solving problems using visual aid more?*

Over 50.00% of students have expressed that they use visual aid to solve mathematical problems (54.60%, to be precise), while 29.92% of students have stated that they do that rarely or never. 15.48% of students had an unclear position on this matter (see **Table 3**).

To analyze these results by gender, it may be noticed that 57.29% of male students and 52.93% of female students have given a positive answer, while 28.75% of male and 30.64% of female students have given a negative answer, while others had an unclear opinion for this question. Application of Pearson Chi-square test (p=0.614), likelihood ratio (p=0.612), and linear-by-linear association (p=0.249) indicates that there is no statistical significance.

If these results are analyzed by grade, it may be noted that 55.70% of first-grade and 50.00% of second-grade students have positively responded to this question, as well as 61.28% of third-grade and 52.79% of fourth-grade students. On the other side, 28.52% of first-grade students and 34.59% of second-grade students have a negative answer to this question, along with 24.06% of third-grade students and 31.28% of fourth-grade students, while the remaining percentage do not have a clear position on this matter (see **Figure 3**).

Application of Pearson Chi-square test (p=0.135), likelihood ratio (p=0.105), and linear-by-linear association (p=0.825) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level.

Table 4. Attitudes of students towards visualizing simple word problems (Do you try to visualize simple word problems?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Always	209	16.90	16.90	16.90
Sometimes	509	41.00	41.00	57.90
Not often nor rarely	160	12.90	12.90	70.80
Rarely	278	22.40	22.40	93.20
Never	84	6.80	6.80	100
Total	1,240	100	100	

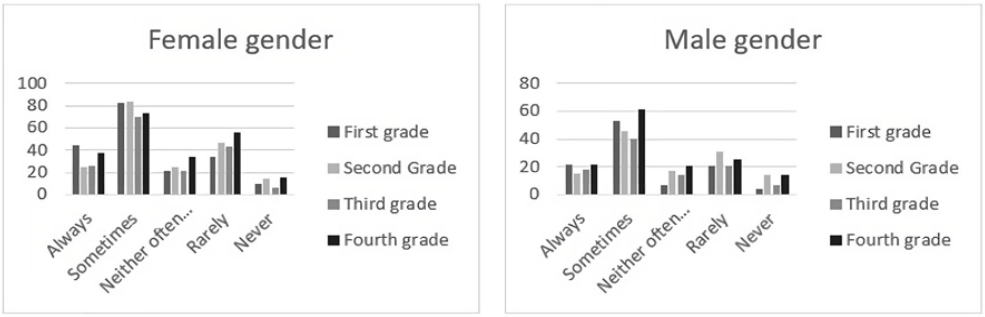

Figure 4. Students' attitudes regarding visualization of simple word problems according to gender & school grade (Source: Authors' own elaboration)

Table 5. Attitudes of students towards visualizing complex word problems (Do you try to visualize simple word problems?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Always	272	21.90	21.90	21.90
Sometimes	481	38.80	38.80	60.70
Not often nor rarely	178	14.40	14.40	75.10
Rarely	226	18.20	18.20	93.30
Never	83	6.70	6.70	100
Total	1,240	100	100	

When it comes to visualizing simple textual information, 57.90% of students attempt to visualize it, while 29.20% do not. 12.90% of students do not have a clear opinion for this question (see **Table 4**).

If these answers are analyzed by grade and gender, then 58.56% of male students and 75.50% of female students try to visualize simple word problems, as well as 67.45% of first-grade students, 53.46% of second-grade students, 57.89% of third-grade students, 53.91% of fourth-grade students. On the contrary, 36.58% of male and 29.34% of female students have disagreed and stated that they do not try to visualize anything in their attempt to solve simple word problems, as well as 23.15% of first-grade students, 33.33% of second-grade students, 28.95% of third-grade students and 30.73% of fourth grade.12.47% of male students, 13.17% of female students could not position themselves in regard to this question, as well as 9.40% of first-grade students, 13.21% of second-grade students, 13.16% of third-grade students and 15.36% of fourth-grade students (see **Figure 4**). In case of gender, application of Pearson Chi-square test (p=0.410), likelihood ratio (p=0.416), and linear-by-linear association (p=0.789) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level. In case of grades, application of Pearson Chi-square test (p=0.016), likelihood ratio (p=0.015), and linear-by-linear association (p=0.017) indicates that there is a statistically significant difference or association between variables. Linear-by-linear association test suggests a linear relationship.

When it comes to visualization of complex word problems, 60.73% of students attempt to create some kind of visual aid, while 24.92% of them rarely do it or do not do it at all. 14.35% of them do not have a clear opinion in regard to this question (**Table 5**).

Analyzing this question in regard to the students' gender and grade, the following observations are given: 57.08% of male students and 62.97% of female students try at visualizing more complex word problems, as well as 65.77% of first-grade students, 52.83% of second-grade students, 65.04% of third-grade students and 60.34% of fourth-grade students. On the contrary, 25.58% of male and 24.51% of female students do not try to do this, as well as 24.50% of first-grade students, 32.39% of second-grade students, 17.29% of third-grade students and 24.58% of fourth-grade students. 17.34% of male and 12.52% of female students could not position themselves clearly in regard to this question, as well as 11.07% of first-grade students, 14.78% of second-grade students, 17.67% of third-grade students and 15.08% of fourth-grade students (see **Figure 5**). In case of gender, application of Pearson Chi-square test (p=0.161), likelihood ratio (p=0.166), and linear-by-linear association (p=0.200) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level. In case of grades, application of Pearson Chi-square test (p=0.000) and likelihood ratio (p=0.000) indicates that there is a statistically significant difference or association between variables. Regardless of the values shown by the linear-by-linear association test (p=0.648), the Pearson Chi-square test and the likelihood ratio test gave very low p-values, so it can be concluded that there is a statistically significant difference or association between the variables.

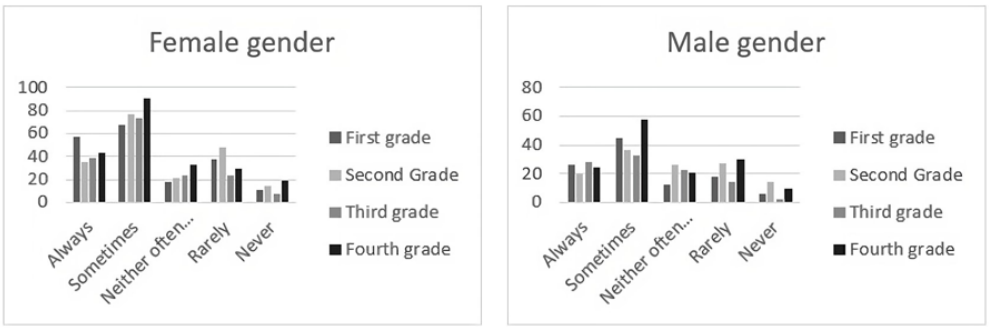

Figure 5. Students' attitudes regarding visualization of more complex word problems according to gender & school grade (Source: Authors' own elaboration)

Table 6. Students' attitudes in regard to misleading visualization of problems (Have you ever been in a situation, where visualizing a problem has led you to a wrong solution?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Yes	332	26.80	26.80	26.80
No	260	21.00	21.00	47.70
I am not sure	648	52.30	52.30	100
Total	1,240	100	100	

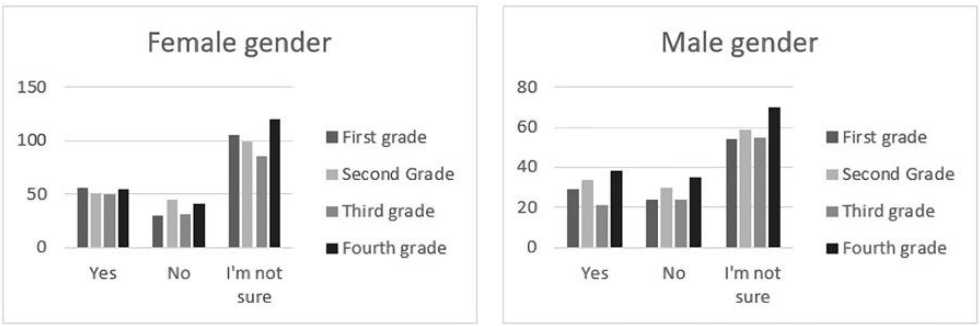

Figure 6. Students' attitudes regarding their experience with misleading visual aid used to solve mathematical problems according to gender & school grade (Source: Authors' own elaboration)

Another point of our research was to examine if visualizing problems has led students to a wrong solution. 26.77% of students responded positively, 20.97% responded negatively, while 52.26% students had no opinion regarding this question (**Table 6**).

Analyzing this question in regard to the students' gender and grade, the following observations are given: 25.79% of male and 19.17% of female students responded positively to this question, as well as 28.52% of first-grade students, 26.73% of second-grade students, 26.32% of third-grade students, and 25.70% of fourth-grade students. 23.89% of male and 19.17% of female students have negatively responded to the question, as well as 18.12% of first-grade students, 23.58% of second-grade students, 20.68% of third-grade students and 21.23% of fourth-grade students. 50.32% of male and 53.46% of female students could not answer this question neither positively nor negatively, as well as 53.56% of first-grade students, 49.69% of second-grade students, 53.01% of third-grade students and 53.07% of fourth-grade students (see **Figure 6**). In case of gender, application of Pearson Chi-square test ($p=0.139$), likelihood ratio ($p=0.143$), and linear-by-linear association ($p=0.755$) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level. In case of grades, application of Pearson Chi-square test ($p=0.774$), likelihood ratio ($p=0.771$), and linear-by-linear association ($p=0.586$) indicates that there is no statistically significant difference or association between variables.

To summarize everything that has been presented so far, the situation is, as follows: 57.29% of male students and 52.93% of female students solve mathematical problems using visual aid (always and sometimes). In regard to simple word problems, that is 58.56% of male and 75.50% of female students and in the case of complex word problems, it is 57.08% of male and 62.97% of female students. 25.79% of male students and 19.17% of female students have occasionally found visual aid misleading in their attempt to solve various mathematical problems. What may be further noticed is that the variance between the answers given by male and answers given by female students is minor. Although a slightly higher number of male students (compared to female students) stated that they use visual aid, a slightly higher number of female students (compared to male students) stated that they try to visualize simple or complex word problems. About a quarter of students stated that they encountered situations, where visualizing a problem has led them to a wrong solution. Slightly more than half of the respondents (male and female students) stated that they had not encountered such situations.

Furthermore, it may be noticed that 55.70% of first-grade and 50.00% of second-grade students use visual aid to solve mathematical problems, as well as 61.28% of third-grade students and 52.79% of fourth-grade students. In the case of simple word problems, that was 67.45% of first-grade students and 53.46% of second-grade students, along with 57.89% of third-grade and

Table 7. Students' attitudes regarding correlation between a more substantial picture & solution of a mathematical problem (Do you consider that a more substantial image [sketch, graph, & diagram] leads you to solution of problem more easily?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Always	303	24.40	24.40	24.40
Sometimes	625	50.40	50.40	74.80
Not often nor rarely	153	12.30	12.30	87.20
Rarely	125	10.10	10.10	97.30
Never	34	2.70	2.70	100
Total	1,240	100	100	

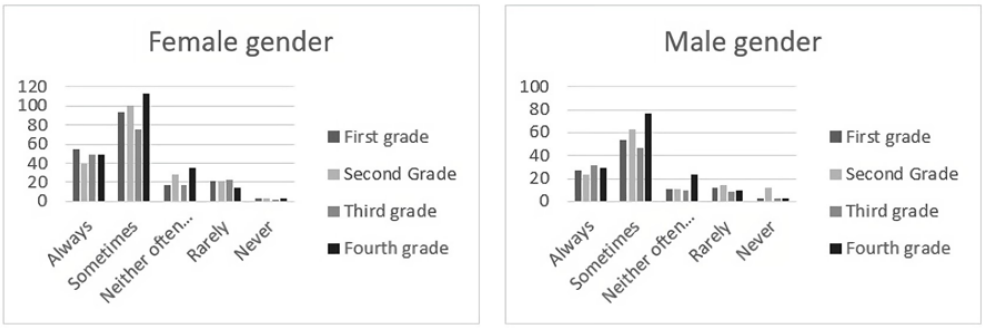

Figure 7. Students' attitudes regarding correlation between more substantial images & solutions according to gender & school age (Source: Authors' own elaboration)

53.91% of fourth-grade students. In the case of complex word problems, 65.77% of first-grade students and 52.83% of second-grade students have stated that they use visual aid to solve these problems using visual aid (images, sketches, and graphs), as well as 65.04% of third-grade and 60.34% of fourth-grade students. Moreover, 28.52% of first-grade students and 26.73% of second-grade students have found using visualization misleading in their attempt to solve mathematical problems, and in the case of older students, 26.32% of third-grade and 25.70% of fourth-grade students agreed. It may be noticed that there are no noticeable deviations in these answers too. The only thing we can conclude based on the obtained results is that in all three cases (using visual aid to solve mathematical problems, visualizing simple or complex word problems), if we look from the first to the fourth grade, the percentage of positive answers (completely or partially) first decreases, then increases, and then decreases again. In the last observed case, the percentage of positive responses is constantly decreasing.

Third Research Question

Our third research task: *Examine and determine the students' attitudes towards the function of a more substantial image in the difficulty of solving problems* has led to the third research question of this research: *What is the attitude of high school students about relationship between substantiality of the picture (the amount of data it encompasses) and the difficulty of solving the problem?*

Students were asked whether they consider that a more substantial image (or sketch or graph or diagram) leads to a solution more easily. 74.84% of students have positively answered this question, while 12.82% students have disagreed with them. 12.34% of students had no clear opinion on this question (see **Table 7**).

To analyze this question by gender and the school grade, 74.42% of male students and 75.10% of female students have positively answered this question, as well as 76.85% of first-grade students, 71.38% of second grade students, 76.69% of third-grade students and 74.86% of fourth-grade students. 13.74% of male students and 12.26% of female students have responded negatively, along with 13.76% of first-grade students, 16.35% of second-grade students, 13.16% of third-grade students and 8.66% of fourth-grade students. 11.84% of male students and 12.65% of female students could not define their position regarding this question, along with 9.40% of first-grade students, 12.26% of second-grade students, 10.15% of third-grade students and 16.48% of fourth-grade students (see **Figure 7**). In case of gender, application of Pearson Chi-square test (p=0.061), likelihood ratio (p=0.069), and linear-by-linear association (p=0.266) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level. In case of grades, the Pearson Chi-square (p=0,001) and likelihood ratio (p=0,001) tests both suggest a significant association between the variables, but the linear-by-linear association test (p=0,494) does not show a significant linear association.

To summarize the given results, it has been proven that 74.84% of students consider the use of more substantial images helpful in their attempts to solve mathematical problems. We got approximately the same percentage when we analyzed by gender and grade. Therefore, we proved that the attitude of high school students is that a more substantial image leads to easier solving of the problem.

Fourth Research Question

The fourth research task: *Examine and determine the students' attitudes towards using software to solve certain mathematical problems.* has led to the fourth research question of this research: *What is the attitude of students about the use of software to solve mathematical problems?*

Table 8. Students' attitudes regarding use of software in their mathematics class (Would you like to visualize mathematical content using software in your mathematics class?)

	Frequency	Percentage (%)	Valid percentage (%)	Cumulative percentage (%)
Always	566	45.60	45.60	45.60
Sometimes	206	16.60	16.60	62.30
Not often nor rarely	235	19.00	19.00	81.20
Rarely	99	8.00	8.00	89.20
Never	134	10.80	10.80	100
Total	1,240	100	100	

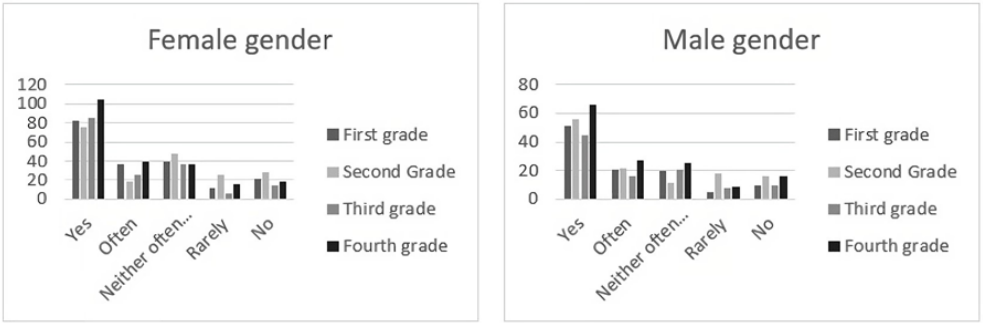

Figure 8. Students' attitudes regarding use of software in their mathematics class according to gender & school grade (Source: Authors' own elaboration)

The students were asked whether they would like to visualize mathematical content in their class using software. 62.26% of students stated they would like to do this, while 18.79% of students disagreed. 18.95% of students had no clear opinion regarding this question (see **Table 8**).

To analyze this question in regard to the students' gender and school grade, 64.27% of male students and 61.02% of female students positively answered this question, along with 64.09% of first-grade students, 54.50% of second-grade students, 64.29% of third-grade students and 66.20% of fourth-grade students. On the contrary, 19.45% of male students and 18.38% of female students negatively responded to this question, along with 16.11% of first-grade students, 27.36% of second-grade students, 14.29% of third-grade students and 16.76% of fourth-grade students. 16.28% of male and 20.60% of female students declared no preference in regard to this question, along with 19.80% of first-grade students, 18.24% of second-grade students, 21.43% of third-grade students and 17.04% of fourth-grade students (see **Figure 8**). In case of gender, application of Pearson Chi-square test ($p=0.369$), likelihood ratio ($p=0.363$), and linear-by-linear association ($p=0.746$) indicates that there are no statistically significant differences or differences between variables at the 0.05 significance level. In case of grades, both the Pearson Chi-square ($p=0.003$) and likelihood ratio ($p=0.005$) tests indicate a significant association between the two categorical variables. However, the linear-by-linear association test ($p=0.127$) does not show a significant linear association.

To summarize the given results, it may be noted that 62.26% of students would like to visualize mathematical content using some kind of software in their mathematics class. We got approximately the same percentage when we analyzed by gender and grade. Considering the magnitude of the obtained percentage, we can argue that high school students wish to enhance their mathematics classes by incorporating specific software. However, it is necessary to further investigate the reasons why some were opposed to this idea, while others did not express their opinion.

Within the framework of the doctoral thesis project, it is envisaged that the research questions or student attitudes will be verified using other instruments (e.g., tests). It will be very interesting to compare how student attitudes align with the real situation. It is worth noting that this is fundamental research, so, for now, we cannot compare the results we obtained with any previous findings.

DISCUSSION

Within the framework of this research, we have examined the students' attitudes towards VMC. Being led by this, we have set four research tasks that have resulted in four research questions (the second research question has been divided in two, therefore there were five research questions). Regarding the first research question (*Do high school students consider that they understand the term 'VMC'?*), we came to the following conclusion: students believe that they understand the term of 'VMC' (79.68%), but they do not consider themselves successful in its application (41.8%).

Regarding the second research question (*Who considers they use more methods of solving mathematical problems using visual aid–High school male students or female students?*

Students of which grades consider that they use solving problems using visual aid more?), we came to the following conclusion: Although a slightly higher number of male students (compared to female students) stated that they use visual aid (57.29%), a slightly higher number of female students (compared to male students) stated that they try to visualize simple (75.50%) or complex (62.97%) word problems. About a quarter of students (26.77%) stated that they encountered situations, where visualizing a

problem has led them to a wrong solution. Slightly more than half of the respondents (male and female students) (52.26%) stated that they had not encountered such situations. The only thing we can conclude based on the obtained results is that in all three observed cases (using visual aid to solve mathematical problems, visualizing simple or complex word problems), if we look from the first to the fourth grade, the percentage of positive answers (completely or partially) first decreases, then increases, and then decreases again (for case - using visual aid to solve mathematical problems: 55.70% ↓ 50.00% ↑ 61.28% ↓ 52.79%; for case–visualizing simple word problems: 67.45% ↓ 53.46% ↑ 57.89% ↓ 53.91%; for case–visualizing complex word problems: 65.77% ↓ 52.83% ↑ 65.04% ↓ 60.34%). In the last observed case, the percentage of positive responses is constantly decreasing (28.52% ↓ 26.73% ↓ 26,32% ↓ 25.70%).

Regarding the third research question (*What is the attitude of high school students about the relationship between the substantiality of the picture (the amount of data it encompasses) and the difficulty of solving the problem?*), we came to the following conclusion: We got approximately the same percentage (74.84%) when we analyzed students' attitudes on this issue by gender (74.42% for male and 75.10% for female) and grade (76.66% for first-grade, 71.38% for second-grade, 76.69% for third-grade, and 74.86% for fourth-grade). Therefore, we proved that the attitude of high school students is that a more substantial image leads to easier solving of the problem.

Regarding the fourth research question (*What is the attitude of students about the use of software to solve mathematical problems?*), we came to the following conclusion: We got approximately the same percentage (62.26%) when we analyzed students' attitudes on this issue by gender (64.27% for male and 61.02% for female) and grade (64.09% for first-grade, 54.50% for second-grade, 64.29% for third-grade, and 66.20% for fourth-grade). Considering the magnitude of the obtained percentage, we can argue that high school students wish to enhance their mathematics classes by incorporating specific software.

The main research question of this article is: *What is the attitude of high school students towards the application of VMC?* Only in two cases did we find that the percentage of positive responses from high school students regarding the posed question is less than 50%. These cases involve–the successful application of visualization mathematical content in the classroom (41.80%) and situations about students' experience with misleading visual aid used to solve mathematical problems (26.77%). In all other instances, the percentage of affirmative responses (either fully or partially) is above 50%. This leads us to the conclusion that high school students hold a positive attitude towards the application of visualization in mathematical content.

We have demonstrated that students believe they understand the term VMS, but they do not consider themselves successful in its application. This leaves an open question as to why they think so and what can be done to change that. When asked if they visualize the text of a problem, almost 30.00% of students stated that they rarely or never do so, which is a significant percentage when it comes to mathematics. We believe students should be encouraged to visualize in math classes, as it often facilitates problem-solving and helps students generate new ideas and approaches. Regarding visualizing simpler or more complex text problems, approximately the same number of students gave a positive response, while female students indicated that they visualize simpler tasks more often. In all these cases, the percentage is higher than 50.00%, which is still a significant number. Students believe that more meaningful images make problem-solving easier, prompting us to consider this when planning teaching and educational content. Concerning educational software that could become part of each class, we can only speculate why just under 20.00% of students do not have a clear stance on it and an equal number are against its introduction. Perhaps students fear changes and believe it could further complicate the curriculum or expand its scope. However, this is only a hypothesis based on the authors' opinions and experiences, which should also be verified in future research.

CONCLUSIONS

We examined the attitudes of high school students related to the posed research questions. This provided insights into their opinions. Students believe they understand the term 'VMC,' but they do not consider themselves successful in its application. Slightly more than half of the students stated that they use visual aids provided in the task when solving it and visualize both simpler and more complex tasks themselves. A significant number of students believe that a more meaningful image facilitates the process of solving a task. A considerable number of students expressed a positive attitude towards the introduction of software into the teaching process. Based on the investigation of students' attitudes towards VMC, the results indicate that there is a general positive disposition towards the application of visualization in mathematics.

Being led by the idea that the motivation is necessary for any positive outcome, we believe that these positive attitudes should be used and that we should visualize mathematical content using various software in various ways. This should further improve their successfulness, self-esteem and satisfaction in mathematics class.

However, while some questions prompted less favorable responses, the majority of students believe that visualization facilitates the process of solving mathematical problems. It is imperative to explore why students perceive themselves as unsuccessful in applying visualization and how their understanding and performance in mathematics can be enhanced. Further research is recommended to deepen the understanding of the relationship between students' attitudes, their achievements, and teaching methods. Additionally, strategies for promoting visualization in the classroom should be considered, considering individual needs and student attitudes.

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Ethical statement: The authors stated that the Commission's report on the doctoral dissertation project of M. Sc. Belma Alihodžić, titled "Visual Representations in Mathematics Education," was approved at the 44th session of the University Council of the University of Sarajevo - Faculty of Natural Sciences and Mathematics (number 01/01-2066/2-022, dated September 8, 2022) and at the 50th session of the Senate of

the University of Sarajevo (number 01-13-151/22, dated September 28, 2022), and the research was also approved by the relevant Ministry of Education (number 11-04/01-34-38-38241-1/21, dated October 25, 2021). As part of the conducted research, all consents of the parents of the students who participated in the research were collected.

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.

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