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Examining 6th Grade Students' Learning of the Subject of Volume with GeoGebra Software Within the Framework of RME Approach

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Abstract

In the world where we always meet geometric constructions, it is a necessity to make sense of the objects belonging to these constructions. In this respect, this study aimed to examine the teaching of volume with the blending of the realistic mathematics education (RME) and GeoGebra. The study group consisted of 12 students attending lessons regularly. In the study, action research was used, and the data obtained were interpreted with descriptive and content analysis. The data collection tools used in the study included semi-structured interview forms, video records, audio records and activity sheets prepared by the researcher in accordance with the RME approach. When the findings were examined, it was concluded that the positive impressions occurring in the visualization and interpretation processes of the students allowed the students to write mathematical sentences as well as to interpret the outputs by making mathematical inferences.

Keywords: mathematics education, GeoGebra software, realistic mathematics education (RME), geometry, teaching volume.

1. Introduction

Mathematics education has been able to continue on its way by interacting with different styles from time to time. The effort to show what exists in the form and extent required by the conditions is equivalent to reaching the saturation point of an unlimited taste because mathematics bases its existence on the real world and can accordingly position its meaning on mathematics in the real world (Gasking, 1940: 214). The idea that more use of different learning styles will increase the number of positive reactions in the process has been one of the biggest helpers in the process (İrmak & Çelik, 2021). The fact that mathematics is accessible to everyone also requires mastery of different learning styles. This will be possible by transforming mathematics education in a way that appeals to more than one sense organ (Yenilmez & Bozkurt, 2006). In this respect, the concretization of mathematics will also lead to a positive increase in levels of learning (Dündar, Temel & Gündüz, 2015). The connection of mathematics with daily life is a different version of being able to associate concrete experiences with mathematics. Various alternatives and materials can be used during teaching so that both conceptual learning and procedural learning can be completed at the same time in the mathematics education process. One of them can be expressed as integrating technology into mathematics education. The role of technological developments has undeniable importance at the stage of concretizing mathematics and students' making sense of it (NCTM, 2020). Computer algebra systems (CAS) and Dynamic

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geometric software (DGS), which certain innovations in information technologies have brought to mathematics education, serve as two important tools in the technological breakthrough process that will occur in mathematics education (Erdener & Gür, 2019). In this respect, a software that can be used during mathematics education is GeoGebra. Markus Hohenwarter, the founder of GeoGebra, defines GeoGebra as Dynamic Mathematics Software (DMS) because it is a combination of CAS and DGS.

It is also important to ask the right questions and to determine the solution methods accordingly in the process during the teaching. Realistic Mathematics Education (RME), which emerged as a way of combining mathematics education with the situations students have experienced in this process, will help them focus on, consider and question the problem. As an alternative to combining the language of mathematics with real-life situations, RME also gives students the opportunity to use mathematical tools to organize and solve problem situations (Heuvel-Panhuizen & Drijvers, 2014). According to Freudenthal, the founder of RME, mathematics should be associated with life, and it should thus be realized that mathematics is actually a consequence of human activities in daily life (Zulkardi, 2002). With the help of these mathematical activities, it is important for students to have more than one focus and to find the right path with the right questions and follow-up instructions in this process. Geometry is one of the important branches of mathematics that helps students understand, analyze and solve the problem. Geometry, which helps students to concretize abstract objects by expanding their world of meaning (Duatepe, 2016), can also provide opportunities for expansions that will take place in their minds. It also paves the way for spatial thinking skills. The teaching of the subject of volume can also be handled in this context, and it is directly related to the spatial thinking skills of students.

Purpose of the study

The purpose of this study was to examine the feedback to be received as a result of the teaching of the 6th grade subject of "Can calculate the volume of a rectangular prism with unit cubes" with the blending of the RME approach and the dynamic geometry software of GeoGebra.

1.1 *Research problem*

The main problem in this study was "How do 6th grade students progress towards formal information about the subject of volume expected to be achieved by solving context problems with GeoGebra activities?" It is possible to list the sub-problems of the study as follows:

- In the teaching supported with GeoGebra activities created within the framework of the RME approach, what are the strategies to be developed by the 6th grade students regarding the output of "Can place the unit cubes on the prism to fill the rectangular prism and calculate the volume of the object by making use of the total number of unit cubes."

- In the teaching with activities related to GeoGebra-supported context problems within the framework of the RME approach, do 6th grade students construct the formal information about the output of "can use unit cubes to form different rectangular prisms with the volume determined and can explain the Base area with the x-height formula to be used in volume calculation."

- Can 6th grade students transfer their formal knowledge about the output of "Can create the necessary formula for calculating the volume of a rectangular prism and solve related problems" to other context problems via the teaching with the help of activities of GeoGebra-supported context problems created within the framework of RME approach?

- What is the effect of teaching supported with GeoGebra activities created within the framework of RME approach on 6th grade students' prospective thinking skills related to the output of "Can estimate the volume of a rectangular prism?"

2. Method

2.1 *Research model*

This study consisted of a part of a completed master's thesis, which was carried out to evaluate learning that occurred as a result of the teaching of the subject of volume in a secondary school in Turkey with the activities prepared in GeoGebra and organized according to the Realistic Mathematics Education approach. The M.A. study included 11 question groups and 19 accompanying sub-study questions (Alan, 2021). In this study, 4 question groups and 7 sub-study questions were used. In the study, action research, one of the qualitative research methods, was used. In action research, process-oriented study is conducted; practice is made; and detailed and in-depth examinations and observations are carried out. In addition, it is a flexible approach which can bring together the research and application process and which makes it possible to include research results into practice. In this approach, the practitioner is also in the role of the researcher (Yıldırım & Şimşek, 2018; Türkkan Turhan, Yolcu & Karataş, 2019). This situation also exists in qualitative research itself, and in qualitative research, the researcher is also at the base of the study (Fraenkel, Wallen & Hyun, 2011).

2.2 *Study group*

The study group was made up of 18 6th grade students studying at a secondary school in Turkey. However, the number of students who attend regularly and who did not cause any interruption during the study was 12. Maximum diversity sampling was preferred when choosing the research sample. In maximum diversity sampling, the purpose is to create a small sample and to maximize the diversity of individuals who might be a party to the problem being studied on (Yıldırım & Şimşek, 2018). In this way, different approaches to the problem may emerge (*Ibid.*, 2018). In this study, as the purpose was to determine the original methods that students would develop to calculate volume without using the formula to find volume, the maximum variety sampling was used.

Because the researcher teacher method was used in the study, the students were selected from the class that the researcher taught. While presenting the data, the students were coded as S1, S2, ..., S12 and the researcher was coded as "R".

Table 1. Gender distribution of the participants

Gender	**Number of Participants**
Female	5
Male	7
Total	12

2.3 *Data collection tools*

In this study, more than one data collection tool was used to ensure the diversity of the data (Johnson, 2015). The data collection tools included semi-structured interviews, video records, audio records and worksheets prepared by the researcher in GeoGebra in accordance with the RME approach. During the preparation of the worksheets, the researcher took lessons in order to create a worksheet suitable for RME and to create an activity in GeoGebra. After these lessons, suitable activity designs were made. Following this, the activity was designed in GeoGebra, and questions were prepared in accordance with RME. Necessary corrections were made by taking expert opinions about the questions. Next, the questions to be used during the activity were finalized. The worksheets are presented in Appendix 2. In the semi-structured interview technique, the researcher prepares in advance the draft of the questions s/he plans to ask (Türnüklü, 2000). The semi-structured interview form can be seen in Appendix 3. This interview form aimed to obtain information about the effects of learning with GeoGebra on students in general and about the effect of context problems prepared based on the RME approach on their learning of the subject. The questions used here were finalized by doing the necessary corrections in line with the opinions of two experts in the field. Necessary permissions were obtained prior to the interview, and then the interviews were recorded.

2.4 *Data analysis*

For the analysis of the data obtained within the scope of the study, descriptive analysis and content analysis, which are among qualitative data analysis methods, were used. The descriptive analysis method can be defined as the process of transferring data in a meaningful way (Merriam, 2009). The data obtained in the descriptive analysis are interpreted within the framework of predetermined themes, and the opinions of the individuals interviewed are presented with direct quotations (Yıldırım & Şimşek, 2018). In content analysis, which is mostly used in the analysis of written data, in-depth interpretations can be made by classifying the data (Miles & Huberman, 1994). The basic process in content analysis is to combine similar data under common concepts and to interpret them in accordance with the principle of clarity to the reader (Yıldırım & Şimşek, 2018). Based on this process, in the coding phase of the data, the concepts with similar meanings were named by bringing them together with the same codes on a common ground. In this way, it was possible to bring together the concepts from different sections (Yıldırım & Şimşek, 2018). The activity titles in this study were thematized within the framework of descriptive analysis. Next, the data obtained from the worksheets, interviews, video records and audio records were categorized and coded within the framework of content analysis.

3. Findings

This part of the study included the findings that emerged from the analysis of the data obtained from the worksheets applied during the teaching process, from the semi-structured interview forms and from the analysis of the video recordings made during the lesson.

3.1 *Candy tower activity*

Table 2. Analysis of the sugar tower activity

Theme	Categories	Codes	Frequency
Candy Tower	Theoretical Approach	Formula Approach	12
		Height-Size Association	1
		Area-Volume Confusion	4
	Practical Approach	Metaphorical Approach (House, pole, box, etc.)	3
		Lack of Knowledge about Elements Required for Prism	**10**

The themes and codes that emerged in the Sugar Tower activity can be seen in Table 2. The situation determined in the majority of the students was that the formula-oriented approach was present in all of the participating students. It was stated in the section of application phase that the situation encountered was not coincidental. Despite having this approach, one student also used the concept of dimension and emphasized that finding volume could actually be an expression of the object gaining dimension.

A few examples of the solution papers regarding the formula-oriented operations of the students are presented below.

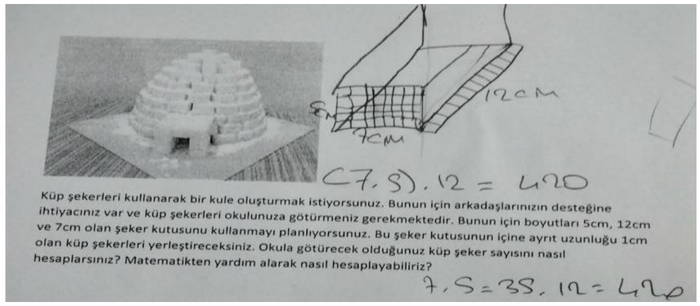


Figure 1. S7's solution on paper

When the student's solution was examined, it was seen that s/he tried to visualize it by doing visualization. However, after this, the student turned to the formula and left the drawing phase unfinished. In the conversation with the student, the student tried to explain the reason for this situation.

...

R: You stopped drawing after a while. Can you explain why?

S7: Teacher, the candies are on the top of one another here, so I left it unfinished.

R: What could be the reason for that?

S7: We put it on top of one another, which results in the height.

R: What does this height mean to us?

S7: It helps us obtain volume...

It would be wrong here to say that the student found a result without turning to the formula because towards the end of the speech, the student said "... to find the formula".

3.2 *Catch the dice*

Table 3. Analysis of the catch the dice activity

Theme	**Categories**	**Codes**	**Frequency**
Catch the Dice	Visualization-based thinking	Distinction of the Cube-Rectangular Prism	5
		Being able to use dynamic software	8
	Formula-oriented thinking	Have a result-oriented approach	7
		Focusing on counting	**3**

When the data obtained as a result of the analyses in Table 3 were examined, two important categories basically observed in the students stood out. These were the development of visualization-based thinking and formula-oriented thinking. When the codes obtained here were examined, it was seen that the students named the rectangular prism that they had created or would create as a "cube". The code of not knowing the elements of the prism, which we examined in the first question, actually turned into not knowing the definition of the prism. This allowed us to make the interpretation that the students did not know the definition of the cube they claimed to know. In this respect, the interview with S4 was as follows:

R: How did you get 24?

S4: By multiplying the edges.

R: Why did you multiply the edges?

S4: To find the result.

R: Although finding the result is important, it is not the answer to this question. Do you want to show me why you multiplied it?

S4: (Starts placing the dice.) Look, there are two placed here… I can't draw it well …

R: Not important. I can understand.

S4: (Places the dice) And it's 24 when we count.

R: So can we find out why we multiplied?

S4: First we find out how many can be placed on the bottom. Here we multiply these (meaning 2 cm and 3 cm), and it makes 6. Then, we multiply 6 by 4 and we get 24, since it will have 4 floors.

But this is too long, I can find it directly with the formula.

R: Wouldn't it be better if you got the formula yourself?☺

S4: Yes, you are right☺

Here, the student only put the height in the formula, and s/he made no statement about why s/he multiplied by the height. In the discussion with the student, hints were given to the student, yet the student insisted on not participating.

3.3 *Combine the legos*

Table 4. Analysis of the Combine Legos Activity

Theme	Categories	Codes	Frequency
Combine the Legos	Being able to Transfer knowledge	Associating with prior learning	8
		Willingness to make Visualization	10
		Making sense through the model	9
	Staticization of knowledge	Distinction of Rectangular prism - Cube	3
		Floor-Height Relationship	**12**

In the analyses in Table 4, two separate categories were obtained, namely transferring knowledge and staticizing knowledge. In the category of transferring knowledge, the striking code was association with pre-learning. The category of staticization of knowledge, on the other hand, indicated that the knowledge was transferred statically, that is, by heart. Here, the students constantly used the expressions "as we saw in the previous question" and "same as the logic of the first question", and this caused us to make the interpretation that they could not transfer new questions to new situations.

An example of this situation is as follows:

S3: Teacher, it is the same, I think. We will find it by multiplying, too.

R: Are you sure?

S3: Yes, teacher.

R: So can you tell me why we multiplied?

S3: Teacher, I don't remember.

R: Shall we think about it together?

S3: All right, teacher.

R: What would you start by doing first?

S3: Let's create our box first, teacher. Then, let's place the cubes inside our box.

R: You can do it.

S3: Can I do this in Geogebra? I can show it better there.

R: Of course, let's see.

S3: First I will create my box so that its length and width are 3 cm and its height is 4 cm.

R: Well, can you tell me the mathematical name of the shape of the box?

S3: It would be a cube if all its edges were equal, but here the height is 4 cm, so this is a rectangular prism.

R: Yes, go on, please.

S3: I place the Legos at the bottom of my box.

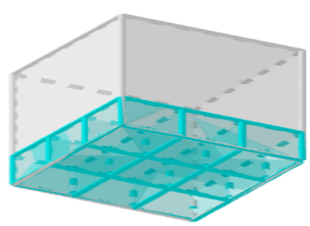


Figure 2. S3's GeoGebra solution phase

S3: Now we can count the base. There are 9 in total.

R: Yes, go on, please.

S3: We will draw 3 floors more.

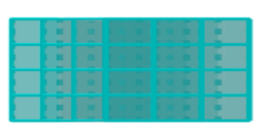


Figure 3. S3's drawing on the GeoGebra screen

R: What does drawing 3 more floors remind you of?

S3: It reminds me of going up to an apartment with a lift.

R: How many Legos in total then?

S3: There are 4 floors in total and 9 on each floor. So there will be 36 in total.

In the conversation between the researcher and the student, while the student first had a static thought, s/he used his/her imagination with the clues given to him/her and reached the solution without feeling the need to use any formula with the help of visualization. The student's initial focus on using formulas was never used at the moment of reaching the result.

3.4 *Partners of the pie*

Table 5. Analysis of the partners of the pie activity

Theme	Categories	Codes	Frequency
Partners of the Pie	Negative acquisition	Size-height misconception about the object created	2
	Positive acquisition	Getting the formula	10
		Creating problem situations	7

In the analysis of this question, "size-height misconception about the object created", which belonged to the category of negative acquisition, was encountered for the first time. Here, two students considered the heights of the created object, that is, the unit cube-shaped objects with dimensions of 1 cm, as the dimensions of the main object (pie). The fact that students think in groups shows that they reach results that support the same inferences. The fact that the students thought in groups shows that they reached the results supporting the same inferences.

Some of the students expressed the formula in their own sentences without using a formula and ended the solution phase.

S12: For example, let this be our classroom, not a pie. Let's fill it with unit cubes. But first let's calculate the base of the classroom, as if it were a field.

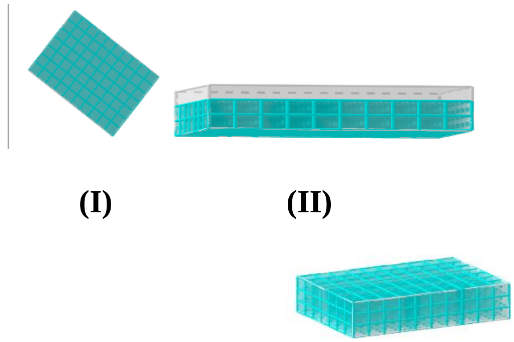
R: What will the dimensions of the classroom be?

S12: Nothing has changed, teacher. We're just going to think of the question that way.

R: Right, you can go on.

(The student stated that s/he wanted to show in GeoGebra and did the next operations in GeoGebra.)

S12: Let our base be 10 cm and 7 cm. A total of 70 things fit here (meaning the unit cube). Since the bottom is full, we will also put on the top. As there will be 3 floors, it will make 210 in total.



(I) **(II)**

(III)

Figure 4. S12's solution phases

S12: So, every time we go up, we multiply the base by that floor number. To find the total result, we must multiply it by the total number of floors, that is, the height.

R: Can you express this mathematically?

S12: I can if you help☺

R: You start, I'll help where needed☺

S12: First we multiplied the edges of the base to find how many can be placed on the base.

R: So you find the area of the base?

S12: Yes, that is what we call the area of the base. Then we multiplied the result with the height. Thus, we found the volume.

R: Well done.

In this way, the student made sense of the equation of Volume = (Base area) x Height.

3.5 *Findings obtained via the semi-structured interview form*

Table 6. Analysis of the semi-structured interview form

Theme	Categories	Codes	Frequency
Use of the dynamic software of GeoGebra in teaching volume	Positive effects on the process	visualization and being able to create the shape	12
		Being able to move the shape	8
		Being able to make as many changes as desired	4
		Being able to interpret the concepts	6
		Time	12

		Developing self-confidence	9
	Negative effects on the process	Having difficulty in the movement of the sliders	3
		Being unable to see how the shape emerges	2
		Not losing the shapes formed	**10**

4. Conclusion, discussion and suggestions

This section presents the conclusions regarding the findings and includes related suggestions for the situations that could be observed.

4.1 *Conclusion and discussion*

In the study, 6th grade students' learning of volume with the GeoGebra software was examined within the framework of the RME approach. When the findings obtained in the study were examined, some major codes emerged, and the number of codes that continued to repeat themselves was also found quite high. These codes were metaphorical perception, volume calculation based on counting, conceptual knowledge of height, the relationship between the concepts of area and volume, the cube-rectangular prism distinction and the effect of visualization on teaching. Based on these codes, it could be stated that they generally have a concept-based background. When the literature is examined, it is possible to see many studies on the importance of concepts in mathematics education (Nasibov & Kaçar, 2005; Aşıcı & Dede, 2019; Zengin, 2017; Yavuz Mumcu, 2018; Yıldızhan & Şengül, 2017; Akkurt, 2020). In addition, contents similar to these codes, which were obtained by teaching the subject of volume, were also found in various studies (Ertem Akbaş, 2021; Bayezit, 2019; Esen & Çakıroğlu, 2012; Koçak & Soylu, 2018; Gürbüz & Gülburnu, 2013; Kültür, Kaplan & Kaplan, 2002; Okuyucu & Erdoğan, 2021; Zengin & Akçakın, 2021; Demirel, Somyürek & Yılmaz, 2017). As can be understood from these studies, it could be stated that the formula-oriented educational studies draw a prototype for the students and that within this framework, they do not leave any space for the students to think freely. Moreover, new approaches that can be created using the imagination of students are often of an original nature, and it is essential to develop them. This situation, which we encountered frequently during the analysis of the first activity, allows us to make a comment on the great place that students' imagination skills occupy in mathematics education. There are various studies that share the same ground with this finding (Erdoğan, 2006; Çoban, 2010; Arı, Demir and Işık, 2019; Kurtuluş and Uygan, 2016; Özçakır and Aydın, 2019). In addition, the concept of dimension, which appeared together with the first activity and which was constantly discussed and commented on until the last activity, also makes it possible to say that the students' 3-dimensional thinking and interpretation skills were developed. This finding contrasts with the findings obtained in the studies conducted by Dane and Başkurt (2012) and Öksüz (2010). In their study, Dane and Başkurt (2012) mentioned the wrong examples that the students experienced in the process of making sense of the concept of size, while in this study, the students were able to fully understand and interpret the concept of size, especially towards the last activities. In addition, in the semi-structured interviews, the students, by expressing this verbally, reported that they could make inferences about the meaning of the concept of dimension. In the second activity, when the students were asked not to think in the formula-dependent manner, it was seen that they used the counting method and counted one by one. However, considering the possibility of this situation to think originally and to reveal a new approach after a while, no negative feedback was given to the students. Towards the end of the study, it was seen that most of the students (75%) made an effort to formulate the counting method. In this way, when the students were given the necessary opportunity, it could be stated that they would attempt to write mathematical sentences. Arıkan (2016) reached similar results in his study. In addition, Canbazoğlu and Tarım (2021) stated in their study that the participants formulated the situations mathematically within the framework of mathematical literacy. The relationship established between the floor (building) metaphor and height, which we encountered in the other activity, made it possible for us to interpret that the students acquired their 3D thinking skills. Moreover, as the students found a part of themselves in the questions prepared based on the RME approach, their ability to make sense of the questions and to comment on the questions caused the time to be used efficiently. While thinking about problem situations that do not have any meaning in the mind of the student, s/he should first find out what the equivalence of the problem situation is in daily life. However, in the questions prepared based on RME, no such problem was encountered, and the students had to specify the expressions only mathematically which they formed in their semantic world. Parallel to these results, there are several studies reporting similar findings (Aydın Ünal & İpek, 2009; Çilingir & Artut, 2016; Tunalı, 2010; Özçelik & Tutak, 2017; Kaylak, 2014). The desire to use a formula encountered in the findings and the statement of "finding the result", which replaces the reason statement, allowed making different interpretations about the students. The prominent ones among these included the fact that the students were subject to a learning system within the dimension of learned helplessness rather than exhibiting a memorization approach and that they failed to approach the questions systematically. In addition, not having a free-thinking space, lack of self-confidence, inability to express oneself, failure to make mathematical sentences, inability to transfer to daily life and failure to visualize them in the mental world caused the students to experience deficiency in terms of theoretical and practical knowledge. When the literature is reviewed, it is seen that there are studies with similar results (Demir & Durmaz, 2018; Yenilmez & Dereli, 2009; Demir & Akar Vural, 2017; Arslan & Yıldız, 2010; Yayla & Bangir Alpan, 2019). The situation that the students liked most during drawing was their ability to move the object dynamically and the changes they could make in the object. This situation will help students develop both their imagination and mathematical processing skills, as they progress in the teaching process with dynamic software that will allow them to move even if they cannot touch and to make the necessary changes (Alkhateeb & Al-Duwairi, 2019; Şahin & Kabasakal, 2018; Topuz & Birgin, 2020; Öçal, 2017; Zengin, 2017; Mutlu & Söylemez, 2019). Another striking situation in the findings obtained in the study was that some of the students gave the formula to be used in volume calculation by associating it with the subject of factors and multiples, which are actually included in the upper grade curriculum. It was thought that the reason why without being aware of it, the students managed not only to make comments on the subject they would learn in the future and but also to reach the formula in an original way with some clues was GeoGebra and the activities that could activate more than one sensory organ of the students. There are also studies emphasizing that Geogebra appeals to multiple senses (Kutluca & Zengin, 2011; Baki, 2000; Balcı Şeker & Erdoğan. 2017; Demirbilek & Özkale, 2014; Gökçe, Aydoğan Yenmez & Özpınar, 2016; Barçın, 2019).

4.2 *Suggestions*

Interpretations and related discussions regarding the findings obtained the study were given above. This section includes suggestions for future research.

First of all, I argue that students, who constituted the pillar of the present study, do not have a meta function in the classroom environment, and we, as teachers, should not thus constantly transfer information to students with the mindset of software developers. It is thought that the use of dynamic software, which is open to intervention by students themselves and which allows students to see inside rather than just touching during the teaching of geometric subjects, will make the teaching process efficient. In addition, it is thought that students can exhibit more original attitudes towards the feedback regarding mathematical activities presented with problem situations that are meaningful in their mental world. In this respect, it is suggested that a lesson plan based on RME be disseminated. Moreover, it is thought that having students watch reminder animations starting from primary school and thus initiating a mental infrastructure construction process in order to encourage the teaching to be carried out on the subject of volume will increase the efficiency in the teaching process. Such a study could be one that will take many years allowing making observations. It is also thought that providing students with the opportunity to think and to express themselves during lessons will increase the quality of education.

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