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Secondary school students' views on geometry teaching via three-dimensional dynamic geometry software Cabri 3D: Solid volume measurement

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Abstract

This study examined students' views on geometry teaching via three-dimensional dynamic geometry software Cabri 3D. Teaching designed with Cabri 3D for solids volume measurement was implemented for 16 students in the eighth grade from a public secondary school in Turkey. The data obtained from the interviews with the students about the teaching, which is two lesson hours per week in five weeks, were categorized into the learning environment, learning, and attitude. The students' views were explained and interpreted according to these categories. The results were supported by sections taken from the worksheets, adhering to the nature of the data. Students stated that Cabri 3D is a functional learning tool that encourages interaction by facilitating drawings and measurements. However, they emphasized that individualized teaching is more suitable for Cabri 3D as group work distracts them. Besides, the students stated that Cabri 3D supports the connection of geometric knowledge about solids volume measurement with daily life by contributing to conceptual and permanent learning. Finally, Cabri 3D had a positive effect on the beliefs and self-confidence of students in measuring the volume of solids.

Keywords: Cabri 3D, geometry teaching, solids volume measurement, secondary school, students' views

1. Introduction

Geometry, which is the science of shape and space, is an important part of mathematics in activating the visual, aesthetic, and intuitive senses and understanding the properties of objects in nature (Ministry of National Education (MNE) [in Turkey], 2015). However, it was emphasized that the desired goals related to teaching geometry could not be achieved (Mistretta, 2000; Kösa, 2011), and the conceptual understandings about geometry could not be developed (Gökkurt et al., 2012). Bako (2003) stated that geometry is one of the most repulsive lessons to students in the 15-year-old group and that only 10% of the teachers participating in the research were achieved in teaching geometry. This result is closely related to the fact that students cannot visualize the three-

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dimensional (3D) shapes (Kösa & Kalay, 2015) and have problems in perceiving concepts such as perimeter, area, and volume (Accascina & Rogora, 2006). The main factor in the emergence of these problems is the inadequacy of geometry teaching in developing spatial skills (Kösa, 2011). Therefore, in geometry teaching, students should be provided with opportunities to experience, inferences, and generalize (Authors, 2018).

Providing dynamic representations in a 3D model, for which depth cues are provided and for which the dynamic representations are linked, facilitates children's generation of mental images and mental transformation between two-dimensional (2D) and 3D representations based on the visual information (Shaffer & Kaput, 1999). In this context, three-dimensional dynamic geometry softwares (3D DGS) is recommended to achieve the desired goals in geometry teaching (Tutak & Birgin, 2008; Köse & Karakuş, 2010). 3D DGS is generally used to analyze geometry problems. Specifically, Cabri 3D, one of these softwares, allows making measurements such as area and volume by moving geometric shapes (e.g., solid rectangle, unit cubes). In this context, it can be said that Cabri 3D can offer important opportunities in teaching difficult subjects such as volume measurement of solids (Huang, 2015a; Authors, 2018).

Since Cabri 3D-based studies in geometry teaching focus on empirical studies examining the effects on students' academic success (Tutak, 2008; Genç & Öksüz, 2015; Kösa & Karakuş, 2010), it has been determined that students' views are ignored. However, students' views on teaching geometry with this software can be considered important. "How does making 3D geometric shapes dynamic affect students' learning?" or "What do students focus on when measuring the volume of solids?" the answers to such questions can be discovered with the students' views on teaching geometry with Cabri 3D. Therefore, students' views should be examined, as it will guide the use of this software as a more effective and useful tool, or it will be useful for revealing the problems faced by the students in the teaching process and producing solutions to them. This study aims to examine students' views on geometry teaching with Cabri 3D. In this context, the problem of this study is "What are the views of secondary school students about using Cabri 3D in teaching solid volume measurement".

1.1. Review of the literature

The literature has suggested that displaying 2D or 3D shapes through dynamic representations through computer technologies may assist students in constructing geometric knowledge (Battista, 2007; Güven, 2012). As the findings of Güven's (2012) study illustrated, eighth-grade students' understanding of geometric transformation significantly benefited more from receiving a curriculum involving the use of the dynamic geometry software Cabri than the other group whose curriculum involved only isometric and dotted worksheets. Işıksal and Aşkar (2003) state that activities developed using dynamic geometry software has a positive effect on student achievement. Similarly, Çetin et al. (2015) reported in their study that teaching with dynamic geometry software increased student achievement in transformation geometry. Despite the studies mentioned above, student views on teaching with 3D DGS are limited in the literature. Kösa and Kalay (2016) focused on the strengths and weaknesses of using 3D DGS in teaching the subject of multi-cube geometric structures and stated that students were willing to use computer-enriched tools in their lessons. Despite this, no studies have been found that examine student views on teaching including the concepts of volume and volume measurement with these software.

Concepts of volume measurement are important subject matters in school mathematics (Ministry of Education [in Taiwan], 2010; National Council of Teachers of Mathematics (NCTM), 2006). Despite the importance of volume measurement, elementary school children frequently struggle with solving volume problems, such as seeing the structure of 3D objects in terms of units of measure and integrating information of three linear dimensions of the objects when reasoning about volume formulae (Battista & Clements, 1996, 1998; Vasilyeva et al., 2013). Knowing how to count the number of cubes in a layer and multiplying the quantity by the number of layers needed to fill in the solid rectangle attribute to procedural knowledge of volume measurement (Battista, 2007; Vasileva et al., 2013). Battista (2007) emphasizes the importance of understanding, internalizing, and associating concepts during volume teaching. Battista and Clements (1996) draw attention to the fact that associating the concept of volume directly with the formula " volume [v] = length [l] × width [w] × height [h]" prevents students from conceptualizing volume. Zembat (2010) emphasizes that primary school students only adhere to the "l × w × h" formula regarding volume measurement and conceptually make wrong generalizations and mistakes in volume calculation. Indeed, it is noteworthy that counting unit cubes and using the volume formula does not imply an understanding of the conceptual basis of measuring volume. The findings of Vasileva et al.'s (2013) and Huang's (2015a) studies showed that some fifth graders used the volume formula without understanding the conceptual foundations of the formula. Therefore, examining students' views on teaching with dynamic geometry writings can be seen as an opportunity to understand the conceptual basis of measuring volume. In this context, this study aimed to reveal the views of the students by taking volume measurements of solids to the center of the teaching carried out with Cabri 3D.

2. Method

In this study, the case study method, which is one of the qualitative approaches and allows the researcher to examine a phenomenon or event in-depth, based on the questions of what, how, and why, was used (Yıldırım & Şimşek, 2013).

2.1. Participants and content

16 eighth grade (14-15 years) students (7 male, 9 female) who select the Mathematics Practices Course (MPC) at a public secondary school in the Mediterranean region in Turkey are the participants of this study. MPC is an elective mathematics course in secondary schools. According to the mathematics curriculum, the content of this course includes solids, transformations, and volume, etc. (MNE, 2015). In the course, students engage in design-based activities related to paper folding or the use of concrete models.

The average grade of seventh-grade mathematics course score of the students in the study group is 83 out of 100. This result can be evaluated as the students' level of readiness in terms of mathematics level is above average (MNE, 2015). The teacher in the role of researcher has ten years of professional experience. Therefore, he has experience in the planning and implementation of the MPC. Also, he had courses on teaching with 3D DGS at the university so he was willing and competent to use Cabri 3D.

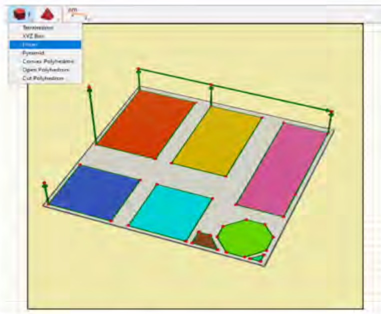
2.2. Teaching activities and data collection procedures

Before starting the teaching, students were trained and practiced on the use of menus in Cabri 3D for two lesson hours (40 minutes + 40 minutes). During the five weeks of teaching, which is two lesson hours per week, each group of two people was given a computer. All students participated in all activities. The activities were implemented by the researcher-teacher with worksheets designed with Cabri 3D. Each worksheet was designed according to the curriculum (see Table 1).

Table 1. Worksheets designed according to the curriculum

Activity	**Worksheet**	**Achievements**	**Duration**
1. Activity	Worksheet #1	Draws solids and determines their basic elements	two lesson hours (40 minutes + 40 minutes)
2. Activity	Worksheet #2	Measures the volume of solids	two lesson hours (40 minutes + 40 minutes)
3. Activity	Worksheet #3	Creates structures with multicubes, draws views of structures created with multicubes	two lesson hours (40 minutes + 40 minutes)
4. Activity	Worksheet #4	Estimates the volumes of solids using strategy	two lesson hours (40 minutes + 40 minutes)
5. Activity	Worksheet #5	Solves problems with volumes of solids	two lesson hours (40 minutes + 40 minutes)

A section from the sample worksheet is shown below (see Figure 1)



The Name Of The Solids	Numbers Of Vertices	Numbers Of Edges
Rectangular solid	8	12
...	...	...

Figure 1. A section from the sample worksheet

In the above worksheet designed for the first activity, students were expected to follow the instructions to draw solids with the help of Cabri 3D and determine their properties (numbers of vertices and edges). Besides the students were asked to record the concepts they used and the measurements they made on each worksheet. In this process, attention was paid to the fact that the teacher was in the role of a guide encouraging access to information in the classroom, and that the students were in the role of researching, discussing, asking questions, and using the necessary resources effectively to obtain information. A semi-structured form was used in the interviews with the students about geometry teaching with Cabri 3D. The interview questions were examined by two academicians who are experts in mathematics education, two secondary school mathematics teachers, and a language teacher, necessary corrections were made and finalized. The interview form consisted of 8 open-ended questions prepared to reveal students' views on teaching geometry with Cabri 3D. Interviews were conducted one-on-one with the students, in an average of 20 minutes, and were recorded with a voice recorder. In this process, external factors (e.g., noise, temperature) were minimized by the researcher.

2.3. Data analysis

In order to determine the views of secondary school students about geometry teaching with Cabri 3D, the answers to each question asked to the participants were examined in depth. Each answer was reviewed repeatedly and the content analysis method was adopted in the analysis process. In the analysis of the data, the dialogues in the recorded interviews were converted into written text. Open coding was applied to obtain conceptual categories from the discourses in the text. Open coding was followed by axial coding, which included a grouping of data. In this process, all data, whether relevant or not, were labeled and conceptualized (Strauss & Corbin, 1998). The data were coded separately by two experts in the field and the percentage of agreement between them was calculated as 92%. To resolve the disagreements in the codes, both experts discussed the differences to reach a consensus. The codes whose frequency values were calculated were associated with subcategories according to their similar characteristics and shown in the tables. Then, the determined sub-categories were brought together around central categories (Yıldırım & Şimşek, 2013). The students' views on geometry teaching with Cabri 3D were explained and interpreted according to these central categories. The results were supported by sections taken from the worksheets, adhering to the nature of the data. Thus, it contributed to the transferability of the research results to similar situations.

3. Results

In this section, the categories and sub-categories identified as a result of the analysis of the data obtained from the interviews with the students about geometry teaching with Cabri 3D are presented in tables with their codes. The findings of the learning environment, which is one of the center categories are shown in Table 2.

Table 2. Findings of students' views about the learning environment

Category	Sub Categories	Codes	Ö1	Ö2	Ö3	Ö4	Ö5	Ö6	Ö7	Ö8	Ö9	Ö10	Ö11	Ö12	Ö13	Ö14	Ö15	Ö16	Frequency
Learning Environment	Functional	More simple	X	X		X	X	X	X		X	X	X	X		X	X	X	13
		More practical	X		X		X	X		X	X		X		X	X	X		10
		More enjoyable	X	X	X	X	X	X	X		X	X	X	X		X	X	X	14
	Interaction	Allows to compare	X		X	X	X		X			X	X	X		X	X	X	11
		Encourages being active in the lesson	X		X	X		X	X		X	X		X		X	X		10
	External factors	Group works are a distraction			X			X	X	X	X		X			X	X		8
		Software language must be mother tongue			X					X									2

Three sub-categories were identified that reflect the students' views on the learning environment; functional, interaction, and external factors (see Table 2). According to the functional sub-category, 13 students stated that they could simply make drawings and measurements with Cabri 3D in the learning environment. In this context, Ö6's view is as follows:

I have a hard time drawing rectangular solids on the blackboard... But I know what to do with Cabri 3D... first I need to draw a layer and then I decide how many layers there will be... Also, unlike Cabri 3D, drawing or measuring on paper is very time-consuming…

10 students stated that while measuring the volume of solids with Cabri 3D, they also discovered their properties by moving them in different aspects. In other words, they emphasized that they gained more benefits. In this context, Ö8's view on the practicality of the learning environment is as follows:

Cabri 3D allowed us to hit two birds with one stone. While measuring the volume of solids, we also discovered their properties. For example, we realized that deciding how many layers a rectangular solid consists of is the length of the distance between the bottom and top layers.

14 students stated that they had fun while doing the activities in the learning environment. In this context, Ö7's view is as follows:

In our previous lessons, creating solids by folding paper was boring for me, and I was worried if I folded it wrong and it made me nervous. I have no such worries with Cabri 3D, I had fun while doing the activities, it's an enjoyable environment...

The students' views that Cabri 3D is simple, practical, and enjoyable indicated the functionality of the learning environment. As seen in Table 2, all of the students expressed a positive view of the functionality of the learning environment. The statement "*But I know what to do with Cabri 3D*" indicated that students control the learning environment, in other words, they manage it. The statement "*While measuring the volume of solids, we also discovered their properties. For example, we realized that deciding how many layers a rectangular solid consists of is the length of the distance between the upper and lower layers,*" indicated that the students engage in exploration in the learning environment. Control and exploration supported students' independent learning.

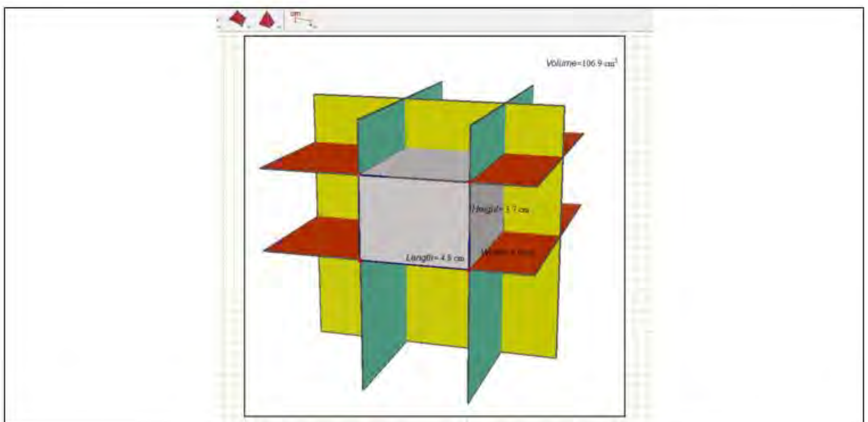
11 students stated that they were able to compare solids by changing their dimensions with Cabri 3D, while 10 students stated that this played a role in their being active in the lesson. The view of Ö15, who emphasized the dynamic nature of the learning environment, is shown below:

By changing the dimensions of the solids, we were able to observe and examine each factor affecting the volume separately. Thus, we were able to visualize the variables and compare them within the classroom… we can't do them on the board or in the notebook because the drawings are fixed on them...

The view of Ö4, who emphasized that Cabri 3D encouraged him to be active in the lesson, is shown below:

In our previous lessons, we did not know whether our solutions or ideas were correct and we expected feedback from the teacher… With Cabri 3D, we can understand the accuracy of measuring by moving and visualizing solids. We no longer have to wait for the teacher. This situation encouraged us to be active and participate in the lesson...

Students' views indicated that Cabri 3D learning environment contributes to the interaction in the classroom micro-culture by encouraging the visualization, comparison, testing of the accuracy of the measurements, and being active in the lesson. The following section from Ö4's worksheet supports this finding.



Inference	Generalization
En boy yüksekliği sabit tuttuğumuzda yüksekliği artırırsak hacmi de artar. yüksekliği azaltırsak hacmide azalmış olur English translation: When the length and width are fixed, if we increase the height, the volume will increase, and if we decrease the height, the volume will decrease.	En x Boy x Yükseklik Bu faktörlere Bağlıdır English translation: The volume depends on the length, width, and height variables.

Figure 2. A section from Ö4's worksheet

In the above worksheet designed for the second activity, students were asked to identify the factors affecting rectangular solids' volume. The students examined the variables by visualizing which factors depended on the volume. Ö4 examined each variable by keeping the other two variables fixed. This allowed him to test each variable. In the last part of the worksheet, Ö4 stated how length, width, and height affect the volume, reached the relevant generalization, and explained the solution to his friends in the class discussion.

However, 8 students stated that group works were distracting due to disagreement. Ö5's view on this subject is shown below:

While doing the activities, my group friend's requests caused me confusion. While I was making measurements, he wanted to make measurements too. It would be better if we worked individually in Cabri 3D.

Another view of the students regarding the learning environment is that technical problems affect them negatively, albeit a little. Two students stated that it would be better if the software language was in their mother tongue. Ö3's view on this issue is shown below:

I had a little difficulty because my English is not good, it would be better if the math terms were in Turkish.

As a result, the students evaluated the Cabri 3D learning environment positively in terms of functionality and interaction. However, they stated that external factors such as group work and technical problems negatively affect the Cabri 3D learning environment.

Another central category determined in geometry teaching with Cabri 3D is learning. The subcategories and codes related to the learning category are shown in Table 3.

Table 3. Findings of students' views about the learning

Category	Sub Categori	Codes	Ö1	Ö2	Ö3	Ö4	Ö5	Ö6	Ö7	Ö8	Ö9	Ö10	Ö11	Ö12	Ö13	Ö14	Ö15	Ö16	Frequenc
Learning	Understanding	Explain the concept	X	X		X		X		X	X	X	X	X	X		X		11
		Providing reinforcement	X			X	X	X		X		X		X	X		X	X	10
	Connection	Relating volume to properties of objects	X		X	X		X		X	X			X		X	X		9
		Association with daily life				X		X	X		X		X			X	X	X	8
	Recalling	Memorability	X	X		X		X	X		X	X	X		X			X	10
		Benefit in the exam		X		X		X	X		X	X	X		X			X	9

According to Table 3, the learning category consists of three sub-categories: understanding, connection, and recalling. 11 students stated that they can now explain the concept of volume and understand the measurement of solids volume. The view of Ö13 is as follows:

In our previous lessons, we used the width x length x height formula to measure the volumes of rectangular solids. However, I could not understand why these variables were multiplied. With Cabri 3D, we first built and then calculated the total number of flats. This made it easier for me to detect volume-related variables. Filling in the blanks made me realize that the width x length is a variable that shows how many cubic units the bottom layer of that solid is expressed, while height is a variable that shows how many layers that solid consists of. Therefore, I can now explain the volume of rectangular solids as the product of the total number of cubes in a layer and the number of layers.

Students can explain the volume of rectangular solids with the total number of unit cubes in the layers indicated that teaching with Cabri 3D contributes to conceptual learning about measuring volume. The following section from the worksheet supports this finding (see Figure 3).

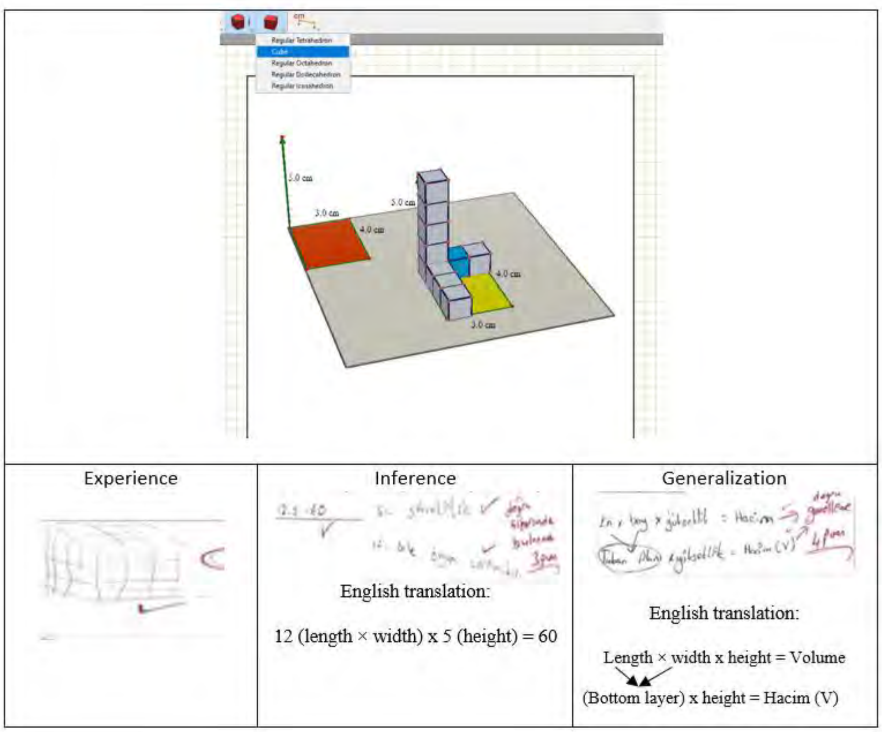


Figure 3. A section from worksheet

In the worksheet above designed for the third activity, students are expected to calculate the volume of the building. The students constructed the building by filling in the gaps and creating the layers. They expressed the total number of flats in the building as the total number of cubes required for the layers. Thus, they were able to make inferences about the concept of volume. This result showed that Cabri 3D supported students to create conceptual understanding by associating the concept of volume with the layer structure and the total number of unit cubes.

According to Table 3, another sub-category is connection. 10 students stated that Cabri 3D also contributed to the reinforcement of previous topics. In this context, Ö1's view is as follows:

…moving and visualizing geometric shapes allowed me to reinforce their image of reflection, rotation, and translation…

This finding showed that teaching with Cabri 3D not only helps new learning but also reinforces past learning. In the worksheet below designed for the fourth activity, the students measured the volume of the triangular solids by relating it to the rectangular solids using the transformation menus. In this context, Cabri 3D can be used as a reinforcement tool to provide connection (see Figure 4).

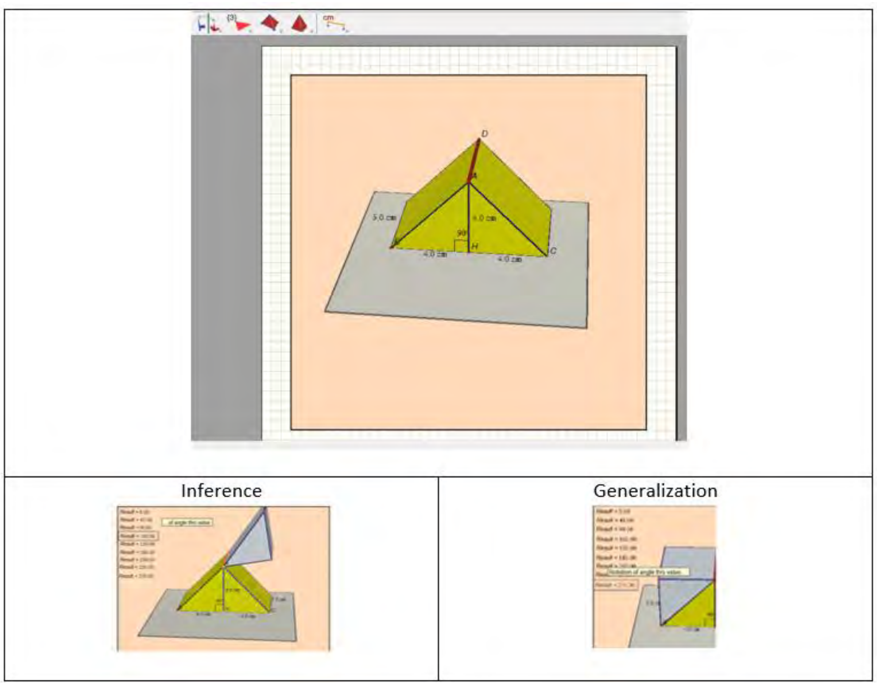


Figure 4. A section from screen worksheet

9 students stated that they were able to connect the base properties of solids with their volumes, and 8 students stated that they could use these connections in daily life. In this context, the view of Ö15 is as follows:

…we discovered why the volume of a triangular solid is half the volume of a rectangular solid. We can now estimate the volumes of solids in our schoolyard using their base properties.

The students' views that the volume of the triangular solids is half the volume of the rectangular solids showed that they can relate the geometry within itself. They try to estimate the volumes of the solids in the schoolyard using these relations showed that it contributes to connecting with daily life.

Another sub-category is identified recalling. 10 students stated that what they learned with Cabri 3D remained in their minds, and 9 students stated that they used what they learned in exams. In this context, the view of Ö11 is as follows:

I remember what I learned with Cabri 3D, it was very useful in exams, especially when solving solid volume problems related to layer structure.

According to the students' views, the dynamic structure of Cabri 3D helped to have a positive effect on creating permanent learning.

Another central category identified from the interviews is attitude. The sub-categories and codes are shown in Table 4.

Table 4. Findings of students' views about the attitude

Category	Sub Categories	Codes	Ö1	Ö2	Ö3	Ö4	Ö5	Ö6	Ö7	Ö8	Ö9	Ö10	Ö11	Ö12	Ö13	Ö14	Ö15	Ö16	Frequency
Attitude	Like	Now I like volume measurement	X			X	X	X		X	X	X	X	X	X		X	X	12
		My perspective on measuremen hasn't changed			X				X										2
	Self-confidence	Now I can measurement the volume	X	X	X	X	X	X		X	X	X	X	X	X	X		X	14
		I solve volume measurement problems first			X		X	X	X	X	X	X		X		X		X	10

According to Table 4, 12 students stated that they started to like volume measurement after the teaching, while 2 students stated that their perspective on volume did not change. The view of Ö6 is as follows:

I started to like volume measurement, I'm surprised why we haven't used this software until now... I'm going to install it on my computer too...

Ö7, who stated that there was no change in his view, is as follows:

I was generally satisfied with the teaching, but I was able to make measurements before using Cabri 3D…

Self-confidence is another sub-category in the attitude category. After the teaching, 14 students stated that they could now solve the volume questions, and 10 students stated that they did not leave the volume measurement problems to the end in the exams. In this context, Ö14's view is as follows:

In previous exams I used to solve solid volume measurement problems last, I believed my measurements would be wrong but now I solve solid volume problems first and I am confident that my measurements are correct…

As a result, students' views showed that Cabri 3D contributes to students' solid volume measurement skills and their self-confidence in doing geometry.

4. Discussion

The results obtained from the interviews with the students about the use of Cabri 3D in teaching solid volume measurement were discussed within the framework of the learning environment, learning, and attitude. Students stated that it is simple, practical, and enjoyable to measure solids volume in the Cabri 3D learning environment. This result is related to the fact that Cabri 3D moves solids and manipulates volume measurement. Cabri 3D allows manipulations also encouraged students to explore the variables of solid volume. Therefore, Cabri 3D not only manipulates (Battista, 2007; Güven, 2012; Hawes et. al., 2017) but also supports students' independent learning by contributing to their exploration skills. The statement "We no longer have to wait for the teacher" indicates that students are less dependent on the teacher in the teaching process. Considering that students' independent learning plays a major role in accelerating their autonomy development (Authors, 2013), it can be said that Cabri 3D's providing a functional learning environment contributes to this.

Another view on the learning environment is that the dynamic structure of Cabri 3D allows visualization, comparing, and testing measurements accuracy. Considering that being able to visualize geometric shapes is important in creating spatial relationships (Olkun & Toluk, 2009), students' ability to visualize the factors affecting the volume in the learning environment contributed to the understanding of dimensionality (Vasileva et al., 2013). In addition, the statement "We can't do them on the board or in the notebook because the drawings are fixed on them" indicates that Cabri 3D shapes the interaction in the classroom by offering richer experiences compared to 2D environments. The students' testing the accuracy of their measurements while examining the factors affecting the volume also supported their active participation in the lesson. Considering that interaction is the most important factor for classroom microculture (Van de Walle et. al., 2012), it can be said that Cabri 3D encourages interaction that supports spatial skills and participation.

Students emphasized group work as a distraction due to disagreements in the learning environment. This result may be due to reasons such as secondary school students not sharing tasks within the group and not showing respect to each other. Therefore, unlike Tutak (2008)'s work with pre-service teachers, learning environments like Cabri 3D are more suitable for individualized teaching at the secondary school level. In addition, the fact that the software language is different from the mother tongue caused the students to have difficulty in the learning environment, albeit a little. In studies examining student views on computer use, problems experienced by students arise due to the inability to complete the activities related to the theme of weaknesses in general (Kösa & Kalay, 2016). The results of the present study have shown that some problems that may arise from the software can negatively affect the learning environment.

Another view that the students emphasized is that they can realize meaningful and permanent learning with Cabri 3D and connect geometry with daily life. The statement "We used the width x height x height formula for volume in our previous lessons, but I did not understand why we multiplied them" indicates that students tended to think that volume should be measured with metric measures, giving weight to unit calculations in the classroom (Dorko & Speer, 2015), and neglect to discuss the relationship between the factors affecting volume. Although research on the traditional approach to volume teaching supports this result (Huang, 2015b; Tan, 1998), the activities designed with Cabri3D have shown that students can use and explain the concept of solids volume in a procedural sense (Battista, 2007). Considering that ignoring the in-depth explorations involving gap filling and layer structure in volume measurement may cause children to have difficulties in solving volume problems (Battista & Clements, 1996; Vasilyeva et. al., 2013), it can be said that the use of Cabri 3D in the teaching of solids volume measurement will be effective both in overcoming these difficulties and in internalizing the concept of volume.

Students stated that Cabri 3D not only helps new learning but also reinforces past learning. This result shows that Cabri 3D plays an effective role in associating geometry within itself. The statement "Now we can estimate the volumes of geometric objects in our school garden by using the base properties" indicates that the geometry teaching carried out with Cabri 3D contributes to the association of students with daily life. These cognitive processes, which involve establishing reference connections between geometric information and the concept of measurement of volume and matching structures in representations in daily life, lead to conceptual understanding (Braithwaite & Goldstone, 2015; Seufert, 2003) and encourage the enrichment of the mental information network. In addition, the dynamic structure of Cabri 3D contributed to the students' learning by doing and experiencing the knowledge they wanted to test, and encouraged their permanent learning. The desire of students to solve problems that require conceptual understanding in exams supports their ability to use what they have learned and to achieve permanent learning.

Finally, the majority of the students emphasized that Cabri 3D made a positive contribution to their perspective on volume and to building self-confidence about being able to measure solids' volume. Eryiğit (2010) investigated the effect of using Cabri 3D on students' attitudes towards geometry; It was concluded that there was no significant difference between the attitudes towards geometry of the students in the experimental and control groups before and after the application. The fact that the activities in the current study were aimed at teaching the concept of volume may have caused the effects of Cabri 3D on attitude to be different. In this context, the use of Cabri 3D, especially in areas related to concept teaching and measurement, has a positive effect in terms of attitude. This result shows that the students respond more positively to the use of Cabri 3D for conceptual learning.

5. Conclusion

The results obtained from the students' views about teaching geometry with Cabri 3D presented some new results to the current literature, such as supporting autonomy, allowing interaction, and prioritizing individuality instead of group work in geometry teaching at the secondary school level. In this context, students' views on teaching with Cabri 3D at different grade levels can be examined.

An effective Cabri 3D teaching, especially integrated with solids volume measurement and supported by worksheets, can contribute to the development of spatial skills, the internalization of the concept of volume, and the development and persistence of volume measurement skills.

Finally, considering that Cabri 3D contributes positively to students' self-confidence about the concept of volume and measurement, research can be conducted on the use of Cabri 3D in other areas of geometry. However, in the teaching process, attention should be paid to the maximum elimination of some language-related problems that may arise from the software.

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