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Demetrios G. Sampson
Dirk Ifenthaler
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GEOGEBRABOOK: PRELIMINARY RESEARCH WITH PRIMARY SCHOOL STUDENTS

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ABSTRACT

GeoGebraBook is a pedagogical resource in the form of a digital book created and developed for free on the GeoGebra online page. This paper presents preliminary research using GeoGebraBook to support explaining the area of a flat figure and the volume of a solid. The study was based on qualitative and quantitative research and involved forty-four Primary school students. Findings suggest that students are receptive to an exploration of GeoGebra applets, get involved in tasks and declare advantages using GeoGebraBook for their learning. The students identified the problem, investigated, debated, interpreted and produced possible justifications and solutions. We observed that the students collaborated to solve the proposed questions in a playful way. This didactic proposal proved to be an enriching experience for students. It served as a basis for the development of a new procedure for the consolidation of mathematical concepts based on the GeoGebra dynamic geometry app.

KEYWORDS

Mathematic, GeoGebra, Learn by Doing, Problem-Based Learning

1. INTRODUCTION

Geometry is present in our lives when we visualize what surrounds us. Geometry is essential not only for its numerous practical applications but also for the development of vital skills in the 21st century. It constitutes a powerful tool from the visualization that allows the connection with the surroundings. Teaching geometry aims to develop in the student these skills (Breda, Serrazina, Meneses, Sousa & Oliveira, 2011). The teaching and learning processes of geometry are complex and multidimensional. The reason why it is common to find students who manifest difficulties with geometric concepts and with your representations or your meaning (Seabra, Barros, Pires & Martins, 2019). Learning geometry benefits from the use of dynamic software (NCTM, 2009; Breda, et al., 2011). Currently, students in the digital age are receptive to the use of technology (Lencastre & Araújo, 2007), so it should be used to improve skills in geometry. The goals that guided this preliminary research were formulated as follows: i) To understand the pedagogical relevance of simulators in understanding the concept of volume and area; ii) To foster student's curiosity in area and volume concepts.

The article begins by introducing the GeoGebraBook as a feature of the online GeoGebra application. Then the methodology adopted in the study and its description is presented. Finally, we offer a discussion of the results and main conclusions. It ends with some proposals for future studies.

2. CONCEPTUAL FRAMEWORK

2.1 GeoGebraBook

The mathematical understanding capacity improves with the experimental capacity of the GeoGebra software (Rohaeti, E. E., & Bernard, M. (2018). A dynamic geometry software GeoGebra is a powerful technological tool for teaching mathematics (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008), being an open-source software available for free. GeoGebra is intended to be used by teachers and students for mathematics teaching and learning that offers geometry, algebra (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008), being very efficient in mathematics education (Seloraji & Kwan, 2017). GeoGebra is a significant dynamic geometry software for meaningful student learning (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008; Zhou, 2012), that improves teaching and learning of mathematics (Hohenwarter, Hohenwarter, Kreis & Lavicza, 2008; Zhou, 2012; Seloraji & Kwan, 2017).

A GeoGebraBook is a type of online book, the educational product being an interactive material, containing proposals of activities, questions, figures, videos, problem situations and learning objects developed in GeoGebra, among other resources, with the aim of providing a dynamic approach to teaching (Lemke & Siple, 2018). It is a resource accessible through any device, easy to share and view, works as an editable and interactive digital book. The basic idea of the software is to combine geometry, algebra, and calculus, which other packages deal with separately, in a single easy-to-use package for learning and teaching math from elementary to university (Hohenwarter, et al., 2008).

The GeoGebraBook can be shared through a link and can be accessed sequentially by order of chapters and sections, or at random, or just by going to the topic of interest (Lemke & Siple, 2018). The GeoGebraBook is a free educational tool available for online use and therefore accessible through any device with internet access. In a GeoGebraBook it is possible to insert several resources (Figure 1), such as text, video, an applet, a GeoGebra file, a pdf, a web page, an image or simply a question.

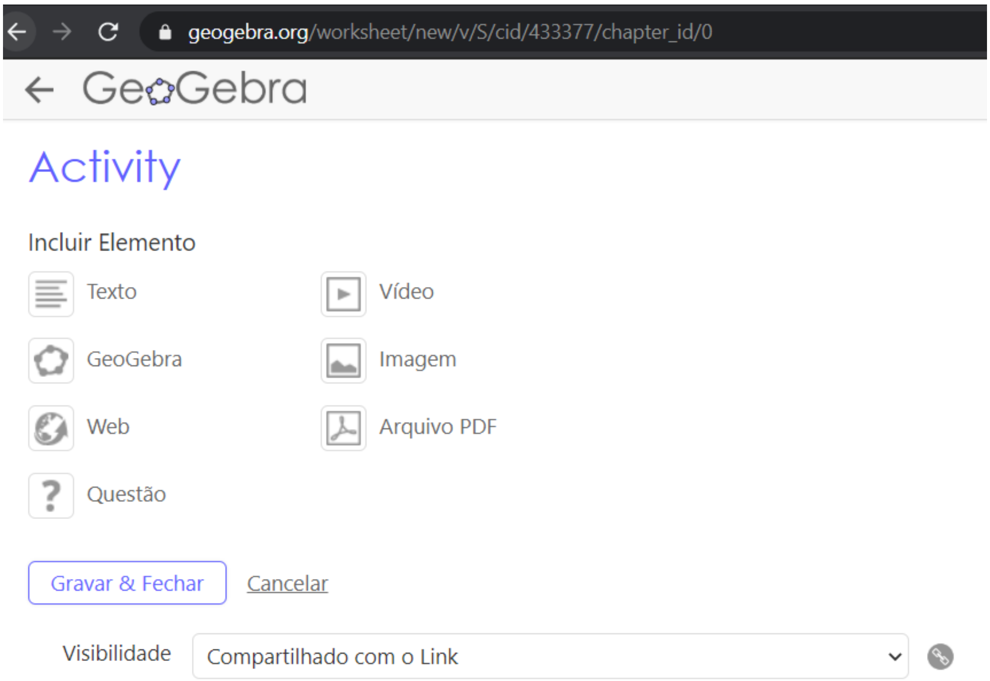

Figure 1. Type of GeoGebraBook activities

A GeoGebraBook is shareable through a simple link, it has an intuitive navigation that allows teaching to be adapted to the student.

2.2 Problem-Based Learning

There is the tradition in research on mathematical thinking that has focused on procedural knowledge, or on how to solve problems and implement procedures. Lately, there has been a paradigm shift, and there is a growing concern not only in problem-solving but also in the development of conceptual knowledge (Crooks & Alibali, 2014). The focus has been also on developing more creative and effective learning environments with the implementation of ICT (Poikela et al., 2009). Throughout the process of learning based on problem-solving, students acquire knowledge based on experiences. For developing creativity in education, it is important to help students realize their creative potential, understand what is known about creativity, and increase confidence in their own knowledge (Zhou, 2012). Experiences that promote the development of logical, analytical, systematic thinking and the critical capacity to deal with a problem (Eviyanti, Surya, Syahputra & Simbolon, 2017).

Problem-based learning is a student-centered pedagogical strategy, where students are sought to learn for themselves, and active learning improves student learning outcomes in education (Ng, Ting, Lam, and & Liu (2020). Development in today's society increasingly demands the community in general to have the capacity to think creatively and mathematically. Improving the quality of teaching is also improving the ability to think creatively and quality education can be promoted to train thinking (Maskur, 2020). In an educational context, there are several organized approaches to learning from experiences that can enhance and complement the learning that takes place in everyday work. In problem-based learning, students organize information to solve problems. It is a method that uses everyday problems to make students think, communicate, analyze information to conclude. A method that leads students to think scientifically and learn scientific thinking skills (Eviyanti, Surya, Syahputra & Simbolon, 2017).

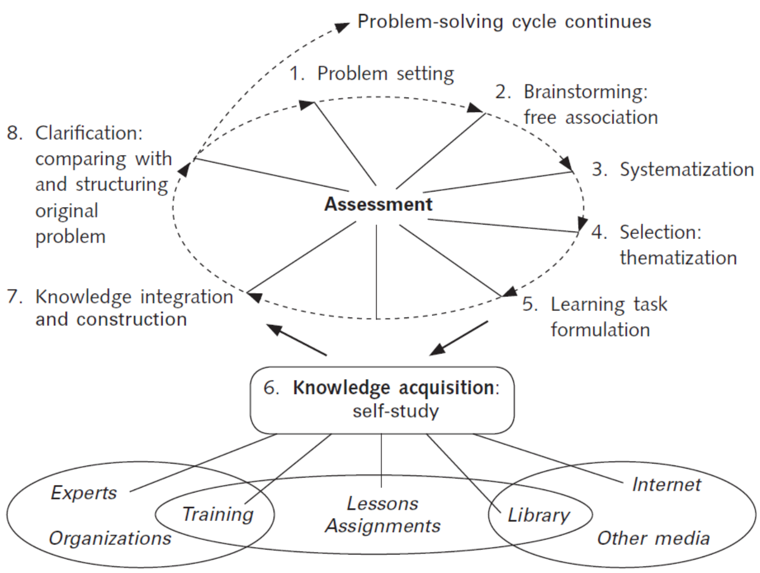

Figure 2. Problem-Based Learning cycle

According to Poikela et al. (2009), the problem-based learning consists in a process of eight steps (Figure 2). In this process, students began by working toward a shared understanding of the problem presented to them. Subsequently, their knowledge and prior experiences originate ideas. Then, similar types of ideas are grouped, and important information is categorized. They take a tutorial, look for information, work individually or in groups depending on the tasks and learning objectives, as well as the strategy considered to be the best. Then, they apply the new knowledge acquired, to tackle the learning tasks, and to reconstruct the problem in a new way, clarifying doubts, reflect on the process of finding solutions to problems to achieve deep learning. Self-assessment is also necessary to close the tutorial with feedback about students' own learning.

3. METHOD

This study took place during the COVID-19 pandemic, where classes were mostly remote. This work main objective is to understand the pedagogical relevance of simulators (applets of GeoGebra) in understanding the concept of volume and area. We intend to foster student's curiosity in these concepts. We intend to build a new paradigm in the teaching and learning process for the understanding of concepts using the GeoGebra application. The intervention will be made with 44 students from the 1st CEB of a school in the central region of Portugal. We articulate the activities based on the problem-based learning methodology to promote the understanding of mathematical concepts. In this method, the student is the protagonist in the learning process, being the teacher a facilitator between the student and the knowledge. In the beginning, we collected concepts from the student's regular teacher, and then we guided students through the following process:

Step 1, students made a diagnosis about basic knowledge;
Step 2, we introduced students to the problematic scenario and students were engaged with the situation
Step 3, students identified the facts, students investigated the situation and new knowledge was applied;
Step 4, students generated hypotheses and explain the situation;
Step 5, students clarified doubts with teachers or students;
Step 6, students solved problem situation and applied their knowledge on the new situation;
Step 7, students reflected about their knowledge with teacher and other students.

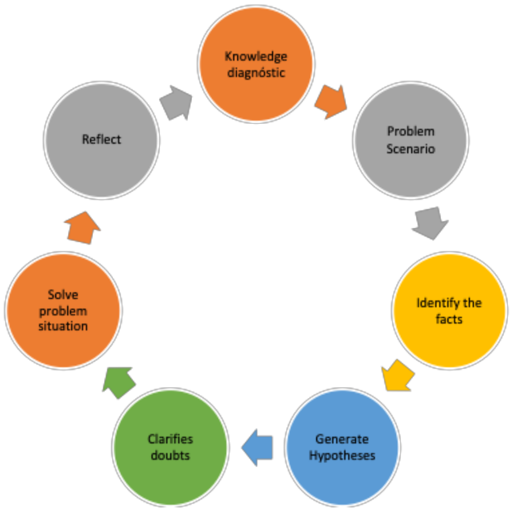

Figure 3. Learning process

Process (Figure 3) was mediated by the Google Classroom platform and by the GeoGebra.org platform, which served as support in all phases of the process described above to communication with students. GeoGebra is a powerful tool to create interactive online learning environments (Hohenwarter et al., 2008), which led us to create on the GeoGebra.org online platform a GeoGebraBook for the theme of the area and volume in primary-school students.

Different methods were applied in order to collect the data: (i) system logs on the platform, (ii) a diary to collect direct observations, (iii) a diagnostic questionnaire and a diagnosis of final reflection and (iv) a final focus group with the students to get a qualitative assessment and to understand their perceptions about the whole process. The questionnaires were subjected to a statistical analysis based on techniques of data collection, analysis and subsequent presentation (Lima & Pacheco, 2006; Coutinho, 2014), and it seeks to establish relationships and explain causes of changes in measurable social facts (Mc Millan & Schumacher, 1997). To code the students' responses, we use the designation Si for student i, with i = 1,…44. With the focus group, a qualitative analysis of the data was carried out, which allows describing the data (Bogdan & Biklen, 1994; Lima & Pacheco, 2006), to understand and interpret them in a context (Mc Millan & Schumacher, 1997). For the analysis of the data of the focus group on the opinion of the students, we considered two dimensions: the understanding of the concept and the visualization of the concept, using GeoGebra.

3.1 Participants

Forty-four students of a Portuguese school (23 females and 21 males), with ages between 8 and 10 participated in this study. Most students showed affection for mathematic, despite facing some difficulties in the subject, especially in certain contents. Initially, students did not mention mathematical experiences previously lived with GeoGebra in their classes. None of the students knew about the GeoGebra application and had never worked with it. Regarding the use of the computer, it was noted that most students had access to this resource at home.

4. RESULTS

The activity took place throughout two classes. At the beginning, a diagnosis questionnaire of the students' knowledge was made, which they did again at the end of each class to verify knowledge. From the initial questionnaire to the end, we found that everyone improved some aspect, with 25 registering that they got all questions right at the end of the process. We presented the scenario of the problem to solve and the students identified the facts and generated hypotheses individually or in groups and answered questions essentially by video call. The students result (Figure 4) are displayed as a graphic chart, which makes it easy to identify the progress.

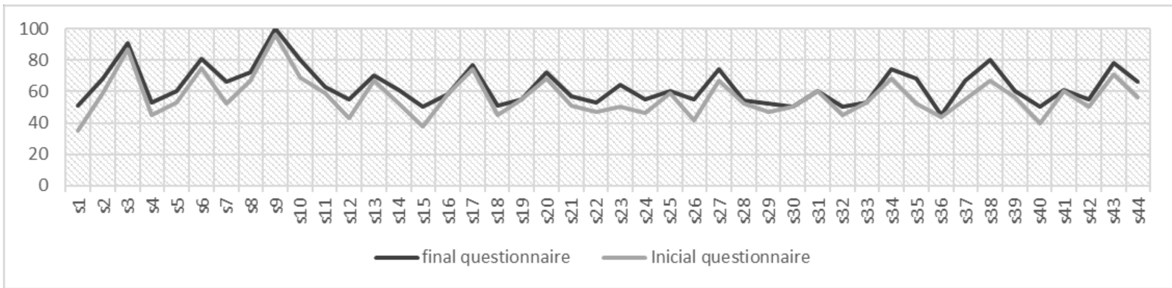

Figure 4. Learning process

Regarding the subject of mathematics, of the 44 students, 8 reported that they did not like the subject and only 5 admitted that they did not felt difficulties in calculating the area of a figure and the volume of a solid. All students except 3, admitted during the work of exploring the GeoGebraBook that GeoGebra helped them to better understand the concept of area and volume. All students were enthusiastic about the task, some referred to “how cool” (S6 & S15), “this is really cool” (S2, S23 & S28), others observed carefully what happened while manipulating the mobile points of the applet. The area and volume applets (Figure 5) available in the GeoGebraBook are fully dynamic, meaning that points can be moved along function graphs, parameters are changeable using sliders, and text adapts automatically to changes.

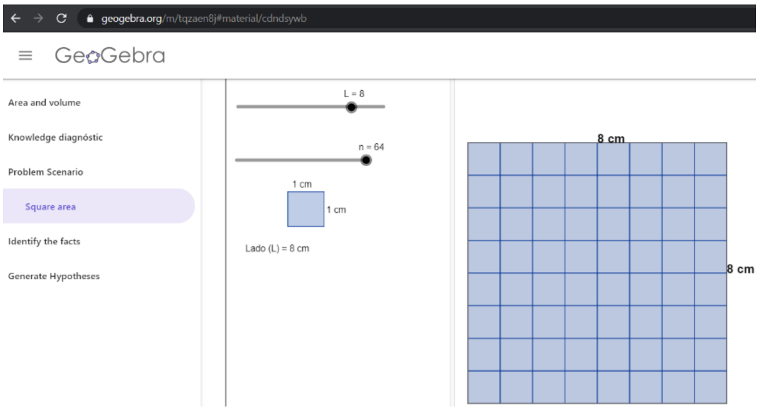

Figure 5. GeoGebraBook Area and Volume

Regarding the interaction mechanism, students interacted with the teacher and colleagues through Google Hangout on asynchronous lessons and video call in the synchronous lessons. Of the 44 students 20 were joining the class through computer and the rest through tablet.

All students were able to view the resources through the link to the GeogebraBook that was placed in the classroom, a place where they were used to access classes every day. The use of the Classroom platform allowed, throughout this new challenge, to shorten distances and streamline the planned learning activities. Children's learning, benefit from activities that involve gesturing in the development of mathematical concepts, the learning by doing (Novack, Congdon, Hemani-Lopez & Goldin-Meadow, 2014). So, we structured the work on GeoGebraBook by tasks that allowed, in a very interesting way, to give accurate feedback on the evolution and acquisition of knowledge by the students.

All students managed to reach to the end of the process successfully. Regarding the use of GeoGebra to explain mathematical concepts, none of the students considered it insufficient or sufficient, 12 considered that GeoGebra was good to help them understand the concepts, 12 considered it to be very good and 20 that GeoGebra was great. Still on the use of GeoGebra, most (27 students) found GeoGebra very easy to use and manipulate, 10 students considered it was easy and the remaining 7 considered that it was moderately easy to use. It should be noted that no student found the manipulation of GeoGebra applets difficult.

At the end of the process, students reflected on the advantages and difficulties they encountered in the process. All admitted that the manipulation of the applets helped them to perceive better the concepts covered. We present the students' speeches in the final focus group below (Table 1):

Table 1. Categories of analysis from student responses

Dimension	Student
GeoGebra helped understanding concepts	it made me understand the story better! (s1)
	it clarified some doubts that I had (s2)
	it was much easier to see (s3)
	learning like this is fun (s9)
	it helped me to understand the area and the volume faster (s11)
	it is easier to learn when we have fun (s12)
	it helps me achieving more easily (s13)
	it is interactive and allowed me to move, see and understand it better (s14).
	it is interactive and when I moved, I realized how it works (s15).
	i saw it, we put measurements, and then it gives us the answers (S17).
	it is very cool and fun (s19)
	it helped me to understand (s21)
	it lets me visualize and interact with the concept of area and volume (s28).
	it helped me to understand, I was able to put the squares and count to check if I was right (s30).
	simplified perceiving and calculating (s42)
GeoGebra helped visualizing concepts	Because it explains me the steps on how can I do it (s2)
	Because it demonstrates how it works and I see it (s4)
	Because it helps us memorizing (s5)
	Because it makes complicated things look simply (s7).
	Because it's more fun (s13)
	When I have difficulty thinking, I go there to understand better and see the result (s15).
	because we can put several measures to see the area (s16)
	It helps me to memorize and to visualize better than other times (s20).
	with GeoGebra it is easier to use because you can immediately see the answer and understand (s21)
	Because I understand and visualize better how it works (s23).
	I think GeoGebra helps me to understand the subject better because I can practice (s31).
	Because it lets me visualize the material and it's fun (s33).
	Because it teaches us things we don't know and reminds us of things we know (s34)
	It allows me to do a lot of things with math (s35)
	Because it is very practical and simple, as we just need to move those little pieces, and I think it is also a lot of fun (s37).
	Because you can see very well when we move (s38).
	Because we see better, and it makes calculations easier to do (s40).

Most students considered that the use of GeoGebra makes classes more attractive. In the opinion of the students, the presentation of the problem and exploration of GeoGebra helped them to understand the concept of area and the concept of volume. It allowed "*perceiving*" (s1), "*clarifying doubts*" (s2), "*moving, seeing and understanding*" (s14) the "*area and the volume faster*" (s11). Through the manipulation of the applets, it was possible to "*make mathematical concepts easier*" (s12), to learn in a fun and interactive way, visualizing the result of their experimentation. They consider that GeoGebra, besides helping to better understand the concepts, helped to visualize what they mean mathematically, since in their opinion, it "*explain steps and how to do it*" (s2), "*demonstrate how it works*" (s4), "*help decorate*" (s5) the contents. The fact that they are able to investigate a phenomenon, promote learning by doing, create ideas and apply "*the contents makes complicated concepts simple*" (s7), allows "*better visualization* "(s20; s23) and makes learning mathematics "*more fun*"(s13). They admit that GeoGebra helped them to "*better understand the subject because they can practice*" (s31), in addition "*it makes calculations easier to do*" (s40).

5. DISCUSSION AND CONCLUSION

Results showed that the manipulation of the simulators promoted the student's motivation to work on mathematical concepts and that the GeoGebra application, namely the GeoGebraBook, can help the teacher to support learning for his students.

The use of the problem-based learning methodology allowed students to develop independence, responsibility, and their ability to work. Additionally, results suggest that these software packages can be used to encourage discovery and experimentation in classrooms, and their visualization features can be effectively employed in teaching. Students admit the advantages of using the GeoGebraBook for their learning but find it difficult to explain why. Our results meet the results of Seloraji and Kwan (2017) when they indicate that the use of the GeoGebra software promotes good learning outcome in geometric transformations, especially in the topic of reflection. NCTM (2009) suggests that the learning of geometry can be done using dynamic software with the use of concrete models through activities and tools that allow students to explore conjectures about geometry and reflect carefully about geometric concepts. The students identified the problem, investigated, debated, interpreted, and produced possible justifications and solutions or resolutions. We observed that students collaborated to be able to solve the proposed problems playfully, meeting what Ng, Ting, Lam and Liu (2020) wrote. According to these authors, problem-based learning is a strategy that allows improving the dynamics of the classroom and the relationship between teacher, student, and content. Our students used video calls preferentially to clarify doubts in line with the study of Poikela et al. (2009), according to which students prefer to use online collaboration to get reassurance for being correct than thinking about solving the problem. Like in Zhou (2012) study, our students developed the ability to solve problems creatively which is essential to think scientifically.

The use of the GeoGebra application, and in particular the Geogebrabook, made it possible to clarify the instructions for students less autonomous, to improve their ability to work online. GeoGebraBook has attracted students' attention since the first minute, engaging them for the activities, motivating them to explore and solve the proposed problems. We observed that the students asynchronously worked with their peers, but we noticed that they preferred synchronous calls with the teacher to clarify doubts. These results are in line with what Poikela et al. (2009) say, according to which on problem-based learning method there is a focus on synchronous learning to achieve shared understanding and knowledge. For students, the Open-source packages are an opportunity to use them in the teaching-learning process, but for the community it also represents an opportunity to collaborate and evolve (Hohenwarter, et al., 2008). We have provided an example on how GeoGebraBook can be used to promote mathematics learning. We found that the area and volume simulators contributed very positively to "understanding the concept of the volume area" (S2, S5, S34 & S38). For the teaching of geometry, GeoGebraBook is more advantageous than a paper or an animation that takes the figures in different directions, because it is interactive, dynamic, and sequentially structured. GeoGebraBook was a useful resource to assist students of primary school in solving problems, but also for checking regularities.

As an exploratory research, this study allowed us to draw some conclusions that constitute suggestions for future studies: the use of Geogebrabook can be revealing to help students understanding threshold concepts, as the sharing of results by students can contribute to the establishment of connections. We live in an environment where the technological tools can be employed for recording, constructing, and visualizing the shared understanding and knowledge in face-to-face tutorials. In an online teaching environment, it seems relevant to us to consider in future studies the implications that, video lessons combined with Geogebrabook, can have for mathematical education. Problem-based learning follows the structure of problem solving within shared or individual learning. It also seems relevant to understand the impact of this teaching model on the development of transversal skills and interdisciplinary content, because it can influence guidelines for education.

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