GeoGebra Classic: Learning of Euclidean geometry in students with multiple subject teaching

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Abstract: The objective of this study is to identify the effectiveness of the application of GeoGebra Classic as a mediation software for learning Euclidean geometry in students with multiple subject teaching. The method employed was quasi-experimental research using a non-equivalent control group design. The subjects of this study were students of the InstituciónEducativa Particular Ciudad de Lima. The data were required through McNemar and Pearson Correlation tests. The results show an increase in the improvement of self-regulation cognitive skills from 25 % to 61 %, for an increase of 36 % after applying GeoGebra Classic. An improvement in learning was evidenced since the correlation coefficient is high (0.725) for learning with software compared to (0.442) for the traditional method. This indicates that there is an impact of the use of the GeoGebra Classic application on the learning outcomes in students, adopting the hypothesis: Teaching Euclidean geometry mediated with GeoGebra Classic improves self-regulation skills in students. It can be concluded that this could be due to the interest of the students, denoting that the low academic performance of the control group was above the level of the good performers.

Keywords: GeoGebra Classic, efficiency, Euclidean geometry, self-regulation, cognitive

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1. Introduction

In geometry learning and teaching, it frequently has observed that students still lack cognitive skills and the geometry comprehension process. While the teacher provides the necessary pieces of knowledge to support the students with the comprehension of the basic concepts. The students seem to be experiencing a challenge when they are doing tasks. It is almost needs something more to guide the trainees, in the way that they will be able to understand and confront the challenges during the Euclidean geometry study (Pachano and Terán, 2008).

Beginning 2021, it showed an uncertain panorama about the continuity of distance education as a substitute for the student's attendance in classrooms. A lot of Peruvian educational institutions started to implement e-learning to substitute the traditional classes. This is used as a manner to decrease the infection transmission caused by COVID-19 in the region. Currently, e-learning is being applied, especially in the study programs of mathematic education, such as GeoGebra. This study seeks to measure the geometry learning in students with multiple subject teaching of the InstituciónEducativa Particular Ciudad de Lima.

GeoGebra Classic may help students to see and understand these concepts during the practice. A literature review also shows that the software has effectiveness in the development of each students' cognitive skills. **Granados et al. (2020)** express that the mathematics teaching motivation had positively affected the learning and performance of students and this improved their motivations. In this regard, **García et al. (2018)** also explain that the students improve their skills of geometry comprehension after using the software. The students were capable to explore and formulate a hypothesis, and at the same time, they can improve their scores. The study results help to inform the teacher about the learning process of the students, especially the related with the use of GeoGebra Classic in the geometry subjects.

The results describe how to affect the different interactions to learning with the technology, students, and teachers. According to the Vygotskian perspective, the social interaction role in the learning process **(Pasqualotto et al., 2015)** may be more evident. In another way, the manner that the students interact with their pairs and the adults help to inform the teacher about the use of GeoGebra.

Based on this proposal, the study provides information about geometry teaching effectiveness, and this results in geometry learning mediated by GeoGebra. This information is essential at the moment to plan the online classes for the COVID-19 pandemic. Therefore, it reveals the technology integration of virtual teaching and learning in students. The results help to redefine, especially, the teacher role, in order to the guiding concept is the more appropriate during the research.

2. Methodology

The research is focused on the positivist paradigm (Ramos, 2015; Pérez, 2015). The approach was quantitively (Sánchez et al., 2018) and the deductive hypothetic method (Hernández y Mendoza, 2018). In addition, this is applied (Del Canto y Silva, 2013; Sánchez, et al., 2018) and quasi-experimental, being 84 students in the intentional sample of the 4 and 5 grade of multiple subject teaching in the InstitutoEducativo particular Ciudad de Lima. This was divided among the experimental and control group. The experimental group received treatment that consisted of the use of the application GeoGebra Classic during the e-learning sessions, while the control group used the self-regulated learning with a video tutorial of the class teacher during the learning session. Therefore, the research design used in this study was a nonequivalent control group in an attempt to investigate the effectiveness of the application in the Euclidean geometry learning results.

For the necessary collection of data, this study used a test as a research instrument. The type of test used was of "performance" in which was investigated the learning result, comparing the pretest and posttest results. The previous test was applied to verify the pieces of knowledge and the students' self-regulation capacity and the subsequence test had the objective to identify the results after had mediated the learning with GeoGebra. The collected data were analyzed through statistical analysis with the SPSS software 26.0 version.

2.1 Statistical analysis

The McNemar test, also known as “differences between two correlated proportions”, is a specific Cochran’s Q test case for the study case that has two responses (Gong et al., 2019). The students respond to the instruments, it is categorized in binary variables, according to the collaborative learning before and after the application of flipped classroom method for the calculus subject. Therefore, the responses were measured if these were equals or different for the sample.

In the study is used the McNemar test to the comparison the experimental treatments of binary data, from closed-ended. The McNemar test assumes that the sample number is the same as the two experimental treatments and the observations are in blocks. The mathematic model for the implementation of the McNemar test is:

$$T = \mathrm{k}(\mathrm{k}-1)\sum_{j=1}^{k} = \frac{\left(Xj - \left(\frac{N}{k}\right)\right)^2}{\sum_{i=1}^{0} \mathrm{Xi}(\mathrm{k}-\mathrm{Xi})} \qquad (1)$$

Where,

K is the number of treatment

X j is the total of the column for the treatment

b is the number of blocks

Xi is the total of the row for the block i

N is the total

Consequently, it was developed procedures of multiple comparisons, with a context application of collaborative learning through ANOVA method. The collected data correspond to a Likert scale. The students are the assessors since have used the methodology after the implementation of GeoGebra Classic. The simple linear regression model is the model:

$$yi = \beta 0 + \beta 1 xi + \varepsilon i \; ; \; i = 1,...,n \qquad (2)$$

Where,

yi: represent the i-th observation of the response variable, corresponding to the i-th xi value of the X predictive variable.

εi: Nonobservable remote error associated with yi.

β0 y β1: The cutoff point in "y" and the slope of the linear regression equation.

3. Results

3.1. Statistical analysis

The McNemar test shows that 21 students confirmed, before the flipped classroom method, to have improved skills in collaborative learning; after implementing that method, 63 students confirmed to improve their skills. The null hypothesis was rejected since the responses are different in the students after applying the GeoGebra Classic; the P-value < 0.0001 is higher than alpha 0.05, i.e., the hypothesis with equal responses is rejected if it is used at a significant level of 0.05. Based on these results, it shows an increase in the improvement of cognitive skills of 25 % to 61 % of self-regulation, for a 36 % of increase after applying GeoGebra Classic. An improvement of learning was evidenced because the correlation coefficient is high, 0.725 for the learning with software and 0.442 with the traditional method.

Table 1 shows the regression summary, which indicates that F is positive and higher than 1, for the posttest (1.495), and the pretest (0.669); in addition, it is adopted the hypothesis: The Euclidian geometry teaching mediated with GeoGebra Classic improve the collaborative learning skills in students (Reinoso&Hechenleiter, 2020).

Table.1. Summary for the pedagogical models' regression that supports the geometry learning

	Posttest	Pretest
R^2	0.054	0.036
F	1.495	0.669
Pr> F	0.222	0.402

Source: Author's elaboration

Based on the quasi-experimental research is define that the mediation with GeoGebra Classic develops the self-regulation skills in students (Díaz et al., 2020).

3.2 Appreciation of the students' activities

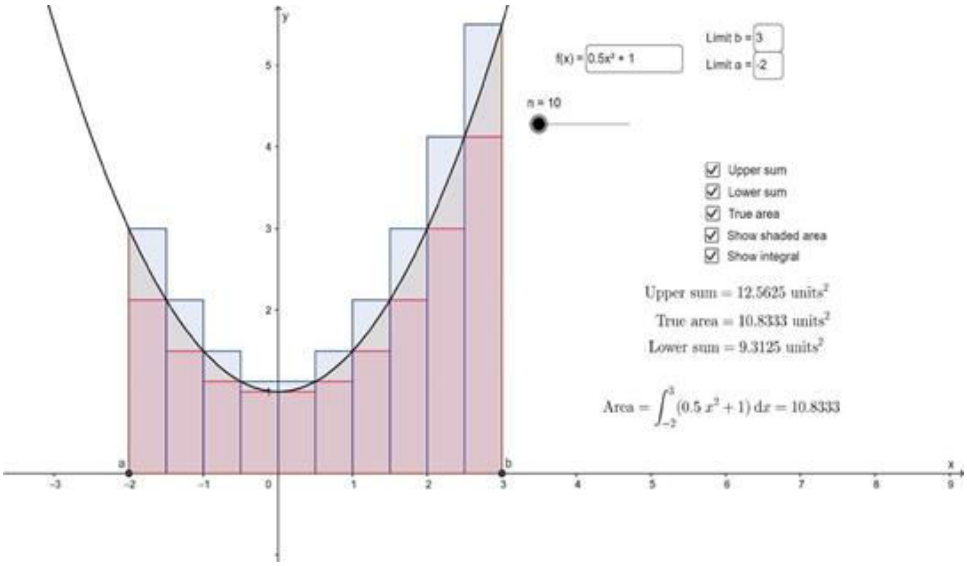
In the current circumstances, teachers should not just arrive and teach. Even the teachers and trainers with more experience in remote education are a great challenge at the moment to measure the students' performance and participation. Therefore, it is necessary to adequately plan and prepared the classes before teaching to the students. The starting point is to think about how to make the delivery interactive using adequate tools and methods. The contents should always be able before the direct sessions and should be clear and have an easy format. In addition, teachers should avoid surprises in the e-teaching or virtual teaching (this also should be avoided in traditional teaching), hence it should not be left the announcements and decisions until the last moment.

- From the total of 84 students, the groups were divided into teams of 7. An activity of integral calculus assisted by GeoGebra Classic software was selected and the following steps were follow-up:
- Specification of the class in cooperative and heterogeneous teams. The material under study was divided into as many parts as members have the teams.
- Preparation as a team of higher skills, each team member are meeting with the other team members that have the same activity about definite integral and they create activities to improve integration techniques through the addition of superior Riemann sum. Once the problems were resolved, they will prepare cooperative pedagogical material, which is shared with the other class members.
- The students of higher skills joined once again to the teams where each student come from as team leaders, they explained the pedagogical material design to the rest of the team.
- Learning activity: Find the superior Riemann sum for the definite integral:

$$\int_{-2}^{3}(0.5x^2 + 1)dx$$

This method allowed that the contributions of all the students, including the students who have fewer skills, equally esteem because these are necessary to obtain the class objectives (Topulli&Neves, 2019). Figure 1 shows the activity guide by the teacher and the students was developed on GeoGebra Classic.

Figure.1. The results of activity No. 1 were mediated by GeoGebra software.

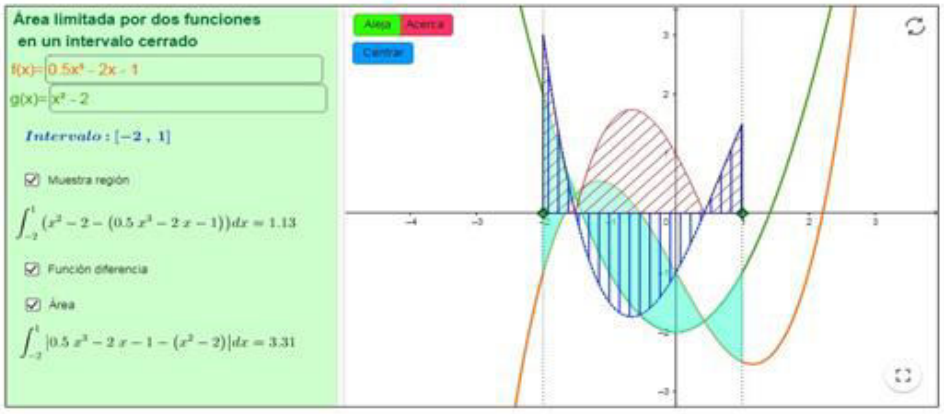


It was experienced with a second learning technique through the socialization of knowledge, at this time applied to the mathematic calculus of the area among two curves. Similarly, with the before method, the teacher is the guide for the students, implementing the online GeoGebra technology as a shared screen using remote accesses software. The following steps are:

- Activities' deliberation and distribution: The students selected their activities, according to their cognitive capacities or skills, within the integral calculus theme.
- Each team selected a different activity, in order to cover the subject theme, but in different techniques: Groups of students were observed developing the same activity in assisted software with different methodologies.
- The planning of the activity: The students and the teachers determine the purpose of the activity as part of the constructivism and planned the corresponding tasks.
- Execution of the work plan: According to the experience of the study, the teacher followed the progress of each group and he acted as a mediator of learning.
- Analysis and synthesis: The students analyze and synthesize the results of the software running. Elaborate a summary of their experiences and worksheets, presenting their worksheets to each cooperative group.
- Presentation of the learning project: Each participation generated the socialization of knowledge, interacting among the students, and making decisions to the improvement of the model worked in classes.
- Self-evaluation and co-evaluation: The teacher and students together evaluate their work roles in a group, beginning of their experiences. They evaluate the teaching and learning process about the theme.
- For the study was taken as an example of application of the theme: Find the limited area for the functions f(x) = 0.5x3 – 2x – 1 y g(x) = x2 – 2.

This method foments the intrinsic motivation with the commitment with the subtheme selected and the work plan of the team members and the autonomy (Torres et al., 2019). Figure 2 shows the results of the practice on GeoGebra assisted by a computer.

Figure.2. The results of activity No. 2 were mediated by GeoGebra software.



4. Results discussion

The results of this study show a significant difference in the procedural and conceptual knowledge of the mathematic function theme among the students that used the GeoGebra software and who were taught with the conventional method. This demonstrated that teaching and learning using the GeoGebra software will significantly improve and strengthen the conceptual knowledge of the students about the function theme. Strengthen the conceptual pieces of knowledge of the students about the theme of the Mathematical function. This is because the GeoGebra software helps students to see the theme concepts and directly relate the concepts with their daily life. Therefore, it will be easier to apply the concepts in other fields.

The results of this study are in favor of Tacuri and Coaquira Cardenas' (2019) confirmation that GeoGebra software helps students to see the abstract concept clearly, hence this helps students to relate the concept to other mathematical knowledge. Conceptual knowledge is very important in the mathematics learning process. Teaching and learning mathematical concepts through GeoGebra software helps students to prioritize mathematical concepts that are interconnected with student learning in the classroom and beyond. Teachers should be aware that knowledge does not easily transmit or transfer from one person to another.

Actually, the knowledge is developed for the students through their interaction process with the learning environment (Espinoza and Ricaldi, 2018). Thus, the students' environment could be used as a real example and taken as a visible link to relate mathematical ideas to daily life experiences. It also provides new meaning to the concept of learning, which would consequently strengthen the students' comprehension of the concepts, help them understand the concepts, and improve their own procedural knowledge. All the students, independent of their skills, have proved an increase in their conceptual knowledge of the function theme. This proves that the GeoGebra software has positive effects and helps to improve the students' conceptual and procedural knowledge about mathematics. High-, moderate-, and low-performing students who learned the theme of the function using GeoGebra software all experienced improvement and their knowledge was strengthened (Garcia et al., 2014).

The software was designed so that users, regardless of their skills, can easily understand abstract mathematical concepts. It also helps students to apply the concepts. This confirms the idea of Arteaga et al. (2019) and Garcia et al. (2018) that the use of GeoGebra software helps students to see abstract concepts clearly, which helps them to

make a connection and have a better understanding of Mathematics. The low-performance students experiment with a little bit of improvement of their procedural knowledge. This shows that GeoGebra software cannot do the best for the procedural knowledge of low-performance students, even if they have used GeoGebra software. Although low-performing students used the software to learn the theme of the function, this shows that GeoGebra software cannot do amazing things for the procedural knowledge of low-performing students (Bozkurt and Ruthven, 2009).

In addition to the challenges confronted by teachers, this study also aims to find out the basic skills that teachers possess to support the application of GeoGebra. The results show two important points of interest. First, this research shows the barriers to the implementation of e-learning in tertiary institutions; for that reason, teachers master the basic skills to support online learning (Díaz and Lingán, 2018; Keong et al., 2005), but especially the barriers to mathematical content (Majerek, 2014). Teachers have difficulties when they have to teach mathematics online (Santos, 2021).

In addition, many teachers use publicly available learning management systems (meet and google classroom) instead of e-learning developed by their tertiary institutions. The results show that teachers were prepared to use e-learning before this pandemic. Therefore, when the pandemic comes, they are not so panicky about doing online learning. This contrasts with research results (Baptista et al., 2020) that show that there are many obstacles in the application of e-learning during the pandemic.

5. Conclusion

During the COVID-19 pandemic, the public and private education institutes have applied many online learning policies. This is a manner of the quick response of the Ministry of Education MINEDU to minimize the COVID-19 infection in the environment of the students. In this study, the guidelines of the governing body are followed and the challenges confronted by teachers in applying online learning of Euclidean geometry are shown. During the activities' development, it shows how the students use the GeoGebra Classic and they integrate it into their learning through self-regulation. It was made clear that the evolution between the students and the software for the learning of the Euclidian geometry, it allowed performing the tasks proposed. Finally, it is confirmed that the GeoGebra tool facilized the performance of the geometry constructions involved and this allowed to promote the development of geometric thinking in the students. In conclusion, this could be for the students' intertest, that the lower academic performance of the control group was on the level of the good performance.

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