# Geogebra Software in Mathematical Skills of High School Students: Systematic Review

Melissa Fatima Muñante-Toledo, Universidad César Vallejo, Perú, (ORCID: https://orcid.org/0000-0001-6094-4175)
Gianinna Del Carmen Salazar – Lozano, Universidad César Vallejo, Perú, (ORCID: http://orcid.org/0000-0003-2907-8269)
Karina Milagros Rojas-Plasencia, Universidad Peruana de Ciencias Aplicadas, Perú, (ORCID: 0000-0001-9324-9478)
Juan Méndez Vergaray, Universidad César Vallejo, Perú, (ORCID: http://orcid.org/0000-0001-7286-0534)
Edith Gissela Rivera – Arellano, Universidad César Vallejo, Perú, (ORCID: http://orcid.org/0000-0002- 3712-5363)
Edward Flores, Universidad César Vallejo, Perú, (ORCID: https://orcid.org/0000-0001-8972-5494)

**Abstract:** The research aimed to analyze the publications about the effect of the software geogebra on the mathematical competences in high school students in the last decade. The final sample includes 17 articles and followed the methodology proposed by the PRISMA Declaration. The results show that the geogebra software has been a determining factor in the development of mathematical competencies, with emphasis on mathematical understanding, geometric reasoning and problem solving. Additionally, the geogebra software produces significant effects in contrast with traditional instruction. Thus, this review addresses the use of geogebra software as a resource to develop mathematical competencies in high school students.

**Keywords:** mathematical competence, Geogebra, problem solving, systematic review.

## 1. Introduction

Knowledge is built by the individual based on reality, it is not only about obtaining answers, but what is really important is how learning occurs (Piaget &Szeminska, 1967); For this, it is necessary to have the predisposition to learn and a potentially significant material Ausubel (2002). At present, learning mathematics in secondary education is given by competences and capacities that the student must achieve to develop (Solar, García, Rojas, & Coronado, 2014); However, students often do not achieve this development of mathematical competencies due to the existence of the digital divide that affects the world's poor, since the labor situation in households is not favorable due to the low economic income that affects Third world public school students have few devices and broadband for the proper use of technology (Has, 2004; Pick, Sarkar, & Parrish, 2020); Another reason is because many times in the classroom the teacher only teaches the chair and does not use other tools that motivate the learning of mathematics and others because the state does not invest in teacher training, or in the necessary resources for that purpose ( Maquilón, 2011).

One of the problems that is anchored in students is the lack of motivation for learning mathematics, a basic condition for the achievement of mathematical competencies (Ricoy& Couto, 2018; Trujillo-Torres, Hossein-Mohand, Gómez-García, Hossein-Mohand, &Hinojo-Lucena, 2020), this situation additionally generates in the student a lack of interest in learning mathematics and that becomes a generational stigma (Tella, 2007). Faced with this situation, technological advances (ICT) such as Geogebra educational software are a great contribution that implements learning, generating in students not only knowledge but also critical and creative thinking, in addition to stimulating the learning of geometry and algebra, when analyzing an exercise from the simplest to the most complex (Vidal et al., 2010; Hohenwarter, 2004).

Geogebra software is used as an open educational resource in different countries of Latin America and the world, for this reason in 2008 the International Geogebra Institute (IGI) was formed, created to support teachers and students who want to learn to handle the software. supporting them in each region where they are, that is why in Latin America the Geogebra Latin America Community (CGL) was created which has countries such as

Argentina, Brazil, Colombia, El Salvador, Mexico, Paraguay, Peru, Uruguay and Venezuela, to disseminate and share educational experiences that contribute to the teaching and learning of mathematics and other sciences (Rubio-Pizzorno, 2020).

In this sense, the Geogebra software is being increasingly integrated into the different levels of education that help to increase mathematical competencies during their learning and this is due to the Geogebra is a free access and dynamic mathematical software that brings together geometry, algebra and calculus, which its creator Hohenwarter who aimed to create a didactic tool that helps in the process of education in the teaching and learning of mathematics and improve their skills; easy to manipulate, simple and be accepted on different platforms (Arteaga Valdés, Medina Mendieta, & del Sol Martínez, 2019); It also has several advantages: individual or group learning, encourages creativity, autonomous learning, free access tool, multiplatform, and composed of easy-to-use tools, supports dynamic scenes, allows saving and exporting files in different output formats, allows entering images, works with LaTeX, is multilingual in its commands and has an international community that share material as educational support (Wassie&Zergaw, 2019). Likewise, it allows students to focus on the procedures to model a problem and interpret its solutions, generating a development of their geometric thinking (Pabón Gómez, Nieto Sánchez, & Gómez Colmenares, 2015)

The objective of this review is to analyze the publications made in relation to the effect of Geogebra software on mathematical competencies in secondary school students between the years 2010 - 2020.

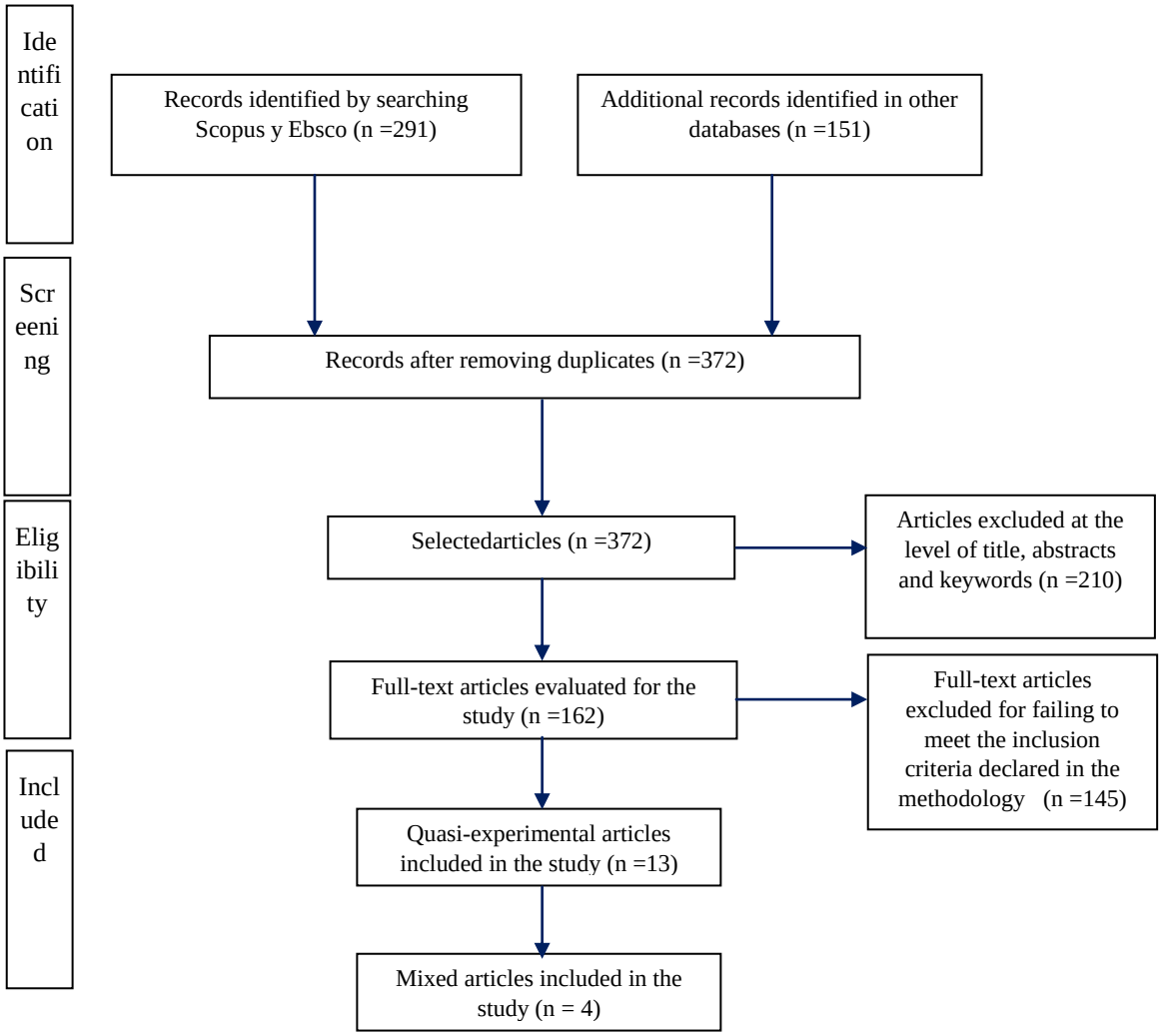
## 2. Methodology

The review was carried out with a qualitative approach and a systematic design, which has a circular analysis process in which certain steps stand out in the analysis of the data obtained (Hérnandez, Fernández, & Baptista, 2014); He also used the technique of documentary analysis that consisted of finding, acquiring and examining the bibliography that contains knowledge and very useful information that will serve to achieve the objective of the research (Tamayo, 2003).

The review followed the methodology established in the PRISMA statement as indicated by its acronym in English (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes) that allows improving the investigations of systematic reviews and meta-analyzes, through a clear process of methods and results (Urrutia &Bonfill, 2010). The target period was from July 01/07/2020 to 12/01/2020, which consisted of identification, screening, eligibility and inclusion, which was carried out in two months. The information search was carried out in the databases of Scopus, Ebsco, Proquest and OneFile, using the following combination of keywords "software geogebra and problem solving", "software geogebra and mathematical skill", "software geogebra and mathematical skill and education". The search results yielded a total of 442 documents that followed the process of the aforementioned methodology, with 17 investigations being selected from the total of reviewed

Inclusion criteria: quasi-experimental, mixed articles for high school students that address the use of Geogebra software in the development of mathematical competencies. Exclusion criteria: those investigations with methodological deficiencies, those carried out for university students and that did not demonstrate a relationship with the study variable were excluded. The empirical articles were evaluated according to the Scale to Evaluate Scientific Articles in Social and human Sciences SSAHS (López-López, Tobón, & Juárez-Hernández, 2019)

Figure 1




Adaptation of PRISMA, flow diagram (Urrutia &Bonfill, 2010).

## 3. Results

The results obtained in the initial search in the databases yielded 442 articles, of which 70 duplicates were excluded. The next filter was the exclusion of 210 articles considering the title, abstract and keywords, leaving 162 articles; Finally, the following filter considered the exclusion of 145 articles that did not meet the inclusion criteria declared in the methodology, leaving 17 articles for analysis for an exhaustive review that is detailed below:

**Table 1**
Number of articles published between the years 2010 - 2020.

| Range | frequency | Percentage |
|---|---|---|
| 2010 – 2013 | 5 | 29.41 |
| 2014 – 2017 | 7 | 41.18 |
| 2018 – 2020 | 5 | 29.41 |
| Total | 17 | 100 |

In relation to the results of the 17 articles analyzed in the period 2010-2020, 41.18% (7) of publications correspond to the period 2014-2017, 29.41% (5) of publications correspond to the period 2010-2013; Likewise, 29.41% (5) were published between 2018 and 2020. The figure shows that the highest production of articles was published before 2018.

**Table 2**
Number of articles found in the different databases in relation to the research variables between 2010 and 2020.

| Database | Frequency | percentage |
|---|---|---|
| Scopus | 10 | 58.82 |
| Ebsco | 5 | 29.42 |
| ProQuest | 1 | 5.88 |
| OneFile | 1 | 5.88 |
| Total | 17 | 100 |

Of the researches analyzed in relation to the queries in the databases, 58.82% (10) were found in the Scopus database, 29.42% (5) in Ebsco, 5.88% (1) in ProQuest and 5.88 % (1) in OneFile. It is evident that the largest number of articles were published in the Scopus database.

**Table 3**
Frequency of articles produced in different countries of the world according to the study variables in the 2010-2020 range.

| Country | Frequency | percentage |
|---|---|---|
| Turkey | 5 | 29.42 |
| Malaysia | 4 | 23.53 |
| Indonesia | 2 | 11.77 |
| Colombia | 1 | 5.88 |
| India | 1 | 5.88 |
| Jerusalem | 1 | 5.88 |
| Nigeria | 1 | 5.88 |
| Peru | 1 | 5.88 |
| South Africa | 1 | 5.88 |
| Total | 17 | 100 |

Most of the articles published were made in Turkey with 29.42% (5), in Malaysia with 23.53% (4), thus articles were also found in 11.77% (2) in Indonesia, finally articles were made with 5.88 % (1) in Peru, Jerusalem, Colombia, Nigeria, India and South Africa respectively. These results show little interest in the use of Geogebra software despite the fact that its results have positive effects on mathematical skills.

**Table 4**
Type of research design of articles related to the use of geogebra software in mathematical competencies.

| *Researchdesign* | *frequency* | *percentage* |
|---|---|---|
| Quasi experimental | 13 | 76.47 |
| Mixed | 4 | 23.53 |
| Total | 17 | 100 |

Regarding the research designs, it was found that 76.47% (13) are quasi-experimental studies and 23.53% (4) are mixed studies. The greatest scientific production is oriented towards quasi-experimental designs.

**Table 5**
Effects of using Geogebra software on dependent variables.

| Variables | frequency | percentage |
|---|---|---|
| Geometry learning | 6 | 35.29 |
| Math learning and performance | 5 | 29.43 |
| Mathematical understanding | 2 | 11.76 |
| Cooperative learning | 1 | 5.88 |
| Mathematical Communication | 1 | 5.88 |
| Knowledge of functions | 1 | 5.88 |
| Achievement and attitude | 1 | 5.88 |
| Total | 17 | 100 |

The results show that 35.29% (6) of the dependent variables related to the use of geogebra software considered in the investigations was learning geometry, 29.43% (5) was the dependent variable learning and mathematical performance, 11.76% (2) was the dependent variable mathematical understanding, 5.88% (1) cooperative learning, 5.88% (1) achievement and attitude, 5.88% (1) mathematical communication, finally, 5.88% (1) knowledge of functions. The highest percentage of dependent variables being the learning of geometry.

**Table 6**
Analysis of the coincidences of the results of the use of Geogebra software in mathematical competences

| Results | frequency | percentage |
|---|---|---|
| R1. Learning the geometry of shapes and spaces using Geogebra software allows you to create critical, creative and innovative solutions. | 1 | 5.88 |
| R2. Geogebra software helped students develop mathematical competencies such as plane geometry, knowledge of functions, mathematical communication, and geometric reasoning in different grades. | 8 | 47.06 |
| R3. The use of Geogebra software showed significant effects on learning achievement, attitudinal and collaborative changes that favored the learning of mathematics. | 4 | 23.53 |
| R4. The Geogebra software showed in contrast to the traditional instruction significant effects in the learning of mathematics based on mathematical understanding. | 4 | 23.53 |
| Total | 17 | 100 |

In relation to the results that show the effect of geogebra software on the development of mathematical competencies of the 17 articles, 52.95% (9) of publications showed that geogebra software helped students to develop mathematical competencies related to plane geometry, statistical learning, mathematical understanding, mathematical communication, geometric reasoning in different degrees.

While 23.52% (4) of the studies showed that geogebra software had significant effects on learning mathematics based on mathematical understanding; Furthermore, no differences were found according to sex, likewise, 17.65% (2) of the participants developed abilities and skills in relation to the achievement of learning mathematics and attitudes towards these learnings, increasing collaborative learning. Finally, 5.88% of the investigations showed significant effects of the Geogebra software in the learning of the geometry of shapes and spaces, allowing the creation of critical, creative and innovative solutions. In conclusion, it can be affirmed that geogebra software, according to the different researchers analyzed, has significant and positive effects on plane geometry, statistical learning, geometric reasoning in different degrees, as well as on attitudes towards mathematical learning, the learning of problem-based mathematics, critical, creative and innovative solutions and cooperative learning.

## 4. Discussion

During the research process of the systematic review, the articles collected using the search criteria were quasi-experimental and mixed studies regarding the effect of geogebra software on mathematical competencies in high school students of the last decade. The analyzed studies show that the use of Geogebra software has important effects on the learning of mathematics and especially related to geometry.

In relation to the production of articles related to the effect of Geogebra software on mathematical competences in secondary school students in the 2010-2020 range, it was observed that the highest production was found between the years 2014 to 2017. In line with these results, has the research of Arbain&Shukor (2015) that showed that students have a positive attitude towards mathematical learning, reaching the expected achievements in their learning through the use ofgeogebra software, as well as in the research of Onaifoh& Ekwueme (2017) showed that students' performance increased when plane geometry was taught using Geogebra software and problem-based learning, but there was no significant difference with respect to gender.

On the other hand, when considering databases as a research source, it was found that 58.82% (10) investigations were located in Scopus, such as the investigations of Medina, Gallardo, & Paz (2019), Saha, MohdAyub, &Tarmizi ( 2010), Zulnaidi& Zakaria (2012); Likewise, it was observed that 29.42% (5) investigations were located in Ebsco as the investigation of Shadaan& Leong (2013); Additionally, 5.88% (1)

inquiries were located in ProQuest and 5.88% (1) inquiries were located in OneFile. This is an indicator that the research carried out on the subject is published in indexed journals in the Scopus database.

Regarding the studies reviewed in relation to countries, it was observed that in Turkey 29.42% (5) where the largest number of scientific productions were carried out; furthermore, 23.53% (3) in Malaysia; 11.77% (2) in Indonesia and 5.88% (1) in Peru, Jerusalem, Colombia, Nigeria, India and South Africa respectively. These results show that Turkey is a country interested in conducting research on the use of geogebra and seeing its effects on the development of mathematical competencies, as shown by the study by Kutluca (2013), who showed that the application of Geogebra software has an effect positive in students' level of understanding of Van Hiele geometry; Furthermore, in the research by Turk &Akyuz (2016) it was shown that the teaching of dynamic geometry using geogebra software showed a significant effect on students' attitudes towards the performance of their learning of geometry and technology compared to traditional instruction.

When addressing the analysis of the research designs of the published articles, it was observed that 76.47% (13) were elaborated with a quasi-experimental design since they manipulated at least one independent variable such as geogebra software to observe its influence on one or more variables. dependents (Hérnandez, Fernández, & Baptista (2014); which are shown in the investigations of Bhagat & Chang (2015) showing that the geogebra software as a computer program showed a positive effect for the learning of geometry; in the same line the Research by (Yuliardi&Nurjanah, 2017) showed that learning mathematics with the use of geogebra software and the Technological Classroom (TAC) improves mathematical communication skills in students. On the other hand, 23.53% (4) of The published articles corresponded to the mixed design; where it is shown that when integrating the geogebra software and cooperative activities have a significant influence mind in the development of mathematical thinking and problem solving in students of (Hashem & Arman, 2013; Zengin& Tatar, 2017); Furthermore, Kandemir&Demirbağ-Keskin (2019) showed that there was a significant positive difference in the achievement of learning mathematics, while attitudes towards learning geometry were not affected by the geogebra software. It should be noted that in the analysis process of the articles published during the 2010-2020 period, qualitative research was found that was not taken into consideration because the study was oriented towards the search for quantitative research that reflected the effects of geogebra software on the development of mathematical competencies.

An important finding was to determine the variables related to the effect of Geogebra software on mathematical competences, the largest amount of research was related to the learning of geometry (35.29%) where it was observed that geogebra software produces positive effects on the learning of geometry, which corroborates with what was proposed by Hohenwarter, Kovács, &Recio (2019), who highlight the importance of geogebra software that aimed to facilitate the learning of mathematics through the construction of geometry, which is reaffirmed with the position by Jean Piaget who considers that knowledge is constructed by the individual (Piaget &Szeminska, 1967; Saldarriaga, Bravo, &Loor, 2016). On the other hand, 29.43% was related to the variable learning and mathematical performance, this agrees with the position of (Vidal, Gómez, & Ruiz, 2010), who states the importance of geogebra software for learning mathematics. In addition, 11.76% were related to the variable mathematical understanding and 5.88% were related to each of the following variables: cooperative learning, student achievement and attitude, mathematical communication and knowledge of functions. In conclusion, the analysis of the selected articles, it is observed that in all the variables related to the geogebra software it had significant effects because it generates a dynamic and participatory activity in the students in which the learning constitutes a process that is shown in a diversity of didactic forms (Hutkemri&Effandi, 2012).

On the other hand, the analysis of the coincidences of the results in the analyzed articles on the use of geogebra software in mathematical competences showed that 47.06% of studies were related to the influence of geogebra software on the development of mathematical competences that included mathematics. plane geometry, mathematical communication, geometric reasoning in different high school grades, as shown in the results of the research by Diaz-Nunja, Rodríguez-Sosa, &Lingán (2018) who found that geogebra software produces highly significant effects on communication mathematics, reasoning and proof, as well as problem solving. Likewise, the study by Romero, Del Mar, &Codina (2015) indicated that the work with DGS contributed significantly to the development of the students' mathematical competencies, in a general way. However, its effect was more noticeable in some competitions, which stood out the presentation and tool of the software that helped most of the students to progress more quickly; Along the same lines are the studies of Zulnaidi& Zakaria (2012), Hashem & Arman (2013), Bhagat & Chang (2015), Yuliardi&Nurjanah (2017), Onaifoh& Ekwueme (2017) and Medina, Gallardo, & Paz (2019).Encuanto a las coincidenciasrelacionadas con los resultadosenrelación a las competenciasmatemáticas, el 23.53% de los estudiosapuntabanhacia el logro del aprendizaje, cambiosactitudinales y colaborativoscomo lo evidencian los estudios de Arbain & Shukor (2015), Turk & Akyuz (2016),Zengin & Tatar (2017) y Kandemir & Demirbağ-Keskin (2019).

Likewise, 23.53% of the studies were related to learning mathematics based on mathematical understanding, where it was observed that geogebra software in contrast to traditional instruction produced significant effects on learning as evidenced by the studies by Saha, MohdAyub, &Tarmizi (2010), Kutluca (2013), Shadaan& Leong (2013) and Adelabu, Makgato, &Ramaligela (2019).

Finally, another of the coincidences found in the results in 5.88% are related to the learning of geometry of shapes and space, because the software allowed students to create critical, creative and innovative solutions and skills to facilitate the solution of mathematical problems using imagination (Md-Ali & Kim, 2018).

## 5. Conclusions

The findings of this review show that geogebra software facilitates the increase of the student's mathematical competencies during their learning and is due to the fact that this mathematical software is open and dynamic, which brings together geometry, algebra and calculus; it is easy to manipulate, fostering creativity, autonomous and collaborative learning. Likewise, it allows students to focus on the procedures to model a problem and interpret their solutions by developing their geometric thinking.

Scientific production shows a greater number of articles published between 2014 and 2017, where it is shown that there was greater interest in determining the influence of geogebra software on the development of mathematical competencies; Likewise, it was evidenced that in Turkey there was greater interest in conducting research related to the effect of geogebra software on the mathematics learning of secondary school students; Furthermore, these investigations were found in greater quantity in the Scopus database.

The researchers analyzed were with a higher quasi-experimental percentage, because the results of these studies allow much better evidence of the positive effect generated by the use ofgeogebra software in mathematical competencies; therefore, qualitative designs were not considered in the research.

Regarding the variables related to mathematical competencies analyzed in the review articles, it was found that geogebra software has a positive effect on the geometry learning variable in a higher percentage, because this dynamic technology software allows students to visualize , understand and master the mathematical concept more easily; In addition, influence was found on the variables: mathematical learning and performance, mathematical understanding, cooperative learning, achievement and attitude, mathematical communication and knowledge of functions, in all of them it was evidenced that the use of geogebra software facilitated understanding, improved performance, increased conceptual and procedural knowledge; Likewise, the cooperative learning variable supported with the DMS (dynamic mathematical software) has an important role in increasing student achievement; In this sense, this research recommends implementing in schools the use of geogebra software in the teaching and learning process to develop mathematical competencies in students.

On the other hand, in the coincidence analysis of the results of the investigations used for the systematic review, in a higher percentage there are coincidences related to the influence of geogebra software in the development of mathematical competencies that included plane geometry, knowledge of functions, mathematical communication, geometric reasoning in different degrees, showing similarity in the results of the investigations due to the fact that mathematical abilities can be developed with the use of geogebra software, allowing students to find new ways of learning, in which they felt motivated, interested and attracted by the dynamic activities that the software provides. Also, coincidences were found in the use of geogebra software, which, in contrast to traditional instruction, showed significant effects on learning mathematics based on mathematical understanding, since dynamic geometry software as an effective tool can facilitate student learning through visualization and improve your mathematical understanding. Likewise, another coincidence found is related to the use of geogebra software that showed significant effects on learning achievement, attitudinal and collaborative changes that allow creating critical, creative and innovative solutions favoring the learning of mathematics. Finally, it is concluded that geogebra software is an effective tool that helps teachers and students to achieve the principles of constructivist learning and to increase their mathematical skills within geometry and algebra.

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