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NATIONAL INSTITUTE OF EDUCATION
មជ្ឈមណ្ឌលស្រាវជ្រាវគរុកោសល្យជំនាន់ថ្មី
NEW GENERATION PEDAGOGICAL RESEARCH CENTER

បម្រើបម្រាស់កម្មវិធី GeoGebra ក្នុងការបង្រៀន និងរៀនគណិតវិទ្យានៅកម្រិតវិទ្យាល័យ

The Use of GeoGebra Applications in Teaching and Learning Mathematics in High School

A Mini-Thesis
In Partial Fulfilment of the Requirement for
Master's Degree of Education in Mentoring

Im Leangsim

February 2021

វិទ្យាស្ថានជាតិអប់រំ

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The Use of GeoGebra Applications in Teaching and Learning Mathematics in High School

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February 2021

មូលន័យសង្ខេប

នៅក្នុងខ្លឹមសារសៀវភៅសិក្សាគោលគណិតវិទ្យា គ្រប់កម្រិតថ្នាក់ (មធ្យមសិក្សាទុតិយភូមិ) ដែលបានបោះពុម្ពផ្សាយដោយគ្រឹះស្ថានបោះពុម្ព និងចែកផ្សាយ ឆ្នាំ២០១៨ គឺមិនមានការដាក់បញ្ចូលការបម្រើបម្រាស់បច្ចេកវិទ្យានៅក្នុងថ្នាក់រៀនឡើយ ខណៈពេលដែលការសិក្សានាពេលបច្ចុប្បន្នបានងាកមករកការអប់រំបែបសតវត្សទី២១។ ប៉ុន្តែមានគ្រូគណិតវិទ្យាមួយចំនួនដែលបានប្រើប្រាស់កម្មវិធី GeoGebra ខណៈពេលដែលក្រសួងអប់រំបានជំរុញឱ្យមានការប្រើប្រាស់កម្មវិធីផ្សេងៗដើម្បីជាជំនួយនៅក្នុងសិក្ខាសាលាមួយដែលបានធ្វើនៅឆ្នាំ ២០១៥។ ភ្ជាប់ជាមួយគ្នានេះ ក៏មានសំណួរជាច្រើនលើកឡើងថា "ហេតុអ្វីបានជាកម្មវិធីមួយនេះត្រូវបានគេលើកទឹកចិត្ត?" "តើកម្មវិធីមួយនេះពិតជាមានសារៈប្រយោជន៍មែនឬយ៉ាងណា?" -ល-។ ដូចគ្នាដែរ ការសិក្សាមួយនេះ មានគោលបំណង រំលឹកពីការប្រើប្រាស់កម្មវិធី GeoGebra នៅក្នុងថ្នាក់រៀនគណិតវិទ្យាពីបណ្តាប្រទេសផ្សេងៗ និងកំណត់សម្គាល់ពីគុណប្រយោជន៍ និងកត្តារាំងស្ទះក្នុងការប្រើប្រាស់កម្មវិធីមួយនេះនៅក្នុងថ្នាក់រៀន ដោយភ្ជាប់ជាមួយដំណោះស្រាយខ្លះៗ។

បន្ទាប់ពីការសំយោគឯកសារ ជាលទ្ធផល បម្រើបម្រាស់កម្មវិធីនេះមានសារៈសំខាន់ដល់គ្រូបង្រៀនដូចជាជួយក្នុងការវិធីសាស្ត្របង្រៀន គំនិតច្នៃប្រឌិត និងមានការអភិវឌ្ឍផ្នែកវិជ្ជាជីវៈ។ សម្រាប់សិស្សវិញ កម្មវិធីបានជំរុញឱ្យសិស្សកាន់តែសកម្ម លើកទឹកចិត្តក្នុងការរៀន និងជំរុញការអភិវឌ្ឍផ្នែកបញ្ញា។ ក្នុងនោះដែរ ការប្រើប្រាស់កម្មវិធីនេះក៏មានការលំបាកចំពោះ គ្រូ និងសិស្សដែរ ដូចជាចំណេះដឹងផ្នែកបច្ចេកវិទ្យា ការចំណាយពេលបង្កើតសម្ភារៈបង្រៀន ការរំខានពីកម្មវិធីផ្សេងៗ។ ជាចុងក្រោយការសិក្សាមួយនេះក៏បានផ្តល់ជាយោបល់ក្នុងការដោះស្រាយកត្តារាំងស្ទះមួយចំនួនទៅដល់លោកគ្រូ អ្នកគ្រូ និងអ្នកពាក់ព័ន្ធ ក៏ដូចជាសម្រាប់អ្នកស្រាវជ្រាវបន្តផងដែរ។

ABSTRACT

Cambodia mathematics high school textbook published by Publishing and Distribution House in 2018, as we can easily observe, do not encourage teachers to use technology in the classroom while it is now 21st century education with the wide range of application. However, GeoGebra was widely used by mathematics teachers as MoEYS had pushing the use of this via a workshop in 2015. Then some questions come out: why this application was encouraged? Is it really beneficials? And so on. Hence, the purposes of this study are to review the use of GeoGebra in mathematic class from other countries and identify the benefits and barriers of implementing a free-cost GeoGebra software in the classroom and some suggested solutions to the barriers. As a result, we synthesis with benefits and barriers to the teachers and students. As for the teachers, it is useful for their teaching method, creativity and professional development. Whereas, for students, it pushes them to be more active, motivative and enhancing their cognitive development. Nevertheless, there are also some challenges for teachers as well as for students such as technology knowledge, time consuming and other software distraction. Finally, we suggest solutions for teachers, other stakeholders and further researchers.

SUPERVISOR'S RESEARCH SUPERVISION STATEMENT

TO WHOM IT MAY CONCERN

Name of program: Master's Degree of Education in Mentoring
Name of candidate: Im Leangsim

Title of thesis: The use of GeoGebra applications in teaching and learning Mathematics in High School

This is to certify that the research carried out for the above titled master's thesis was completed by the above-named candidate under my direct supervision. I played the following part in the preparation of this thesis: guidance in research problem development, literature review, methodology, data analysis, and discussion finding.

Supervisor (Name): …….

Supervisor (Sign): …….

Date: ……

CANDIDATE'S STATEMENT

TO WHOM IT MAY CONCERN

This is to certify that the thesis that I "**Im Leangsim"** hereby present entitled "The use of GeoGebra applications in teaching and learning Mathematics in High School"

for the degree of Master's of Education in Mentoring at New Generation Pedagogical Research Center is entirely my own work and, furthermore, that it has not been used to fulfill the requirements of any other qualification in whole or in part, at this or any other University or equivalent institution.

Signed by (the candidate): …….
Date: ……..

Countersigned by the Supervisor: ……
Date: …….

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CHAPTER 1: INTRODUCTION

Within the century of technology, the Ministry of Education, Youth and Sport (MoEYS) had set up some main areas policy for ICT use in education which encourage teachers to use technology in their teaching. However, Cambodian Mathematics textbooks as well as curriculum do not include the use of technology in teaching and learning. As a result, most of the teachers especially mathematics teachers follow the teacher's guide book for teaching by using only paper and pen method; by that, some teachers have limited capacity in using technology in their teaching process as well as the lack of materials to implement it.

There are benefits when applying the software in teaching and learning, whereas barriers also occur unexpectedly. As the objectives of this research, this paper will be about the benefits for teachers when using GeoGebra in teaching and learning such as new teaching method, creativity and professional development, and benefits for students as active explorers, motivative and improve cognitive development. In contrast, teachers have barriers if they are unfamiliar with the software or on how to apply technology in the classroom; while students have some barriers in using the application if they are lack of prerequisite and have distraction during the course. The other issues are the time constraints in applying and creating the materials of the software for the class. Finally, it ends up with suggestions and recommendation for teachers as to have to introduce the software before the class, monitoring the class with clear instruction, intentionally explore the application tools and on how to use it and recommendation for further researchers.

Thesis structure

This paper is structured with four chapters as the following:

Chapter 1 which is this section is the introduction of this research.

Chapter 2 will state the reasons behind this paper come out and the objectives of doing this. Then it will show the scopes and limitation of this study and end up with some definitions of key terms used in this paper.

Chapter 3 is written about result found from synthesis. It consists of the benefits and barriers of using GeoGebra in teaching and learning for teachers and for students.

Chapter 4 will conclude the synthesis and suggest solutions to the barriers for teachers and stakeholders.

CHAPTER 2: PROBLEMS AND METHODOLOGY

1.1. Statement of the problem

Within the century of technology, MoEYS (2004) had set up four main areas of policy for ICT use in education. Those areas are (1) to provide ICT access to both teachers and students, (2) to emphasis on the roles of ICT in helping teaching and learning process in different subjects, (3) to promote education for all by distance learning and self-study using ICT and (4) to increase productivity, efficiency and effectiveness of teaching and learning management through ICT. By that policy, ICT has been applied to all subject matter including Mathematic.

Richardson (2011) had studied the adoption of ICT skills by teacher trainees in Cambodia, and found out that it is hard to implement ICT in the classroom due to (1) the computer incompatibility of the teacher, (2) language barriers in the application, (3) lack of electricity which is unstable and expensive, (4) lack of the sufficient number of computers, (5) lack of internet access especially in the province, (6) ICT skills with the software or coding are difficult, (7) inability to understand the advantages of ICT which cost time-intensive and complexity, and (8) failed to practice using ICT skills regularly.

MoEYS (2018) responding to the technology education, had released another policy of information and communication technology intending to enhance the use of technology for teaching and learning. There are eight significant points included in the policy, in which the sixth point prioritizes the use of open-source software for teaching and learning to ensure that technology is used in the classroom.

However, the mathematics high school textbooks published by Publishing and Distribution House in 2018 did not include or mention the use of any specific software in the lesson. To alternative their teaching method, some teachers need to be creative in

finding the application free of use and some resources to supplement their lessons. Besides, in Cambodia public school classrooms, there is a lack of material, as well as the ability to supply technology. Teachers' ability and other barriers are the causes of the lack of use of technology

In 2015, MoEYS held a national mathematics conference at Siem Reap to improve quality and effectiveness of mathematics education in Cambodia with many objectives including introducing GeoGebra software in high school curriculum. After that, in 2017, MoEYS also translated and released a GeoGebra guide book in Khmer for teachers to further their learning with the software.

Via the reading some articles for further information of the GeoGebra software as well as its uses in other countries, a question came out: "why is it mentioned in the conference?", what is this software used for?"

Therefore, a study should be conducted on the software used in the lesson, how it benefits to the classroom as demanded by the Ministry and how it should be used in the classroom. Thinking of the free software, its popularity and worldwide used of GeoGebra in today's teaching and learning, it should be applicable in Cambodia Mathematics classroom.

The specific research objectives are as follows:

- To synthesis what GeoGebra contribute in teaching and learning mathematics by reviewing the benefits and barriers on using this software.

In order to achieve the objectives, the specific research questions ask the following:

- What are the benefits and barriers in using GeoGebra?
- What are the contributions of this software in mathematics classroom?

1.2. Methodology

This paper is research synthesis in which we read the sources related to teaching and learning using GeoGebra in the classroom, and summarized those data. Among the sources' summarized, there were 35 articles and thesis; either published or unpublished from other countries especially from Malaysia were all were primary research. Those sources were selected by their titles and related to GeoGebra's contents. Some sources and articles were written by GeoGebra's designers were excluded to prevent research bias. Moreover, the sources mentioned about other software besides GeoGebra were not added. After summarizing the information, notes were categorized into themes using **thematic analysis**. By Braun and Clarke (2006); Nowell et al. (2017) *thematic analysis* is a kind of analysis used in qualitative research. It identifies, analyses, organizes, describes, and reports the themes within the data collection. According to above authors, there are six phases to form the themes in thematic analysis.

Phase 1: familiarizing with the data: getting to know the topic and data that need to collect. Then read and re-read to get more detailed ideas of the data. Via this paper, the sources were downloaded from ResearchGate, Springer, Academia.com, and Google Scholar and others recommended. There was also further sources research by key terms; GeoGebra, GeoGebra in mathematics and mathematics teaching and learning with software. Most of the resources selected were journals and thesis from other countries; both published and unpublished. Some sources downloaded from mentioned above were excluded while they were not related to the topic such as the problems and benefits of ICT in general not the GeoGebra software, GeoGebra used in other subject rather than mathematics, and other applications besides GeoGebra were not use as the references. Along the process, we also explored the GeoGebra Classic software version 6 and its

objectives; doing exercises to observe its manipulation and searching for some information on the application.

Phase 2: generating initial codes: after reading and understanding the data, noting down or highlight the important points related to the topic in a list such as “importance of the software”, “difficulties in using GeoGebra”, and so on.

Phase 3: searching for themes: sorting the codes and put them in categories or sub-categories; for instance, “confidence”, “motivation”, “professional development”.

Phase 4: reviewing themes: refining the themes whether they are problematic or not, they have enough data or they need more coding in each theme.

Phase 5: defining and naming themes: when they are already fit into the themes, give them names which give the sense what they are about.

Phase 6: producing the report: writing up the information with sufficient evidence within each data.

Finally, we came up with the following themes:

The first theme is the benefits of using GeoGebra which will be talking about the benefits of use for teachers and learners,

The second one is GeoGebra’s barriers for teachers and learners, and

The third point is how GeoGebra contributes in mathematics classroom by giving some GeoGebra use in mathematics lesson of other researchers.

1.3. Scope and Limitations

There are a few limitations of this work that should be noted. This article is used only for the benefits and barriers of the software in mathematics class. Moreover, since this

research is a research synthesis, it mostly offers benefits and some guidance for teachers on how to use the software from other countries, but it does not report on how effective using it might affect the students learning or performance in the real classroom in Cambodia; the future researchers can take this as consideration. Furthermore, future research should conduct experimental research or interview to clarify its' usage and find out more about GeoGebra.

1.4. Significances of the study

This study will offer some benefits to educational stakeholders. It will help teachers in considering the benefits of using software in the classroom, applying mathematics software in their classroom by not using only conventional methods and considering which software should be applied in the classroom for the sake of students' interest and motivation. It will also motivate students to use this software as their learning tools in mathematics topic. Moreover, it will help teachers and learners to find the solutions to the barriers beforehand.

CHAPTER 3: GEOGEBRA'S BENEFITS AND BARRIERS IN TEACHING AND LEARNING

In 2001 *Markus Hohenwarter* created ***GeoGebra*** firstly for his master's thesis in mathematics education and computer science at the University of Salzburg in Austria. It was called GeoGebra since the founder wanted to combine the topic of geometry and algebra into this software. Since 2006 GeoGebra is sponsored by the Austrian Ministry of Education to keep the free availability of the software for mathematics education at schools and universities. GeoGebra is a Dynamic Mathematics Software for learners and educators from middle school through college level. It is a free source and easy to use as Dynamic Geometry Software but also provides basic features of Computer Algebra Systems to bridge some gaps between geometry, algebra and calculus. Furthermore, Zakaria and Khalid (2016) stated that GeoGebra was objective and created to help students gain a better understanding of mathematics. Students and teachers can use it for active and problem-oriented teaching and learning, it fosters mathematical experiments and discoveries both in the classroom and at home. More than that, Dikovic (2009) mentioned that due to the new technique tool applied in the classroom, it can develop a graphic environment, dynamic worksheet, mathematical analysis to visualize mathematical processes, while students explore a wide range of function types and discover connections between math objects and graph representation.

Although this software is worldwide used, when applying this in the classroom, there will be some advantages and difficulties. The following will describe the benefits and barriers for teachers and also for the students, and some lesson guides of using GeoGebra in the classroom.

2.1 The Benefits of using the application

2.1.1. To teachers

Using GeoGebra application has benefited teachers with new instructional methodology – save time, easy and fast to understand, students centered approach and paper and pen assisted. It also promotes teachers to be more creative in teaching resources, sharing knowledge and confident when using the sources. The last one is professional development with concept change of mathematics contents and pedagogical method. The following will be the details of these points.

2.1.1.1. New instructional method

According to Hutkemri et al. (2011), whose study comprised four respondents who are currently enrolled in a mathematics education course at Universiti Kebangsaan Malaysia, had affirm that the instruction which the help of GeoGebra is clear and straightforward. Students can get the point of what to do while using symbols and simple language in the application. As mentioned in Šumonja (2015); Zulnaidi et al. (2019); (a quasi-experiment conducted to determine the effects of using the software GeoGebra as teaching aid), using GeoGebra sources, teachers save time in presentation and reduce the burden of explanation by showing graphs that hide a hundred words. In their research, while students take time to visualize the real perceptions of mathematics content of 3D dimension, introducing GeoGebra allows students to visualize the concepts easier and faster and better understand the procedure of the lesson taught and nicely accepted the technological approach method.

Similarly to above researchers, Alkhateeb and Al-Duwairi (2019); Ibrahim and Llyas (2016) conducted research comparing between the GeoGebra use and expository teaching found out that using the application was really assisted the instruction by allowing

students to interact with the software. Then students understand sufficiently the meaning of the formula since GeoGebra help them to flip between abstract, visual, and concrete representation of mathematics concepts. It is also an alternative way of teaching which draws students' attention and focus on the topic.

Furthermore, it gives the opportunity to teachers to try a new alternative strategy to deliver the teaching which shifts teaching method from teacher center to students center that leads learners to be more active as a case study in a book of Brahier (2016) on page 202-204 when students coincided figure out a question with 2 different methods but get the same answers. The teacher knew that one answer is wrong, but saying that will not satisfy students' doubts. Hence, teacher let students solve the problem by using the graph in the application which immediately explain to students that the answer that they had discussed was right but the process was not.

2.1.1.2. Resource system creativity

In GeoGebra, teachers can either create their own sources for teaching or adapt from other educators. Azizul and Din (2016); Yildiz et al. (2017) claimed that with the sources adapted from GeoGebra application, teachers have opportunities to share and adapt widely with other teachers for the sake of teaching and learning. To get the sources, teachers just go to the link and copy the interactive figures for their class.

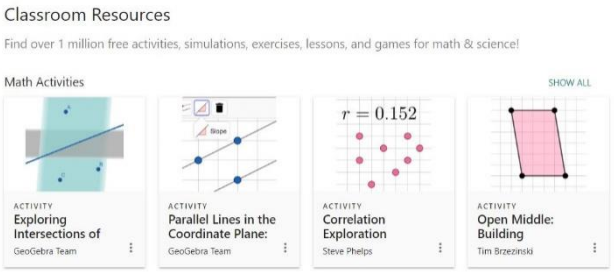


Figure 1: Resources for mathematics activity. Reprinted from https://www.geogebra.org/

Moreover, when exploring other sources, teachers will come up with some creative ideas in designing effective teaching materials for their students. When teachers had materials on hand, teachers have enough confidence in their teaching. Bozkurt and Ruthvens (2009) compared less experienced, experienced novice level, and advanced experience teachers using technology which focus was on how teachers manage their resource system with the use of GeoGebra. The finding figured out that less experienced teacher took some times to create her sources and got some files prepared by others but the sources gave teachers' confidence in teaching. Whereas other experienced teachers gained confidence from the sources they created and were more creative in designing tasks for students to discover different strategies of problem-solving.

In another research, Preiner (2008) found out that creation of varieties of materials with GeoGebra, allowed teachers to develop more independence from the published textbook and the materials' creation are better match with their students' need and knowledge in their classroom situation *(see figure 8)*.

2.1.1.3. Professional development

Escuder and Furner (2011) described that applying GeoGebra in teachers' pedagogical course had changed teachers' habit from only applying paper and pen methods but assisted their teaching with technology when students think, visualize and explore the concept, relationship and patterns of mathematic. He continues that GeoGebra increases teachers' enthusiasm for their effective pedagogy and enhances their own practice by making the graph to represent mathematical concepts with its symbol and picture in the software. While using the software, teachers feel confident in teaching, give more significance to their work and growth with technology presentation.

As well as teachers' habit, GeoGebra had changed teacher belief in teaching mathematics. Kul (2018) precise in his research that, before knowing GeoGebra, teachers thought that; for instance, "Mathematics is only the collection of rules", "cannot implement collaborative work with many students in class" (p. 236) and so on. However, while the GeoGebra has been introduced, teachers had a discussion in a small group about the application, and created a wide range of mathematical discussion environment via the software, they shifted their belief. They believe that it is a new way of mathematics thinking which is more than the traditional method, and consideration of alternative teaching and learning by using technology-assisted as a participant in his research said that *"*you can come up with innovative ideas through interacting with GeoGebra activities*."*

When introducing the software with many areas in mathematics to graduated students who are to become teachers, Hall and Chamblee (2013) saw that they were eager to learn technology and implement it in their classroom. Moreover, those teachers to be learn that there needs to be a technology focus pedagogical method and how mathematics should be taught with application in their future career.

In addition, Agyei and Benning (2015) confirmed that GeoGebra improves teachers' conceptual understanding and competency in the content knowledge. It helps teachers to relearn some mathematics concepts, and learn new mathematical content knowledge that they are deficient in before. Also, they are not only developing the subject matter knowledge but also technology integration in mathematics. They can apply the software in their teaching that makes their class more active and more student center as an effective instructional strategy.

Wan Salleh and Sulaiman (2013), GeoGebra improved not only students understanding but it is also more effective to lecturers' conceptual knowledge (knowledge of underlying ideas for procedural knowledge), procedural teaching (teaching techniques

use by teachers for the sake of students understanding). Using GeoGebra in his research, students (mathematic lecturers) have to input the problems and find out the mathematic process. By this interaction *(see figure 6)*, the software shows the process of the problems while students can see the wider range of mathematics concepts and make connect between mathematic symbol and its representation. In addition, it stated that GeoGebra brings an in-depth understanding of the selected topic and encourage as a teaching tool to aid and facilitate the lecturers. Verhoef et al. (2015) also stated that GeoGebra encourages teachers to enact and reflect on what they have taught, and to note down what students have done and how students make sense of learning activities in derivative and other areas.

In conclusion, dealing with technology, teachers in the researches show that GeoGebra brings them new creativity with critical thinking, ease their teaching performance by providing resources, learners active methodology and professional development in using technology in their teaching process.

2.1.2. To students

Not only beneficial to teachers, it is more crucial to students. The following will be the reviewing of the benefits of using GeoGebra to students within 3 subtopics, (1) it encourages students to be active explorers with interaction with software and learning by doing or practicing, (2) motivative students to learn mathematics concepts and create enjoyment in the class, (3) develop students' cognitive process to visualize mathematics knowledge, and help under achiever students to understand difficult and complex mathematics.

2.1.2.1. Active explorer

By its easy access which can be either used in mobile or other devices everywhere with or without internet supply, Kissane and Kemp (2009) observed that the application

helps students engage in the concepts, interact directly in more active ways, more quickly, with more insight to explore the nature of the lessons. In his research conducted in trigonometry teaching with technology, GeoGebra provided students moveable applet available online and offline to interactively explore the movement of the angle in a unit circle which was much more powerful for students than pictures drawn on board.

Teaching and learning with the technology offer meaningful interactions, which bring students to be more confidence and certainty in using to visualize the concepts that lead them to self-explanatory, and validity. Ibrahim and Llyas (2016); Šumonja (2015) both emphasized that GeoGebra let students perform high participation, apply the formula, conceptualize and form knowledge of the lesson and best for operational learning *(see figure 4*). Moreover, exploring directly with the software, students do more than only remembering, they understand math concepts independently, and confidently develop their problem-solving skills in mathematics concepts.

The studies of Alkhateeb and Al-Duwairi (2019); Zulnaidi et al. (2019) affirmed that the students, through these devices, promotes the learning process by practice and presenting their knowledge, so that the students became the focus of the learning procedures. It also makes the students acquire knowledge (conceptual, procedural and problem-solving), because of the large amounts of scientific knowledge these devices can provide. It increases the students focus on the educational content, positive interaction in doing the exercise, problems solving, and dynamically develop the students' ability to use this software in their education.

Dikovic (2009) also studied the implementing of GeoGebra with students by giving them the interactive GeoGebra applet and allowed them to explore the relationship of the function and its derivative. As a result of his conclusion, with the use of GeoGebra students can manipulate the variable to gain a better understanding of mathematics relation

dynamically while they can see the connection between the mathematical objects and its graphing representation. He also suggested that students should learn this new methods to deals with challenging situation and real display. (Antohe, 2010; Scott & Ii, 2017; Shadaan & Eu, 2013; Takači et al., 2015) They can discuss with their pair or group or to investigate mathematics concepts with the help of the application and learn from one another, which promote cooperative learning and achieve the constructivist learning environment.

2.1.2.2. Motivation

Exercises from school or additional practice for learning made students feel in burden; but Naidoo and Govender (2014) research found that GeoGebra is comfortable and more relaxed in usage, the compositions of the materials bring high confidence to students learning as they stated: “GeoGebra is attractive and appealing”. As well as by Shadaan and Eu (2013) GeoGebra also can enhance learners’ confidential level, improve knowledge and skill, visualize and decrease complicated calculators, scaffold and facilitate learners in mathematics understanding, and competence in computer skill which cause the school works no more pressure to them. The conclusion in his research confirmed that the use of GeoGebra is beneficial for the students by controlling the learning process, which becomes independent and self-regulated.

In the software, they can interact with the tools and view it as attentive and attractive. It shows them the steps in the topic and allows them to look back and correct their mistakes. It provides the relevant importance and usefulness in controlling their learning process, association and connection to their future career. Pupils also have high satisfaction upon working with the topic and enjoy the application (Takači et al., 2015). Furthermore, Rahman and Puteh (2016) said that when learning with GeoGebra students increase their positive motivation level as the students mentioned in his research that “trigonometry topic is not difficult to learn”.

They are active learners and motivated while teachers play the role as gatekeepers of knowledge and facilitators; for instance, (Brahier, 2016), students felt that learning with the software is attractive and makes their time fly fast while they are completely engaged in learning with technology.

2.1.2.2. Increasing cognitive development

Research on students' perceptions of trigonometry function precise that GeoGebra was very beneficial as a cognitive tool in this regard by also allowing the students to perform some actions beyond what they could have been able to demonstrate using only paper, pencil and a basic hand-held calculator such as the concepts of derivation and some difficult trigonometry functions. Besides, the indications are that performing relatively easy actions on the unit square before moving on to the unit circle, helped students to construct meaning. (Demir, 2012, p.118) With the use of this cognitive tool, students can improve their cognition development of the difficult concepts of mathematics *(see figure 2 and figure 3)*. Moreover, Dikovic (2009); Takači et al. (2015) pointed out that graphing can influence to cognitive transition from pictures of mathematics process to the concept of derivational slop function as well as enrich students' abilities of the application to the properties of the functions *(see figure 5*).

In this platform, Zengin et al. (2012) concluded that it creates activity incorporating multiple representations of math concepts, makes the learning of abstract concepts easier, makes the subject more dynamic, concrete and visualization, and has a positive impact to enhance students' learning and understanding**.** Using this, students answer in the activity with a meaningful process of trigonometry function, approximate the value of trigonometry function, justify the function properly, and determine the property with understanding.

In addition, Students have visualization and are independent in solving mathematical problems which bring the learning achievement high and enhance students' recognition of the correlation of mathematics with technical subjects. It is also visualized by students to see the relationship of mathematics concepts, learn by doing exercises, enable understanding and explication of skills and conceptualize learning (Scott & Ii, 2017; Šumonja, 2015; Tatar & Zengin, 2016).

Using GeoGebra helps students to explore mathematics concepts more and in detail and bring them to build confidence in mathematical knowledge and understanding. For instance, teaching geometry needs a visual object, with technology-aided, students can visualize the 3D shape that helps them to understand the concepts of the lesson and have a positive attitude toward the method (Rohaeti & Bernard, 2018; Seloraji & Eu, 2017).

For the underachiever learners, Puteh et al. (2015); Rahman and Puteh (2016); Saha et al. (2010) emphasized that it improves students' potentials and master difficult mathematical ideas in simple and attractive ways and helps underachiever pupils get a better understanding of this topic since it visualizes and stimulates the complex mathematics, involves the use of multiple senses and can do a quick calculation. Moreover, Shadaan and Eu (2013) concluded that the GeoGebra module design gave priority to the concept of scaffolding, increasing students' procedural memory that connects procedural knowledge with conceptual knowledge.

To summarize, with the help of technology, GeoGebra, learners can explore new things, visualize the mathematics concepts and their relation, become more active in learning and reflective to their learning which improve their cognitive thinking faster than paper and pen method alone. Their attitude toward mathematics is also improving when they are more motivated, confident, independent and learning by doing rather than memorizing.

2. 2. Barriers in applying GeoGebra

Even with a lot of good points that had been mentioned above, it still has some barriers that prevent teachers and students from using it in class.

2.2.1. To teachers

2.2.1.1. Teachers' instruction

Wassie and Zergaw (2019) suggested that when letting students play around the software, teachers have to give clear instruction and purposes of doing it *(see figure 7)*; if not, students will not know what to do and explore another thing besides the topics.

According to Little (2009), the accessibility of the program cause teachers problems while students intended to learn the software rather than the mathematics concepts. Furthermore, the instruction needed to be precise; not too detailed and not too little. While the tool terms are hard to learn, teacher tried to give detailed instructions which made students too occupied by the instructions and not flexible with their learning. And if the instructions were too short, students will get lost during the interaction.

2.2.1.2. Teachers' understanding

Using technology in the class, Dikovic (2009); Wassie and Zergaw (2019) advised that teachers have to be familiar with the technology tools, if not; they will not be confident enough in teaching and be familiar with the terminologies of the tool since it is dynamic software which will have more complex updated tools in the future.

Scott and Ii (2017) are also concerned that when creating lesson plans with GeoGebra, teachers need to be aware of the process of the application while some teachers did not know how to apply and they lack experience of using the software in the classroom.

If the teacher knowledge does not develop with the progress of the technology, the class will be in trouble.

As well as, Agyei and Benning (2015); Mehanovic (2011) admitted that some teachers are not aware of the software and its tools in teaching and learning. Although GeoGebra is popular in more than hundred countries around the world, less teachers know about this application since there are less training and resources available for them on how to use it. Moreover, they think that GeoGebra's sense is only for visualization. There are also technical obstacles when teachers have limited experience working with the software in the classroom. By that teachers need to play a very active roles to organize the classroom and students' activities. This complexity made teachers feel uncomfortable in using the software in the classroom and they sometimes misunderstanding the concepts of the application use in the teaching.

2.2.1.3. Others' barriers

Wassie and Zergaw (2019) had listed some other issues when applying software in the classroom. The first thing is material applicability. Some schools, teachers, and learners do not have smartphones or computers that can apply the software in the classroom, especially in the rural area. The second thing is relaxation, less research, and careless teachers. They do not want to get out of their comfort zone to learn new things and update their point of view. Learning with technology need preparation; hence, teachers need to get ready and be patient to teach by learning some tools beforehand. For instance; some tools in GeoGebra need some order to create as their algorithm, one cannot by their own idea do this first and the other next.

Another issue in Scott and Ii (2017) research is teachers' rejection of using GeoGebra in their teaching. Teachers stated that "there is no test about the application in the national examination, why they have to teach or apply it in their class." This rejection made the implement of the software got stuck. As well as teachers' commitments, Preiner (2008) pointed out that GeoGebra's concepts are difficult to be familiar if teachers have less practice.

Finally, Agyei and Benning (2015); Richardson (2011) mentioned the time constraint and commitment in lesson preparation is another cause. Teaching by using technology takes teachers' time to design the pictures or materials in the software to show to the students that make teachers feel that it wastes their time, especially when it is a new environment while with other strategies, they can save their time to do something else.

2.2.2. To students

Mehanovic (2011); Scott and Ii (2017) conducted a research on students' challenges on using GeoGebra found out that when applying the software, students were enjoying the computer rather than mathematics' knowledge taught. Moreover, they got confused with the application use in the lesson; therefore, they stated that "it is better to solve the task by hand if there is no exam with the use of the software" which means that students have less effort in exploring with the software.

The other thing was students' prior knowledge of the software. Dikovic (2009); Wassie and Zergaw (2019) suggested that teachers need to make sure that students have prior knowledge of using it. If not, the students will feel lost and they will not only struggle with the mathematics concepts but also the software use.

In short, applying GeoGebra in the classroom has some difficulties to consider such as teachers' technology distraction as getting stuck with the algorithm and technology errors, teachers' awareness and commitment, and materials availability and students' background knowledge and understanding of the technology use.

2.3. Synthesis conclusion

GeoGebra had given teachers with the benefits of new teaching strategy supplement to paper and pend method, promote critical and procedural knowledge and increase teachers' creativity in teaching, and improve their professional development with enthusiasm and open-mind. Similarly, to students, it makes learning environment more active, motivate students and make them confident in learning difficult mathematics concepts, help them understand the relation between mathematics and real life and improve their cognitive development in learning assisted to traditional method.

However, there are still some barriers to consider when using technology in teaching and learning. Teachers' understanding the use of the application, his instruction, and behavior toward the software are the points to consider for teachers. Whereas, students need to have requisite of the software use, and the distraction during dealing with application in case students do something else out of the lesson. However, in the next chapter, there will be some solutions addressed to those barriers.

2.4. Its contribution in Mathematic classroom

This research's part will give the readers some guideline lesson had done by other researchers as some concepts for teachers for consideration. Appendix 1 and 2 are also showing of how to use some tools in GeoGebra platform.

- Trigonometry function extract from Demir (2012)

GeoGebra is used to instruct the trajectory[1] of trigonometry for students to investigate the process of sine and cosine graph to support their reflect mathematics discourse as didactic object. First students draw the graph of unit square then polygon with 5-side to n- side. Then they notice the graph variation. It is the assisted of paper and pen method.

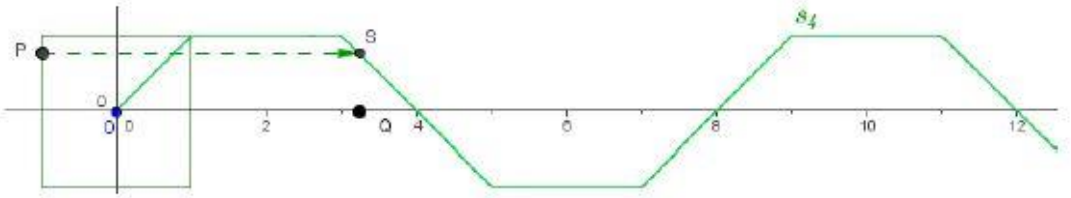


Figure 2: Screenshot of a GeoGebra activity on the graph of the sine-like function by using unit square[2].

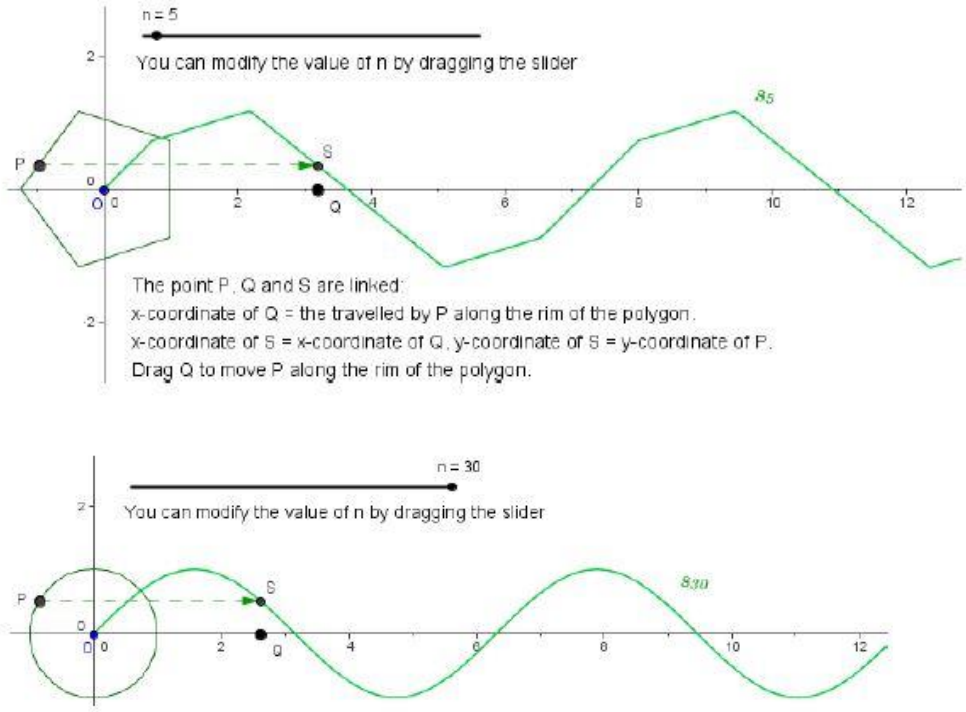


Figure 3: Screenshot of a GeoGebra activity on the graph of the sine-like function when moving/ modifying the n value on the slider.

[1] a curve or surface cutting a family of curves or surfaces at a constant angle.

[2] The unit square is the square whose center is placed at the origin of the Cartesian coordinate system with a side length of 2 units.

- Roots of complex numbers extract from Šumonja (2015)

Finding roots of complex numbers is an area that students find very hard to understand. Researchers made an applet in GeoGebra that displays the solutions of n-th root, $\sqrt[n]{z}$, of an arbitrary complex number z. Free input is used to enter the real and imaginary components of z. The slider for n determines which root students are looking for, and the slider for k ($0 \leq k \leq n-1$) determines which solution is displayed *(Figure 4).* The applet was posted on the website http://tube.geogebra.org/material/show/id/303675.

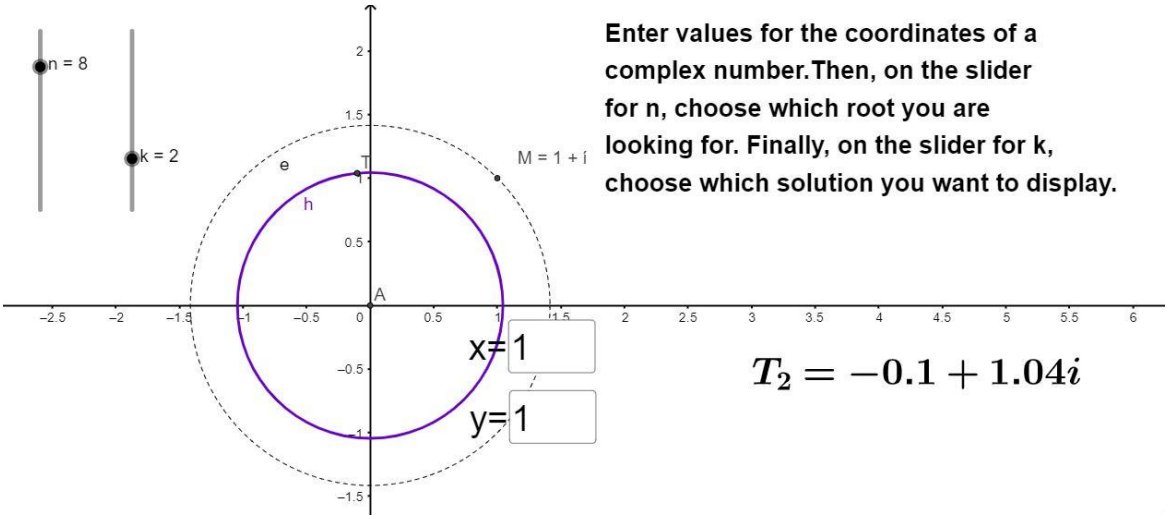
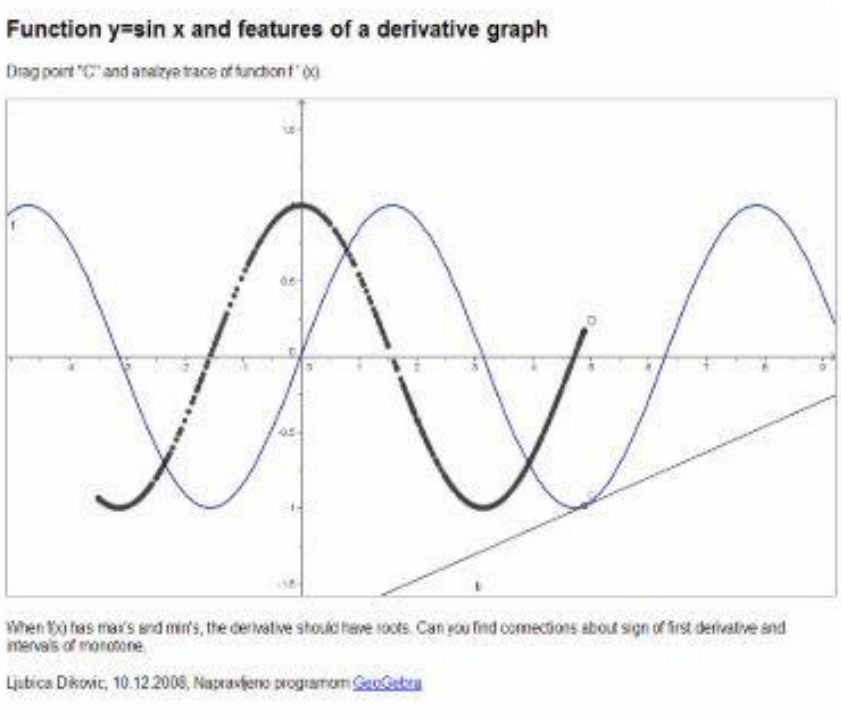


Figure 4. GeoGebra applet for finding roots of a complex number

- Derivative graph extract from Dikovic (2009)

The applet shows a movable point T that lies on the function f (x) = sin x. Tangent t is created for the point T with respect to f (x) = sin x as well as its slope s. Then, point B is defined as B = (x(T), s). When someone drags point T along the function f (x) = sin x, the trace of point B shows the slope of that function for every x.



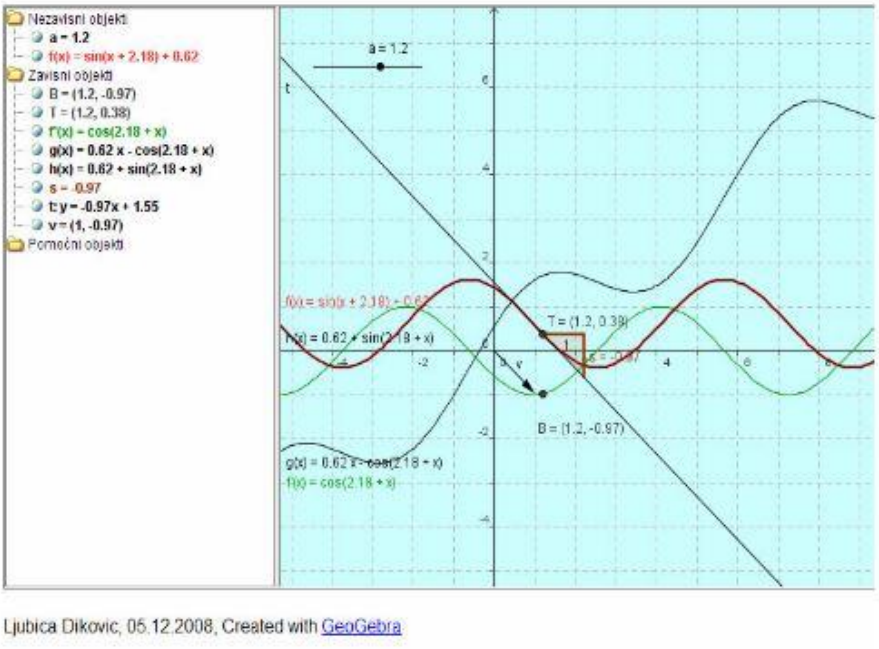
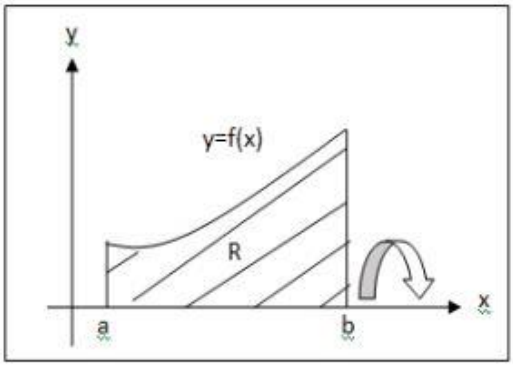
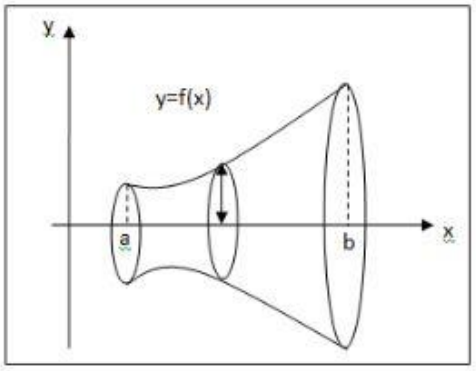


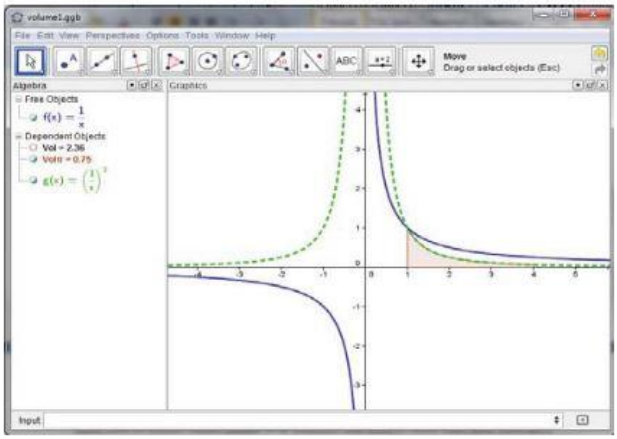
Figure 5. Graphs of y=sin x and y'= (sin x)' or the slope function of sin(x).

- The volume and area extract from Wan Salleh and Sulaiman (2013)

Suppose f is a continuous function on [a, b] and let R be a region covered by y = f(x), under which the x-axis and on the sides by a line x = a and x = b. The volume of a solid of rotation obtained by rotating on x-axis. Then GeoGebra assisted by finding the volume by means of integration by using Integral[<Function>, <Start x-Value>, <End x-Value>].







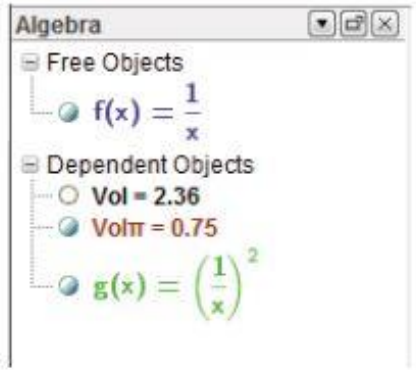


Figure 6: Screenshot shows the area of volume required and its answer by GeoGebra

- Integral extract from Wassie and Zergaw (2019)

The relation between the upper sum, lower sum, and the definite integral of a function explored using GeoGebra

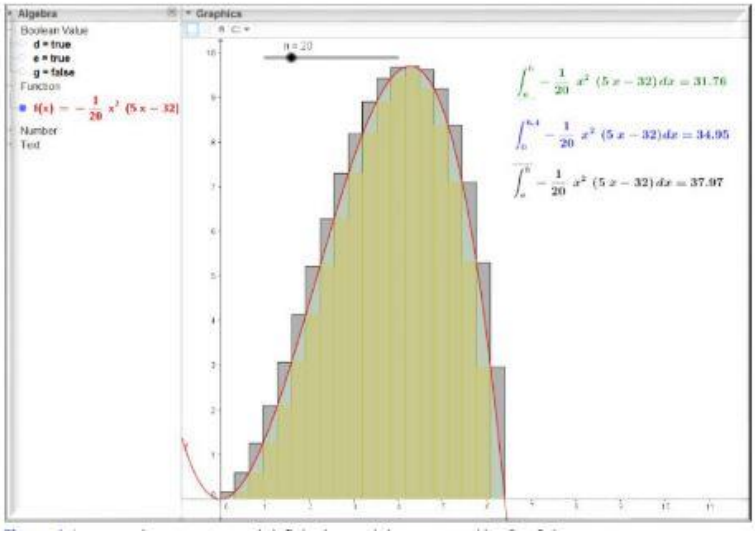


Figure 7. Lower and upper sums and definite integral

- Integer Addition on the Number Line extracted from Preiner (2008)

Figure 8 shows two stages of a dynamic visualization of integer addition on the number line. Sliders a and b is moveable with the mouse to create a new addition problem. The corresponding numbers are shown as arrows on the number line and automatically adapt to the modifications of the sliders. Additionally, the actual addition problem is displayed in the right upper corner of the dynamic.

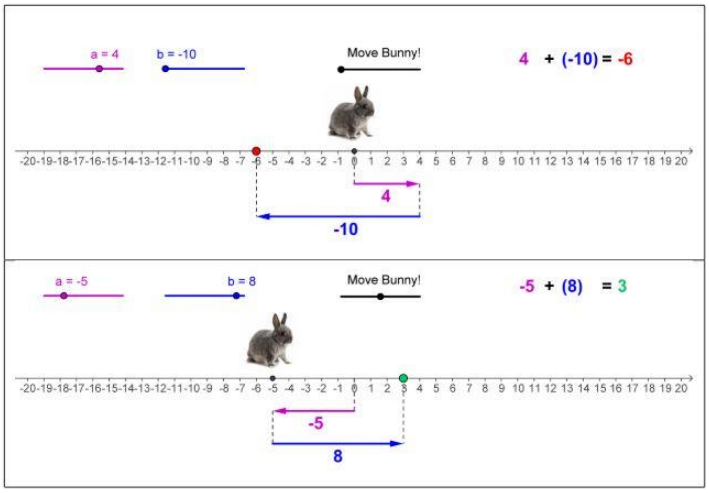


Figure 8: Dynamic visualization: Integer addition on the number line

*** Some other sources available online by classroom resources- GeoGebra[3]

[3] https://www.geogebra.org/

CHAPTER 4: CONCLUSION

3.1. Summary

Technology is important for enhancing teaching and learning and supplementing the 21st century teaching methodology. As a free software, GeoGebra helps visualize the difficult math concepts that cannot be done by pen and paper, to make the class more active, students be motivated, confident and independent and teachers save time to help students and promote new teaching method. Within the class of mathematics, in which students feel difficult to catch the point and visualized the ideas in the lesson, GeoGebra helps them to interact with the application, explore what the values are, draw conclusion to the identities and figure out the differences of the graphs of the function and others.

As for its benefits and barriers, although there are some barriers for teachers and learners, there are more benefits to teachers and students than barriers and we will be suggested some solutions for the barriers. If teachers are willing to improve their teaching strategies, they will learn more of what they are not sure and make changes for better development. For the solutions of the source availability, even most of them are in English, teachers can play with the software most often, then they will get used to its terms. Therefore, as mentioned by Little (2009) no single teaching style suits all classroom and students, it is the teacher's responsibility to choose and use the software *(see the previous chapter's examples*). Yet, this software, GeoGebra should be applied in the classroom alongside with paper and pen method such as graphing to clarify students' misunderstanding and to increase the attractiveness and the effectiveness of the learning environment. Also, teachers can apply the materials of teaching guides mentions above as the ideas.

3.2. Suggestions and recommendation

Although there are some difficulties for students if they do not handle some background knowledge of the application and barriers for teachers to implement it in the class due to their knowledge, materials, and time bound, this application should be used in the classroom.

For the solutions of teachers' barriers are listed in the following, teacher should

- Learn or explore more on the application which had manual either in Khmer or English,
- Read or do more research on technology use in the classroom,
- Spend time in creating the platform of the software in the lesson which can be used next time. It might be hard for the first time, but next time teachers can reuse it, which will save time,
- Ask experts or experienced teachers with the software for help when dealing with problems if there are some,
- Introduce technology in the classroom since the elementary level (grade 7),
- Improve teaching methodology by assisted of instruction with technology(Agyei & Benning, 2015),
- Ask stakeholders such as students' parents, NGO, sponsors, or MoEYS for help with the materials use in the class.

To stakeholders, it will be helpful if they can contribute time, materials, training to assist teachers into applying technology in the classroom while it will bring the students to

get through the technology world as well as helping our country to be more up-to-date (Demir, 2012).

While this research is research synthesis, further research should consider applying this lesson guide or this software in the real classroom especially in Cambodia to see the effectiveness of the application and its barriers while there is less research conducted on the difficulties of using the software.

Further learning of GeoGebra are in GeoGebra manual https://wiki.geogebra.org/GeoGebra-en-Manual.pdf

Or https://wiki.geogebra.org/en/Tutorials .

We also have some lesson guides added to this article, see appendix 3.

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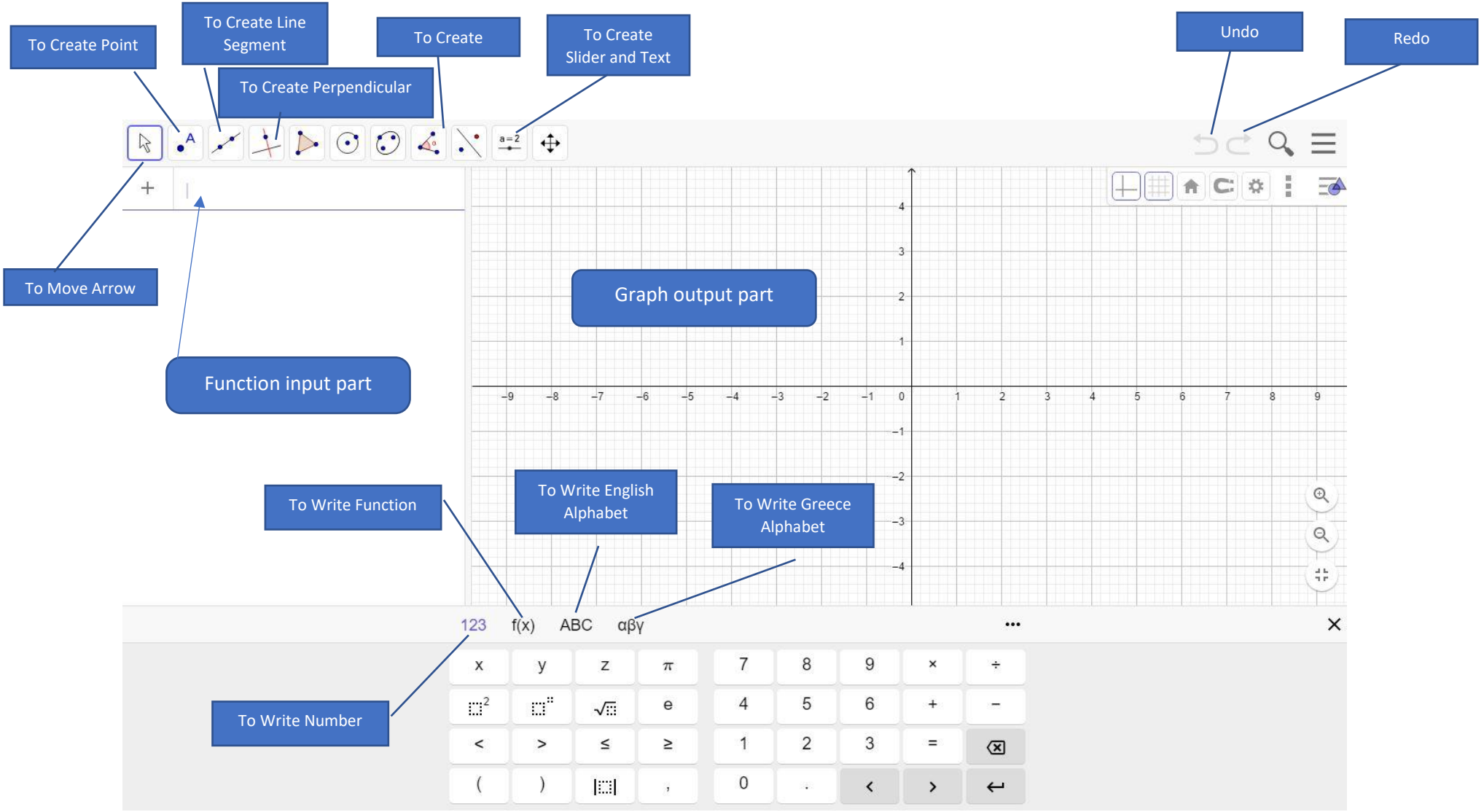
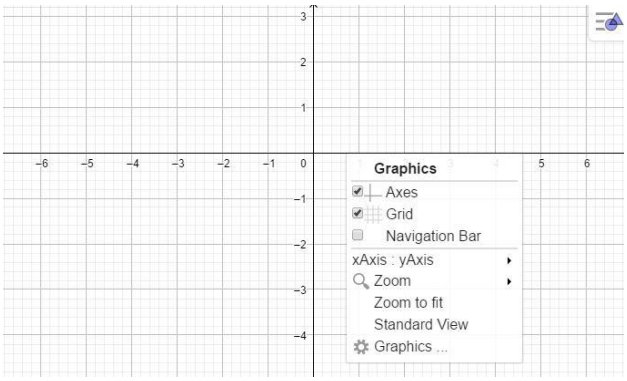
Appendix 1: GeoGebra Platform

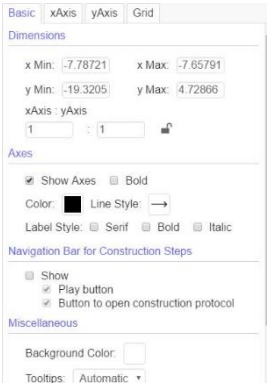


Appendix 2: Graph creation

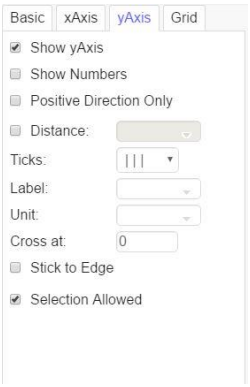
1. **To set and change the x-axis and y-axis value**

   a. Right click on the axis ➔ Graphic ➔Basic => Dimension: set the x min/ max and y min/max you want ➔ Close.



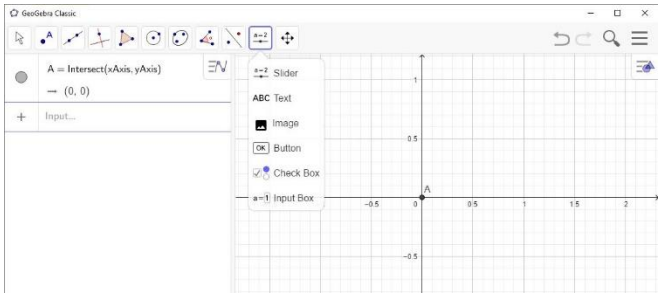


   b. Right click on the axis ➔ Graphic ➔Basic => xAxis/ yAsix: tick the "show number" if you want the graph to show the value ➔ Close.



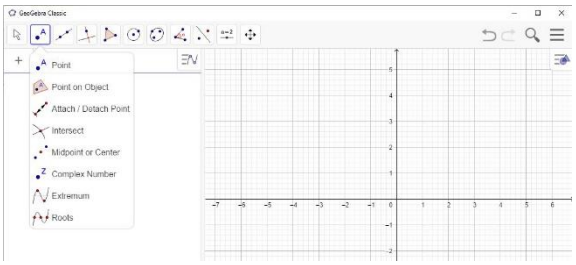
2. **To create the slider of radius and angle**

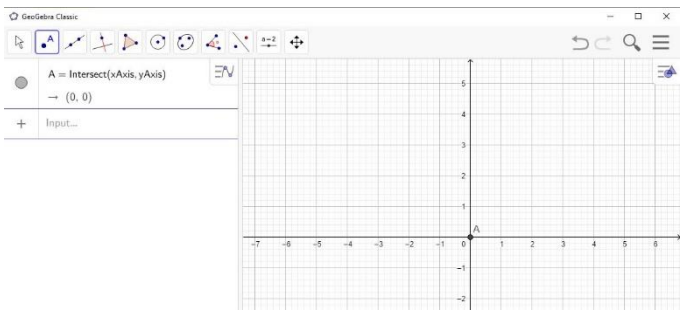
   Go to create slider tool ➔ Slider ➔ Click on where you want slider to locate ➔ Name the slider ➔ Tick the number / angle ➔ Set the min/ max value ➔ Ok



3. To create point

Go to the creating point tool ➔ Point ➔ Click on the graph where you want to have the point.

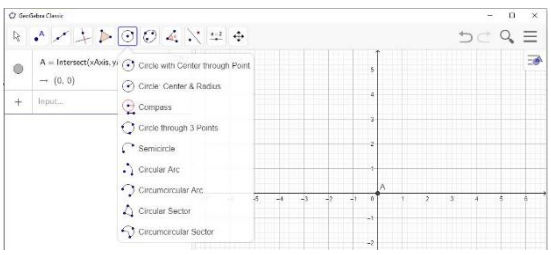


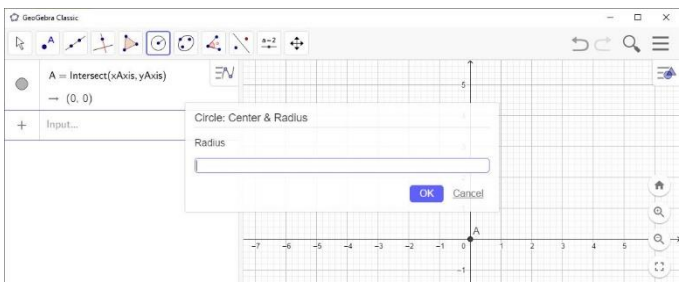


4. To create circle with radius input

Go to create circle tool ➔ Circle: Center and Radius ➔ Click on the central point ➔ Input the radius number ➔ Ok.

** if you set the radius the same as the slider set, make sure both names are the same.

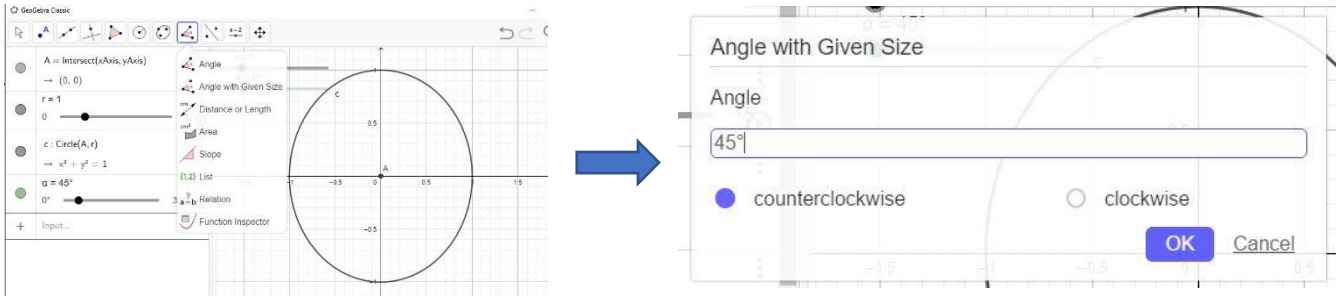




5. **To create angle**

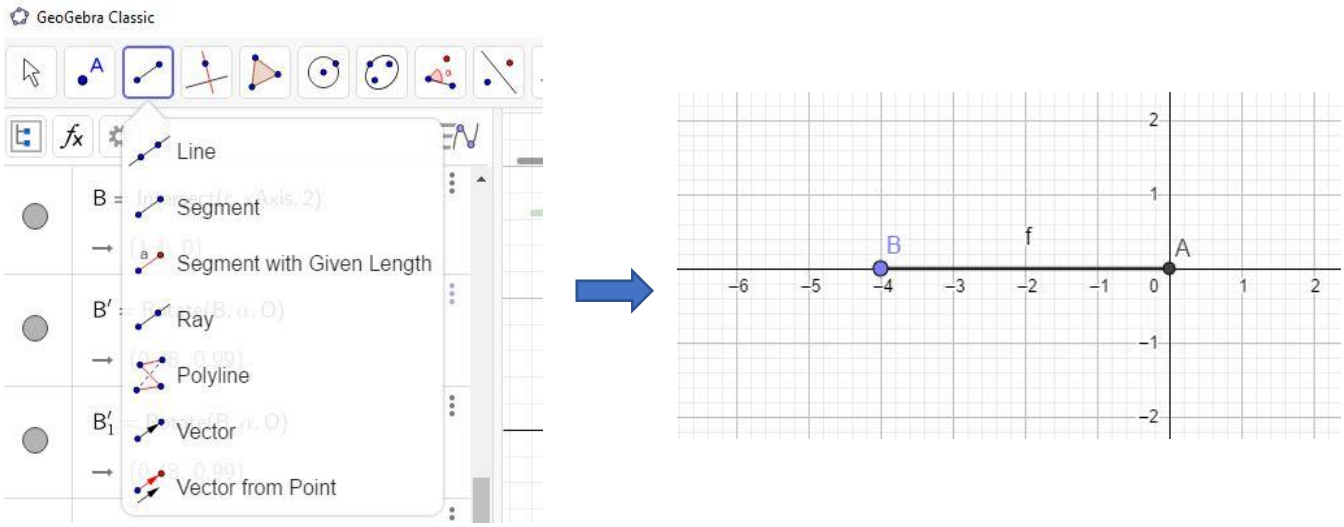
Go to create angle tool ➔ Angle with given size ➔ Click on any point on the circle and another click on the central point ➔ Set the angle size with Counterclockwise ➔ Ok.

** if you set the angle the same as the slider set, make sure both names and degrees are the same.



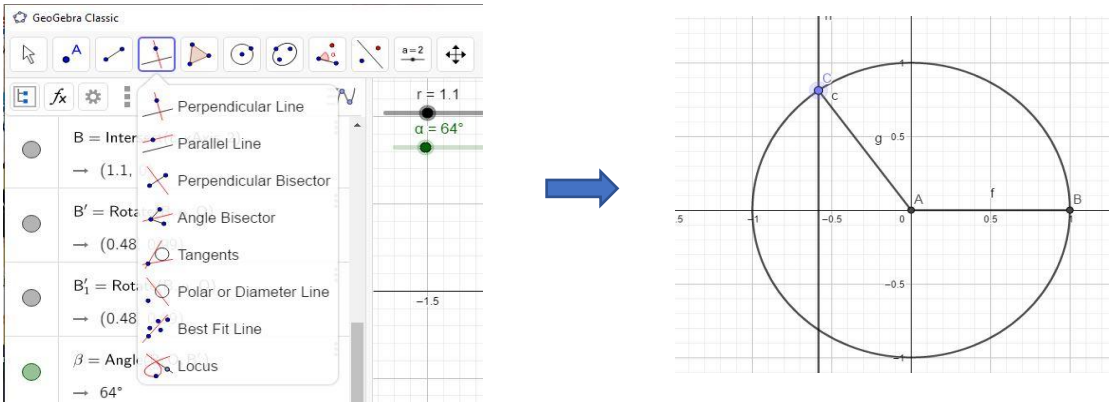
6. **To create segment**

Go to create line segment tool ➔ Segment ➔ Click on two points you want to make segment.



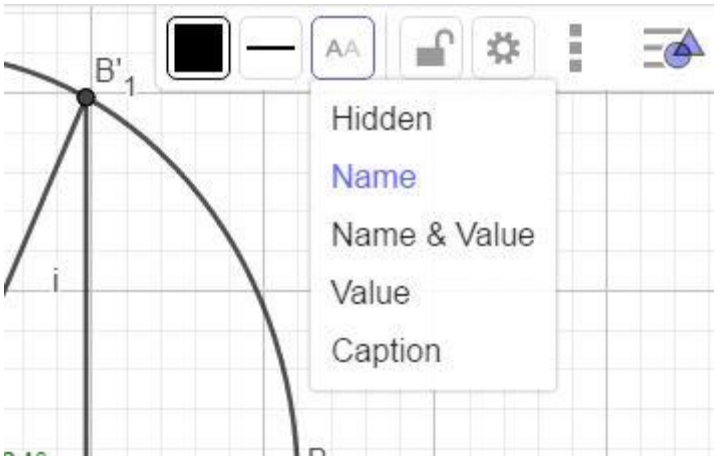
7. **To draw the perpendicular**

Go to create perpendicular line ➔ Perpendicular line ➔ Click on two lines that you want to make perpendicular.



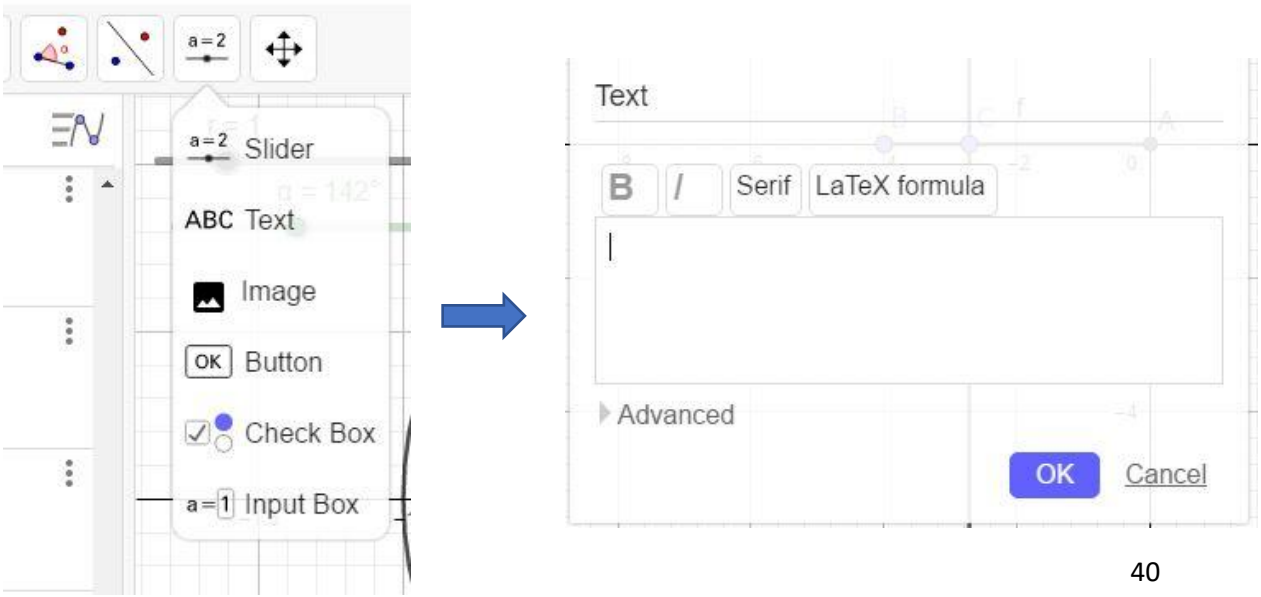
8. **To hide or show the name**

   Click on the line you want to hide or show the name ➔ On the top right-hand side tools ➔ "AA" tool.

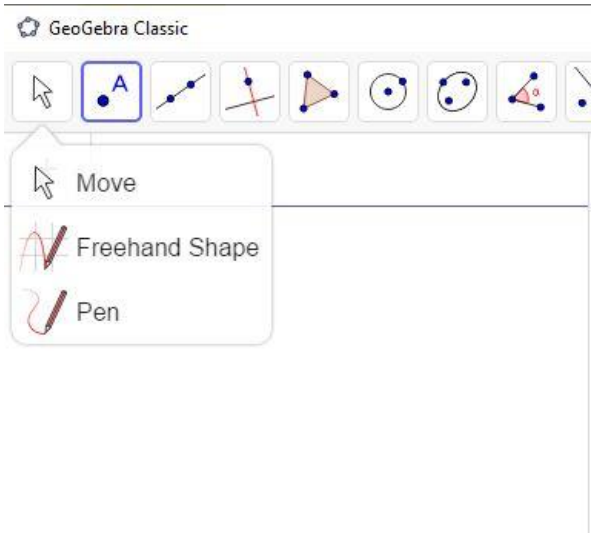


9. To add text to the graph

   Go to slider tool ➔ Text ➔ Click on the place you want to ass text ➔ Write the text you want ➔ Ok



****** Whenever you finish using each tool, you need to click on the move tool to prevent tool confusion.



Appendix 3: guided lesson plan for Cambodian teachers

This guided lesson plan is following the Ministry of Education, Youth and Sport, grade 11 students' book page 68-85. It is included with some detail activities and attached exercises of the lesson process.

Lesson points and objectives	**Students and teacher's activities**	**Materials**
To review students' prior knowledge of trigonometry in right triangle before moving to the unit circle lesson - Pythagoras theorem - Sine and cosine formula and angle values in right triangle (0 degree to 90 degree) - Trigonometry identities	Students will do the diagnostic test for the lesson learnt at grade 10	Exercise #1
Angle in the circle: students will be able to - Explore the application using the slider - See the direction of sine and cosine in the unit circle - Manipulate the angle in the applications (0 degree to 180 degree) (to make students be familiar with the application before explore it and figure out the values of sine and cosine on axes.)	Teacher - Create the unit circle before the class start - Instruct students of activities #1 - Feedback the values students noted down in the worksheet of activities 1 of the special angle values (0 degree to 180 degree) - Give homework to students to explore the other special	Activity #1

	angle values (180 degree to 360 degree) Students - Explore the software created by teacher before the class. - Use the software to slide the angles and note its movements whether it is positive or negative in each angle. - Move the slider to see the values of sine and cosine of special angle value - Note value of some specific angles provided in the worksheet	
Trigonometric identities: students will be able to - Note the correlation value of sine and cosine - Identify the identities of sine and cosine relationship	Teacher - Review the values of special angle 0 degree to 360 degree - Instruct students to note down the value of 45 degree in each quadrant in activity #2 - Draw conclusion of trigonometric identities Students	Activity #2

	- Note down the same value of the angles (start with $45^{\circ} \& 60^{\circ}$) - Note down others same value of the sine and cosine - Draw conclusion of the identities	
Sine and cosine function - Graph the function on the software - Conclude with the differences of the graph of sine and cosine of their kinds of function and loop value.	Teacher - Instruct students in activity #3 - Draw conclusion of graph sine and cosine Students - Use the applications to graph the function - Draw conclusion the differences of the function of sine and cosine - Graph some functions and investigate the graph animation	Activity #3

1. **<u>Exercise #1</u>**: to review what you have learnt from the previous class (grade 10) of trigonometry function in right triangle, please answer the following
   a. What is Pythagoras theorem? Can we use it in what kind of triangle?
   b. How can we find the values of sine and cosine in right triangle?

c. What is the value of $\sin^2 x + \cos^2 x$?

2. **Activity 1**: look at the unit circle in either GeoGebra and answer the following questions

   a. Which axes sine and which one is cosine axes?

   b. What are the min and max value of each axes?

   c. From which degree the sine is positive? Sine negative? Cosine positive? And cosine negative?

   d. Move the slider and list down the value of sine and cosine of each angle below.

	0°	30°	45°	60°	90°	120°	135°	150°	180°
Sine									
cosine									

3. **Activity 2**: use the table an activity one and the GeoGebra application

   a. Examine the values of sine and cosine of $45^\circ, 135^\circ, 215^\circ \& 305^\circ$ angle (45° of each quatrain).

   b. Observe each value and make conclusion of their relationship and pattern. Then sum up with general identity.

   c. Observe other values and figure out their relationship. Draw conclusion.

4. **Activity 3**: using GeoGebra, graph the function of sine and cosine as below.

   a. Draw the graph of $y = \sin x$ and $y = \cos x$

   b. What are the differences of both graph? Are they odd or even function? What is their loop?

   c. Draw conclusion

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