

Teaching mathematics with interactive motion infographics created with GeoGebra

Ioanna Giakati¹, Apostolos Syropoulos² and Eleni Tatsiou¹

¹ 2nd Gymnasium of Xanthi, Xanthi, Greece

² Greek Molecular Computing Group, Xanthi, Greece

Abstract: Teaching mathematics to middle-school pupils is always quite challenging. One has to introduce pupils to formal thinking and teach them the importance of this kind of thinking. Naturally, any tool that can assist the work of a teacher is more than welcome. GeoGebra is a tool that has been created by a mathematician for math teachers. This tool has the ability to create interactive motion infographics that can be used in a classroom. Creating such motion infographics is not particularly difficult but of course designing them is quite demanding, therefore, we first explain how one can create interactive motion infographics with GeoGebra and then we briefly discuss what one should have on her mind before starting to design such motion infographics. The ideas presented are by no means exhaustive; instead they can serve as a starting point for the development of a theory for the design of motion infographics for mathematics education.

Keywords: Motion Infographics, interaction, mathematics education, Web

Contact: Apostolos Syropoulos (asyropoulos@aol.com)

1 Introduction

György Pólya in his famous monograph entitled *How to Solve it* (Pólya, 2004) noted on page 103 that “figures are not only the object of geometric problems but also an important help for all sorts of problems in which there is nothing geometric at the outset”. In addition, Francis (2007) wrote a book that emphasizes the importance of drawings in mathematics. If figures provide significant help when trying to solve a (mathematical) problem, then clearly they should be significant help when teaching mathematics. Indeed, the philosophy of the programming language LOGO, which was designed by Wally Feurzeig, Seymour Papert, and Cynthia Solomon, is constructivism, that is, the idea that knowledge is created through the interaction between their experiences and ideas. Thus drawing a geometric shape on the computer screen with the aid of a “robot”, allows pupils to learn mathematics, in general, and geometry, in particular, easier. The reader can read more about Papert’s ideas in (Papert, 1980), which is freely available from the LOGO Foundation Web site.



The Marriam-Webster dictionary defines an infographic as a chart, diagram, or illustration (as in a book or magazine, or on a website) that uses graphic elements to present information in a visually striking way. A motion infographic is an animated infographic. Now, we can easily create an animation from the moves of the LOGO turtle when drawing a figure. By augmenting this animation with extra information, we can create a first class motion infographics. This idea is very important and it has been used by other systems to allow users to create motion infographics. According to Wikipedia¹ “GeoGebra is an interactive geometry, algebra, statistics and calculus application, intended for learning and teaching mathematics and science from primary school to university level.” GeoGebra² was created by Markus Hohenwarter and it is basically freely available to anyone. This tool allows users to create simple and interactive animations and pictures. Nowadays, people can relatively easily create interactive motion infographics using the <CANVAS> HTML5 element [see (Fulton & Fulton, 2013), (Syropoulos, 2019)] and GeoGebra allows users to create such content. This, then, can be embedded in one’s Web page, blog, etc., and used in a classroom as supplemental educational material.

2 Creating interactive motion infographics with GeoGebra

It is very easy to create animations with GeoGebra and we will explain how it can be done by scribing how to animate a triangle whose three corners are points of three different circles and move around the circles thus changing the shape of the triangle. Initially, we press the “start calculator” button to get the working environment that is shown in Figure 1. We select “Tools” and from there we select “Circles with Center”. We choose a point on the graph and create a circle. We do the same of all three circles. The next thing to do is to select three points—one point on each circle. From the “Tools” menu we select “Point” from the (visual) “Points” submenu. We place the pointer of the mouse on the first circle and when we have selected the point, we press its left button. We repeat the simple procedure for all three points. In Figure 2 the reader can see that the three circles have three designated points: G, H, and I, which will be used to create a triangle.

¹ See <https://en.wikipedia.org/wiki/GeoGebra>

² See <https://www.geogebra.org>

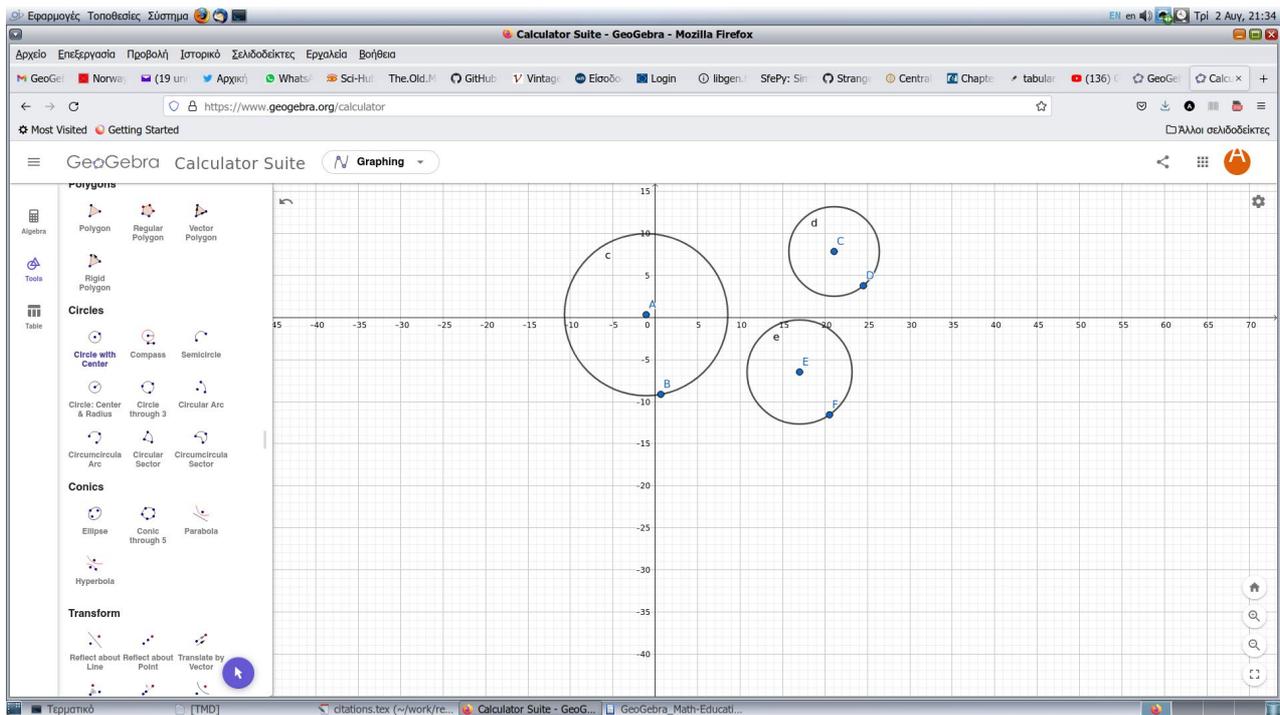


Figure 1. Drawing the three circles.

In order to create the triangle, we select the “Polygons” (visual) submenu. Then, we put the mouse over the first point and press its left button to create the first point of the polygon. We repeat the step two more times and in the end we connect the third point (i.e., point I) with the first point (i.e., point G). Figure 3 shows the result of this process.

Now we need to create two buttons that will control the animation. The first one will be used to start the animation and the second one to stop it. From the “Others” submenu we choose “Button” and move the pointer of the mouse at the spot we want the button to appear. As expected, we simply press the left button of the mouse to make the selection. At this point a little window will pop-up. This window will ask us to enter the text that should appear on the button and to enter a GeoGebra script. In this simple case we had to enter a command in the GGBScript language. Note that one can enter code in either GGBScript or in JavaScript. The first button that is the “Start Animation” button and its GGBScript code is simply the command `StarAnimation[G,H,I]`. The second button button is the “Stop Animation” button and its GGBScript code is simply the command `StarAnimation[False]`. In Figure 4 the reader can see the pop-up window and what we had to type in order to create the first button. Figure 5 show the result of this little experiment. It is possible to embed the final example in a Web page using the “Share” option. Here is the HTML code we got for our example:

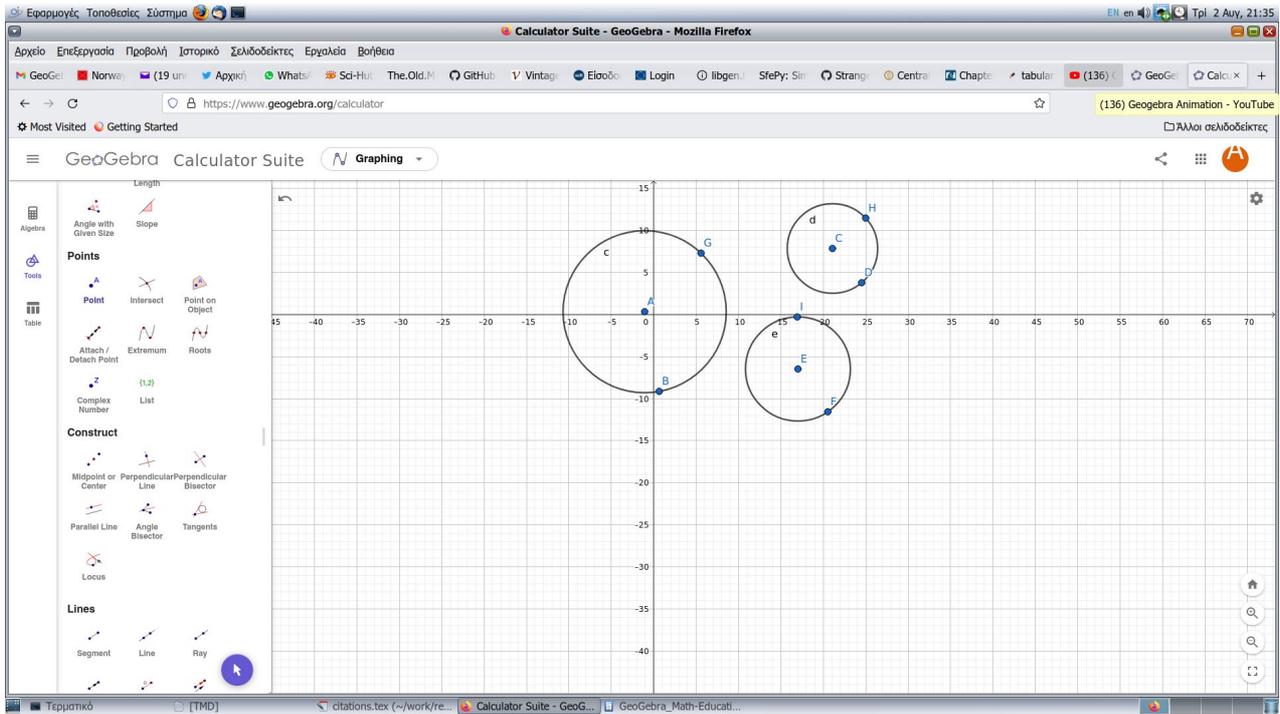


Figure 2. The three circles with three points.

```
<iframe src="https://www.geogebra.org/calculator/hjhmwxdr?embed" width="800" height="600" allowfullscreen style="border: 1px solid #e4e4e4;border-radius: 4px;" frameborder="0"></iframe>
```

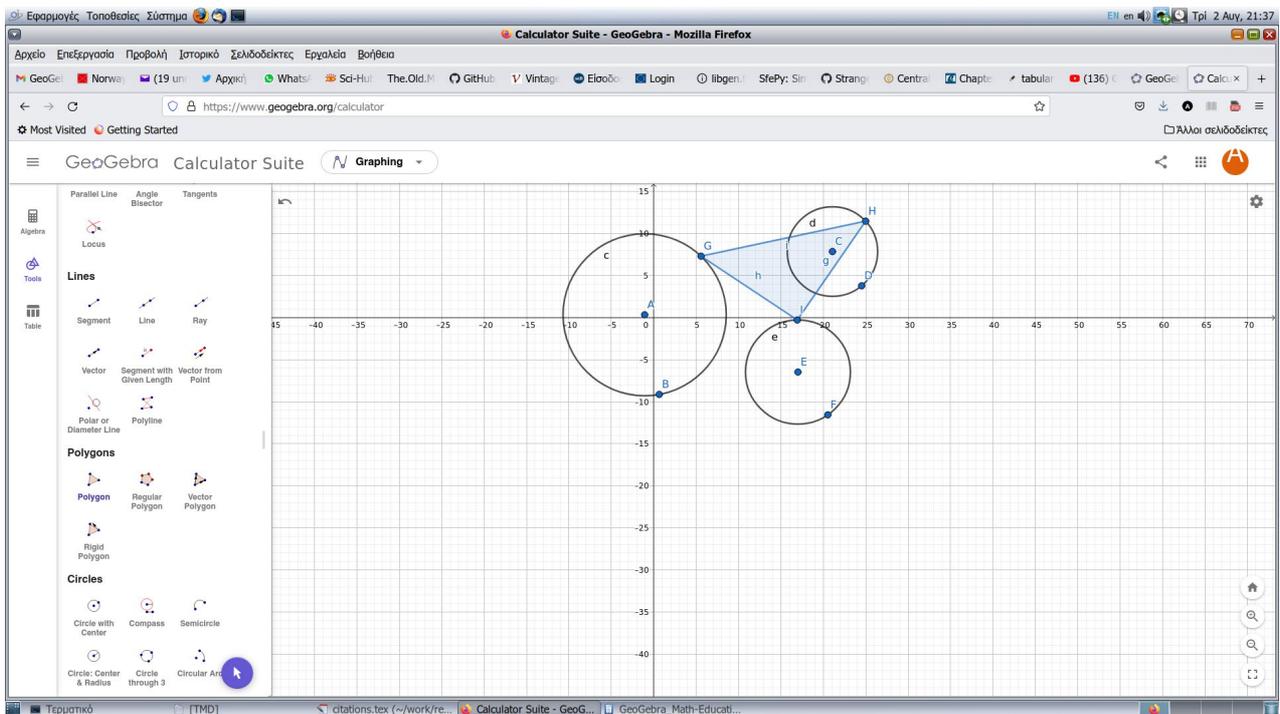


Figure 3. Connecting the three points.

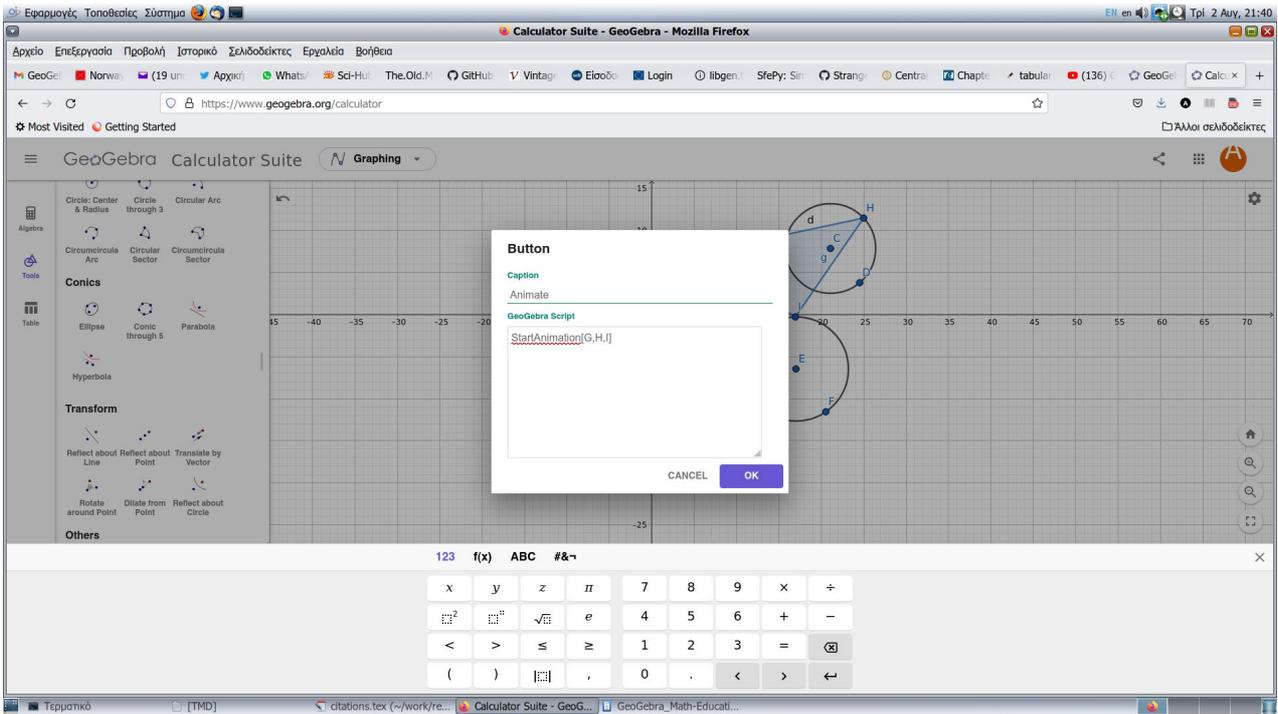


Figure 4. Creating buttons that will start and stop the animation.

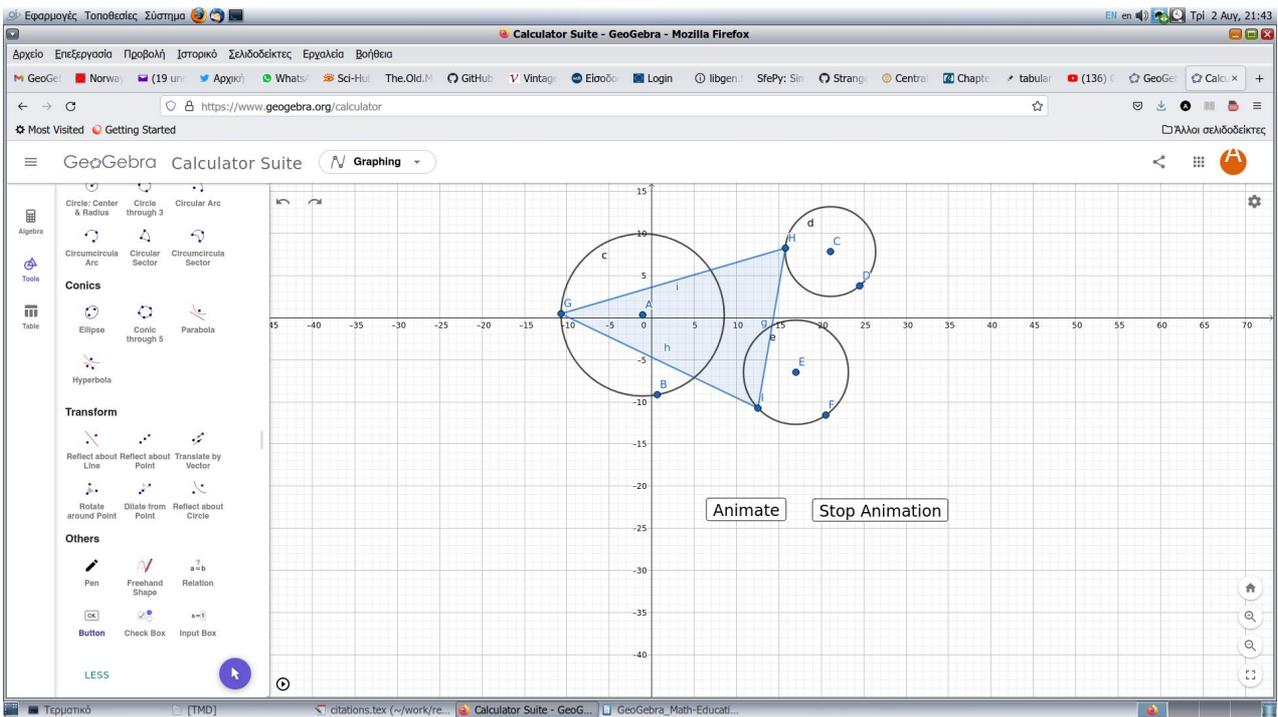


Figure 5. The result of our labour. We stopped the animation in a position different from the initial so to "demonstrate" the animation.

3 Educational motion infographics

The examples that we will present in this section are, in a sense, generalizations of the simple animation that was presented in the previous section.

The first example is about the geometric solution of a quadratic equation. In general, a quadratic function is a function of the form $f(x) = ax^2 + bx + c$ and its graph (i.e., its visual presentation) is a *parabola*. In general, a parabola is roughly “U” shaped and it may have a highest or lowest point that is called the *vertex*. A parabola may open up or down and it may not intersect with x -axis but it will always intersect the y -axis. The points of intersection are called x -intercepts and y -intercept, respectively. If a quadratic function has x -intercepts, this means that the corresponding quadratic equation has real solutions. Thus, if we draw the parabola that is described by the quadratic equation, we have a visual solution of a quadratic equation.

The initial screen that is shown in Figure 7 starts the application. In this case, this screen is useless but sometimes one needs such a screen to allow users to adjust the appearance of what comes next or to just display a logo. In Figure 8 we see the full interface of the application. There are three slide-bars that can be used to choose the coefficients of the quadratic equation. For reasons of simplicity, one can choose only integer values but it is not difficult to adjust the application to allow users to choose decimal values. Naturally, it is next to impossible to allow arbitrary precision for decimal numbers. Now, as the user slides the bars, the equation changes as well as the shape of the parabola. In addition, we can see that the x -intercepts change also.

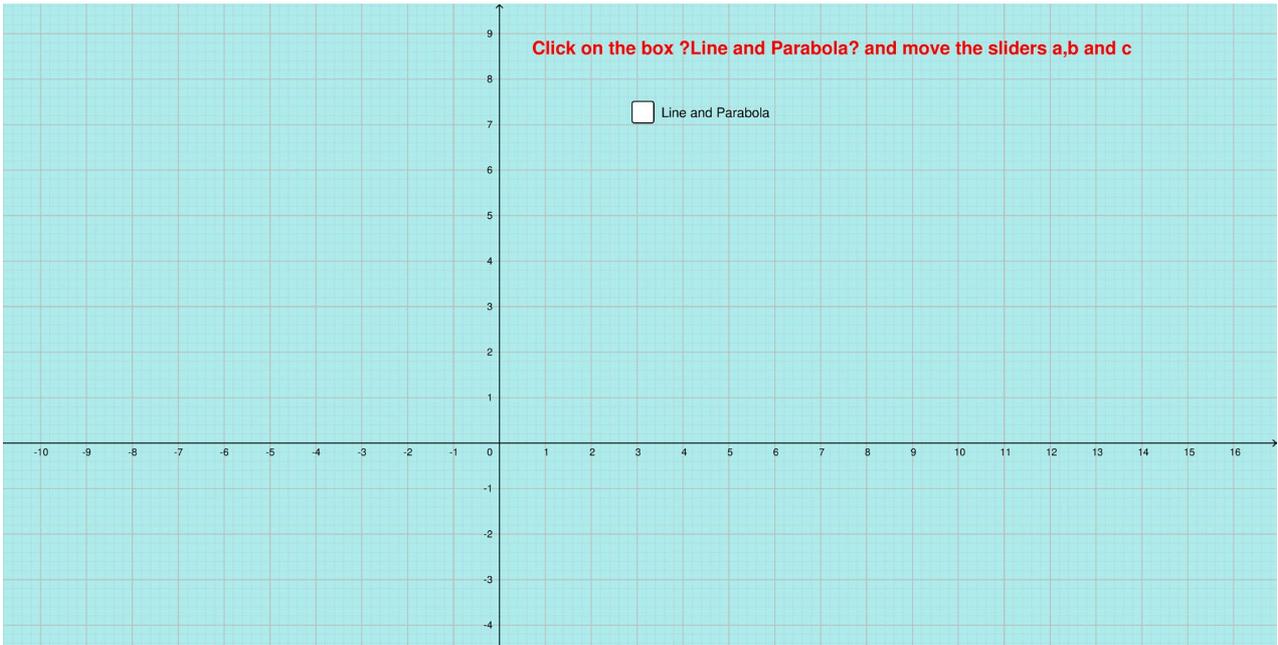


Figure 6. The initial screen of the GeoGebra application that visually solves quadratic equations.

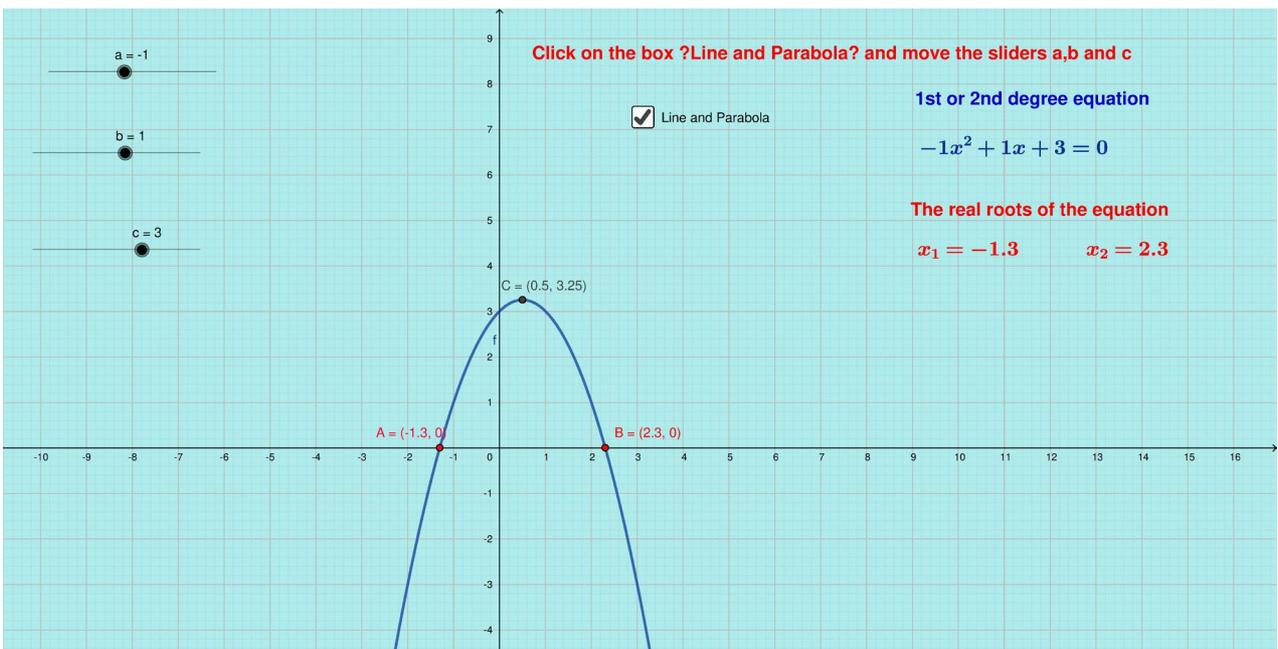


Figure 7. Solving graphically a simple equation. The three slide-bars can be used to set the coefficients of the quadratic equation.

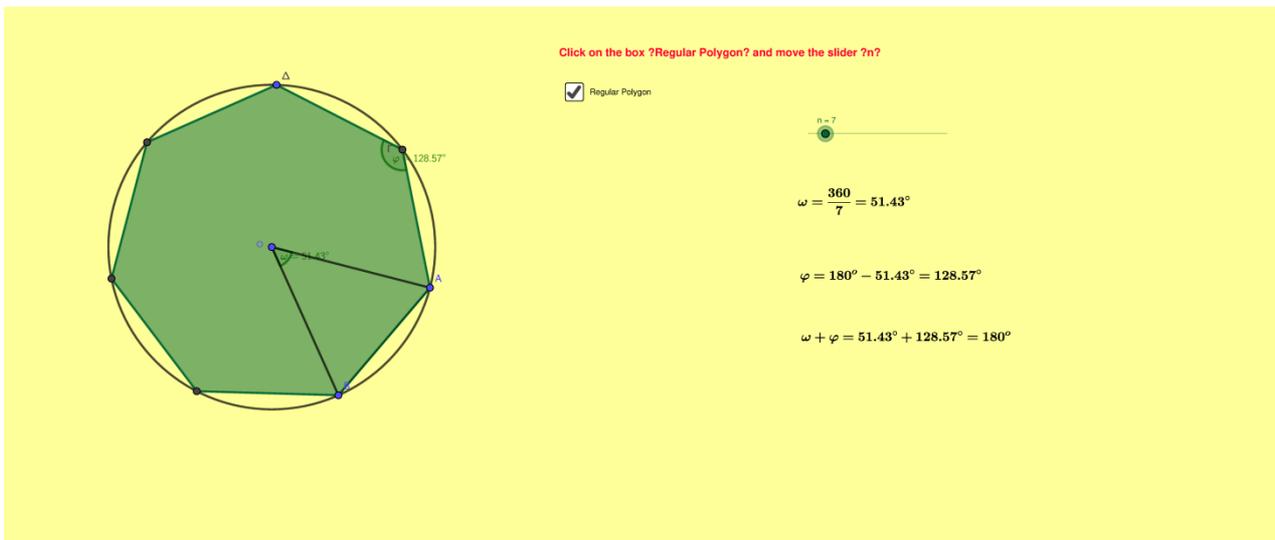


Figure 8. Learning about polygons and their relationship to circles.

The next example is about polygons and their relationship to circles. The interactive motion infographic includes a slide-bar that can be used to select the number of angles of a polygon. Thus one can create triangles, squares, etc. From this simple infographic pupils learn also the notion of infinitesimal quantities (i.e., a quantity that is closer to zero than any standard real number, but is different to zero). In particular, when one creates a polygon with say n sides, where $n \gg 0$, then pupils tend to believe that the resulting object is actually a circle. But when they zoom-in and discover that the polygon is not a circle, they are surprised. And this is quite instructive.

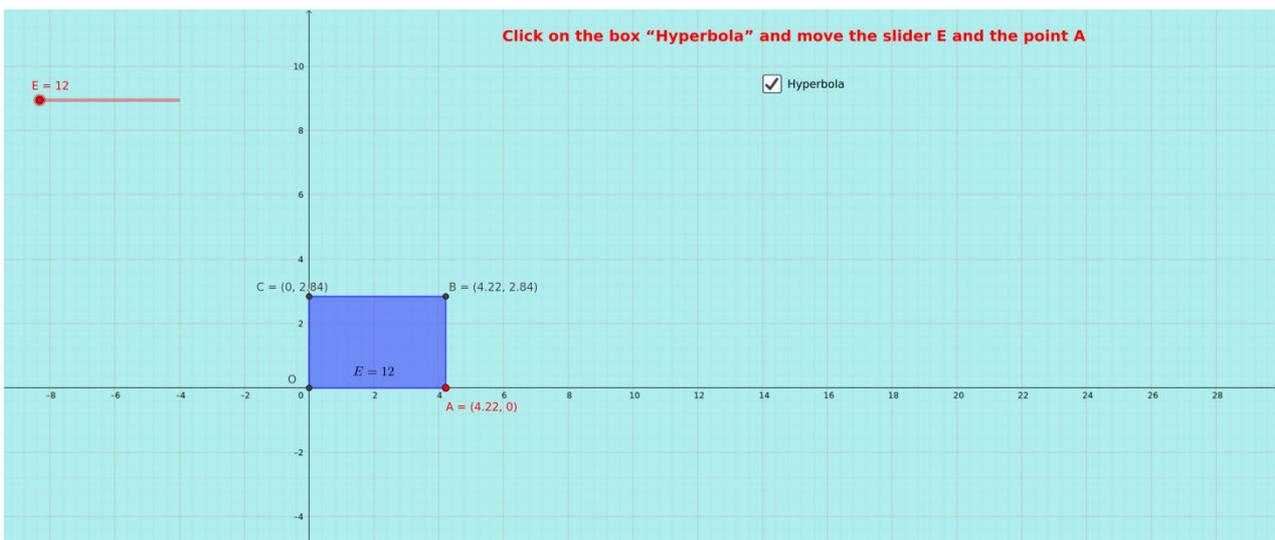


Figure 9. Learning about reciprocal quantities—initial screen.

Figure 9 shows the initial screen of an interactive motion infographic that has been designed to teach the notion of reciprocal quantities and, therefore, reciprocal numbers. The pupils are presented with a rectangle whose area is constant but the user can change it using a scroll-bar. Pupils are asked to move point A (see Figure 10) and to observe how the height and the width of the rectangle change so as to keep its area constant. This way, pupils visually understand the notion of reciprocal quantities.

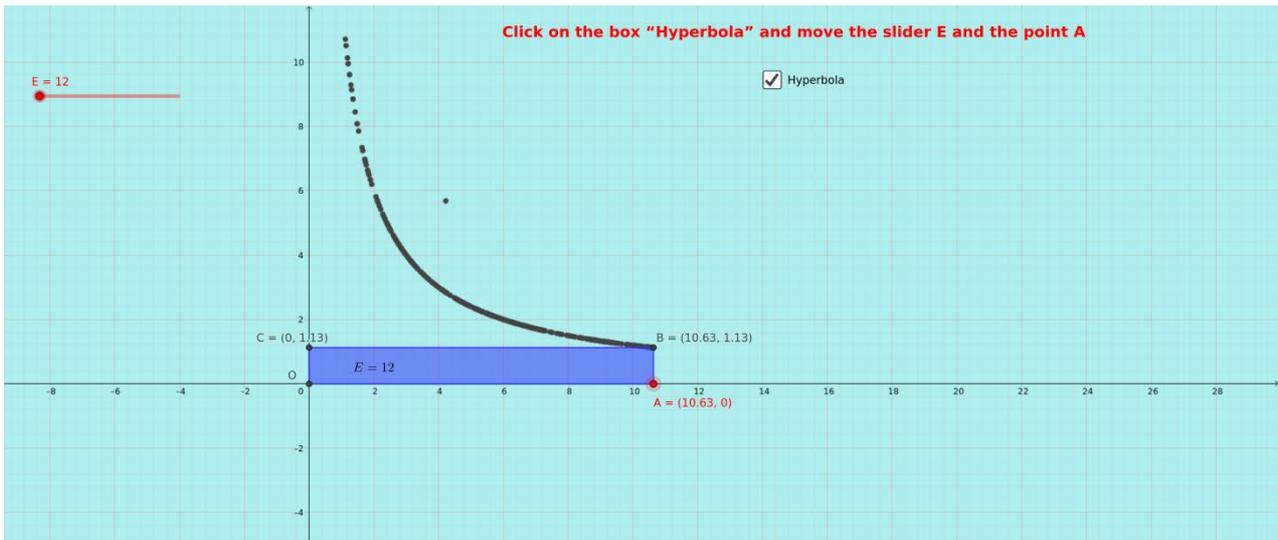


Figure 10. Moving point A changes the width and the height of the rectangle. The dots create a graph.

4 Alternative implementations

We have presented a few examples of interactive motion infographics created with GeoGebra that can be used to teach basic mathematical notions. Naturally, one can create such examples using the <CANVAS> of HTML5, something that was designed to replace the Adobe Flash content (in fact, as of January 12, 2021 Adobe has obsoleted the Flash player).

5 Design principles

As was demonstrated, creating an interactive motion infographic using GeoGebra is particularly easy, nevertheless, what really matters is whether the result will be really useful. Naturally, the ultimate judges will be the users, in this case the students that will use it to learn new concepts and ideas. Our experience has shown that there are a few things that one must do in order to have a really useful result.

Since we are dealing with middle-school students aged 13-15, our interactive motion infographics have to be visually appealing. This means that we need to use pale colors so that students are not distracted by what they see. Also, we need to use relatively big size letters and visual components that students have already used before.

Any infographic should have a specific goal. This simply means that its author must be aware who are going to use it, what do they know about the subject, and how can we make sure they will understand what they are doing when using the infographic.

Students of any age want some sort of reward when solving an exercise or a problem. Although this would complicate things, still it would be possible to embed the infographic inside a web page that communicates with a database, which will keep the names of those that have used the infographic and really understood its goal. Of course, this is a rough sketch of what one may do and should by no means be considered as the only way to reward students.

The last thing one should always do is to ask his students to judge their experience using the infographic. This is particularly useful as the students get the feeling that they actually participate in the learning process and they can influence the way they learn.

6 Conclusions

We have described how one can create a relatively simple interactive motion infographic using GeoGebra. Then we presented a number of such infographics that have been designed for use in a classroom and they have been used and tested in real classrooms. We also presented a few design principles. The discussion so far should have made clear that GeoGebra is easy to use and has the capabilities to produce really good infographics. Naturally, if one has a good knowledge of programming in JavaScript, then she can do really impressive things. Either way, one should use GeoGebra to create infographics that will be used in classrooms to teach mathematical concepts and ideas.

GeoGebra has been used to teach calculus (Machromah & Purnomo & Sari, 2019) and topology. In addition, there many GeoGebra applets that can be used to teach calculus.³ Practically, this means that the lesson learned from this work can be easily

³ For example see <https://www.geogebra.org/m/r4A2xSSp>

extended to tertiary education. However, this is a much more involved problem that requires extensive consideration and study.

References

- Francis, G. K. (2007). *A Topological Picturebook*. Springer.
- Fulton, S., & Fulton, J. (2013). *HTML5 Canvas* (2nd). O'Reilly Media, Inc.
- Machromah, I. U., Purnomo, M. E. R., & Sari, C. K. (2019). Learning calculus with GeoGebra at college. *Journal of Physics: Conference Series*, 1180, 012008.
- Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. Basic Books, Inc., Publishers.
- Pólya, G. (2004). *How to Solve It* [Expanded Princeton Science Library Edition, with a new foreword by John H. Conway]. Princeton University Press.
- Syropoulos, A. (2019). JavaScript and the HTML5 <canvas> Element. GlobeEdit.