USING GEOGEBRA TO CREATE RANDOMIZED PRACTICE PROBLEMS WITH FEEDBACK

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Introduction

During the 2021-2022 academic year, as many of us returned to face-to-face instruction, following a year of virtual and hybrid instruction caused by the COVID19 pandemic, a larger percentage of my students reported wanting more practice problems to help master the content in my core classes. Although the major commercially available assignment software programs offer many opportunities to work practice problems, I found myself wanting to provide more free examples outside of these systems. Instead of thinking up new values for every problem that I write, I have found it useful to create problems in GeoGebra that take advantage of built-in functions such as "RandomBetween" and "RandomElement" to write problems for which the user can quickly generate new versions. GeoGebra's input buttons and GeoGebra script also allows users to write step-by-step solutions that can be paced by the click of a button.

Creating a well-written randomized problem in GeoGebra takes an initial time investment, but once written, the problems can easily be shared with web links, allowing anyone access to a set of practice problems that can be used to quickly generate fresh problems with detailed feedback. Readers interested in using any of the problems that I have written can find many College Algebra and Calculus problems on my webpage:

http://faculty.ung.edu/tecooper/GGB/Algebra/GGB-Algebra.htm

http://faculty.ung.edu/tecooper/GGB/Calculus/GGB-Calculus.htm

The purpose of my 2022 ICTCM presentation was to present this idea of randomized practice problems and explain how to create one of these problems in GeoGebra. In this paper, I will provide instructions for the example that I built at the conference using GeoGebra Classic Version 6. This version of GeoGebra can currently be downloaded and installed from the GeoGebra web page or accessed directly from a web browser at https://www.geogebra.org/classic.

Example – Solving a Quadratic Equation by Factoring

For this example problem, users will be asked to solve an equation of the form $x^2 + bx + c = 0$ by factoring it into the form $(x - m)(x - n) = 0$ for algorithmically generated values of m and n. To ensure integer solutions and to avoid a constant coefficient of 0, we will start by creating the random values of m and n. Figure 1 shows a screenshot of the finished problem with all the feedback displayed. A completed version can be found at https://www.geogebra.org/classic/k6nmr8br.

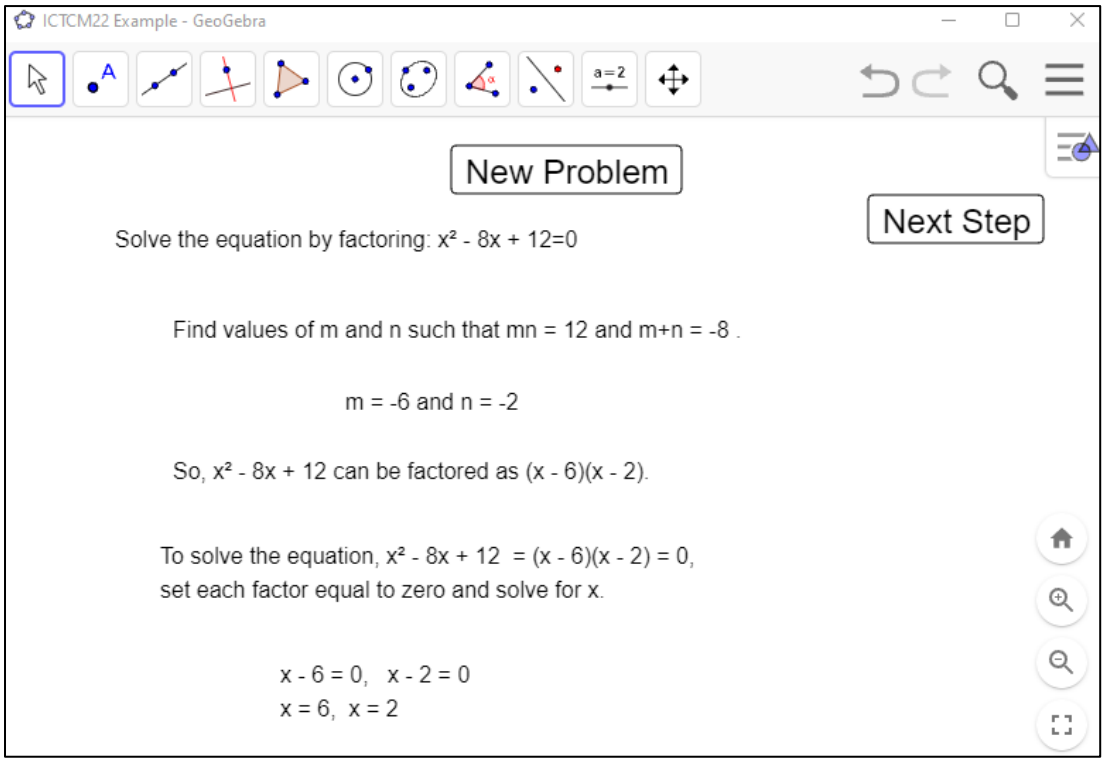

Figure 1. Screenshot of the randomized quadratic equation with feedback

Before beginning to write the problem, right click in the Graphics view and mouse click on "Show Axis" to hide the displayed Cartesian axes. Also, right click and select "No Grid" under "Show Grid" to hide the grid if it is currently displayed, leaving a blank view to write the problem and feedback.

Next, we will create the necessary objects in the Algebra view.

Use the GeoGebra input command $L = Sequence(-10,10)$ to create a list of integers ranging from -10 to 10, and then use the command $L2 = Remove(L, \{0\})$ to create a copy of this list with 0 being omitted. Note that such a list could be created with the single command $Remove(Sequence(-10,10), \{0\})$.

Once the list of possible values is created, use the commands $n = RandomElement(L2)$ and $m = RandomElement(L2)$ to select the two random values from the list. Ultimately, these values will be the solutions to the quadratic equation.

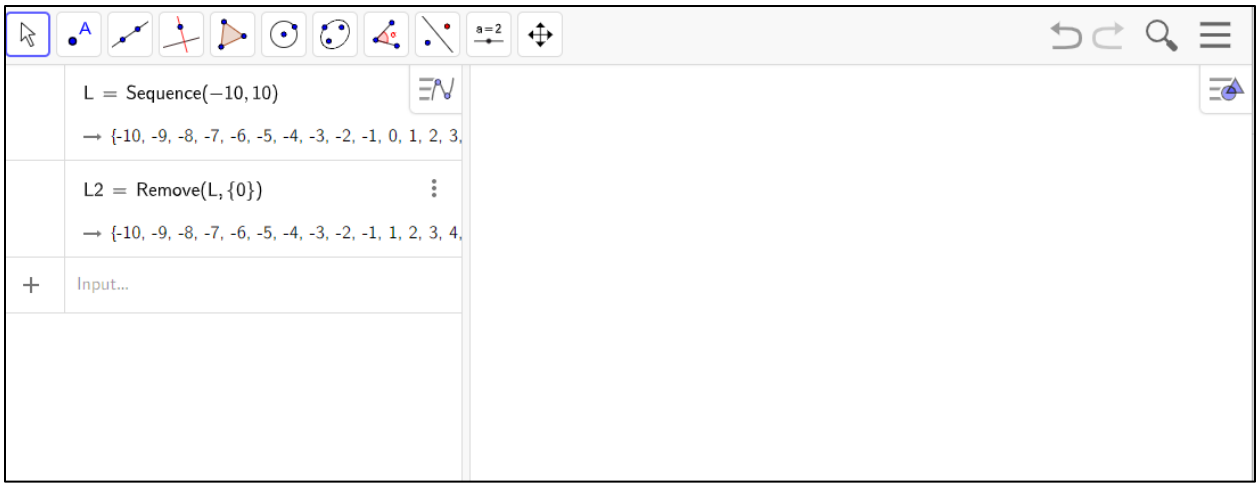

Figure 2. GeoGebra screenshot with the lists for selecting random values

Next, define the functions representing the two factors with the inputs $f1(x) = x - m$ and $f2(x) = x - n$. Note that GeoGebra will create the functions in the Algebra view and plot them in the Graphic view. Mouse click the shaded circles beside the functions in the Algebra view to hide the plots. Then, use the input $f(x) = Expand(f1(x)f2(x))$ to create the expanded form of the function for the problem. Mouse click the shaded circle to hide the plot of $f(x)$.

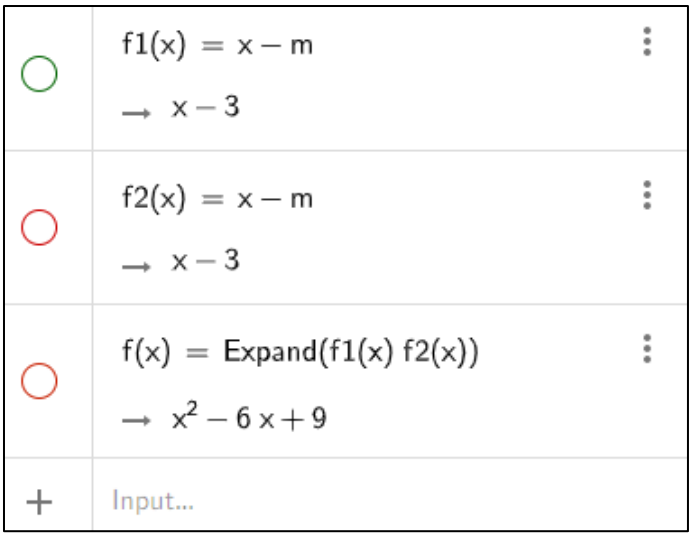

Figure 3. Screenshot with the factors and quadratic function in the Algebra view

To define the coefficients for use in the feedback, input $b = -m - n$ and $c = mn$. Then to initialize a counter for displaying the feedback, input $s = 0$. Note that in Version 6 of

GeoGebra, defining this numerical value will create a slider with a maximum value of 5. If you create a problem with more than five pieces of feedback, you will need to increase this maximum value. To change a slider's limits, mouse click on the three vertical dots to the right of the variable in the Algebra view and select "Settings".

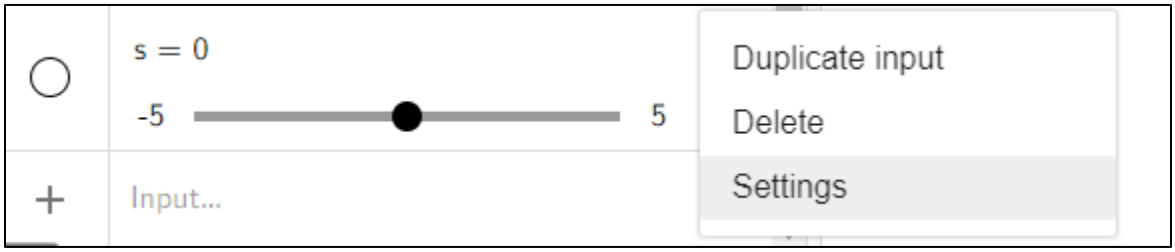

Figure 4. Selecting the settings for the counter variable *s*

In the Settings window that opens, select the "Slider" tab. Under this tab, you can set the minimum, maximum, and increment values. Once finished with the settings, click the "X" in the upper right corner of that view to close it.

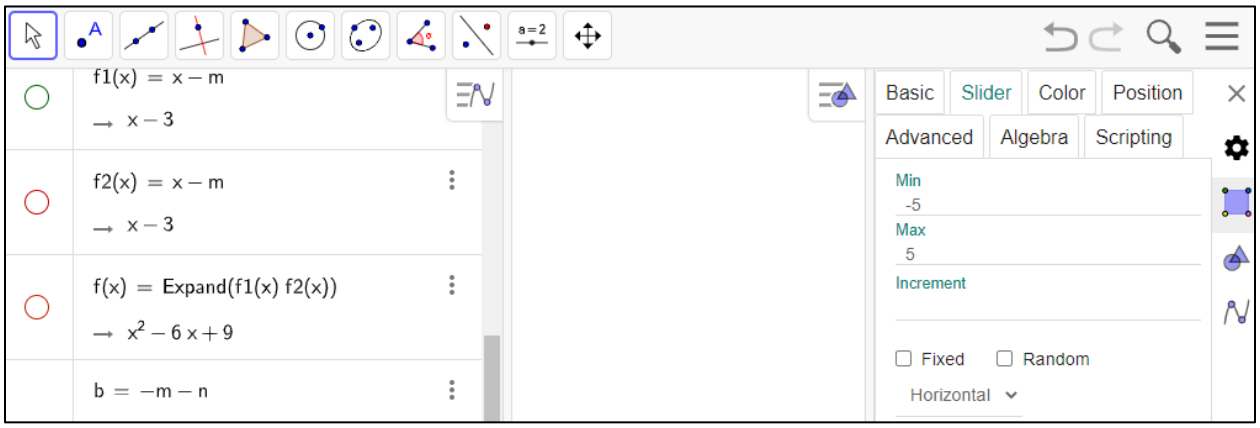

Figure 5. Screenshot with the Slider tab open

To write the problem in the Graphic view, select the text tool from the icon toolbar. To find the text tool, click on the slider icon and a drop-down menu with more options will appear.

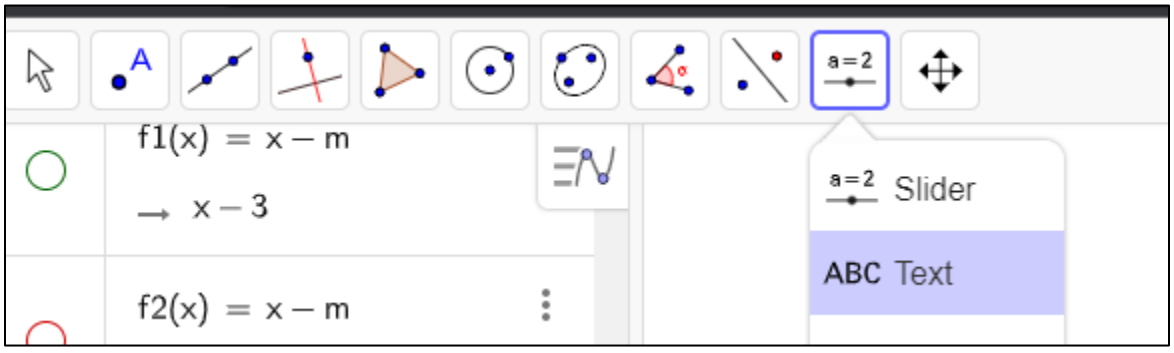

Figure 6. Selecting the Text tool

Once the text tool has been selected, click the approximate location that you would like for the text to appear in the Graphic view, and a text input box will appear. Users familiar with LaTex can use it for typesetting equations and symbols if desired. For this example, I will use standard text combined with GeoGebra objects. First, type the initial statement for the problem, "Solve the equation by factoring:" without the quotes in the main text input box. Then to insert the formula for the function f, click on the "Advanced Tab", followed by the GeoGebra icon to access a list of all objects that have been defined in the Algebra view. Click on f in the list to insert it into the text string. You can click the "Preview" tab to get a preview of how the text will display.

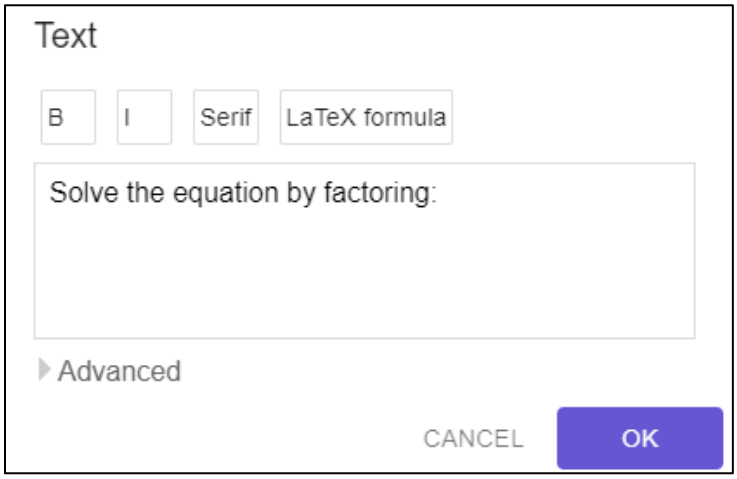

Figure 7. Entering the text in the text dialog box

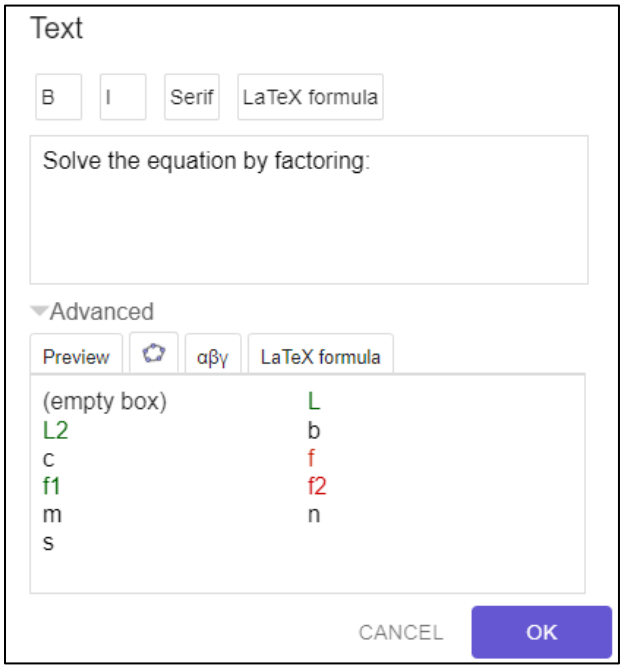

Figure 8. Accessing the GeoGebra objects for text

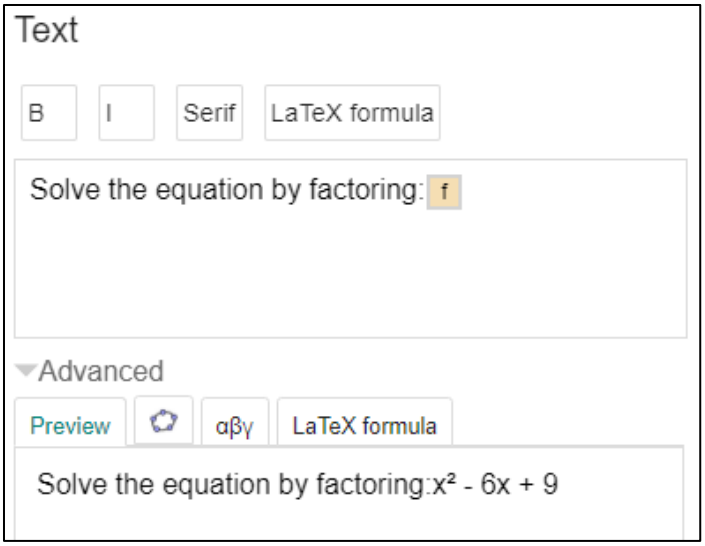

Figure 9. Preview with the GeoGebra object *f*

Then, add "=0" without the quotes to the text, and click "OK".

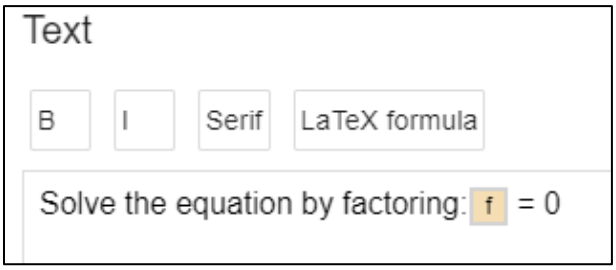

Figure 10. Completing the problem stem

The text will display in the Graphic view. If you want to reposition it, select the "Move" tool, which is the first icon in the list that looks like an arrow. Then you can click and drag the text string. If you want to edit a text string, be sure to select the move tool first. Then, either double click the text or right click and select settings.

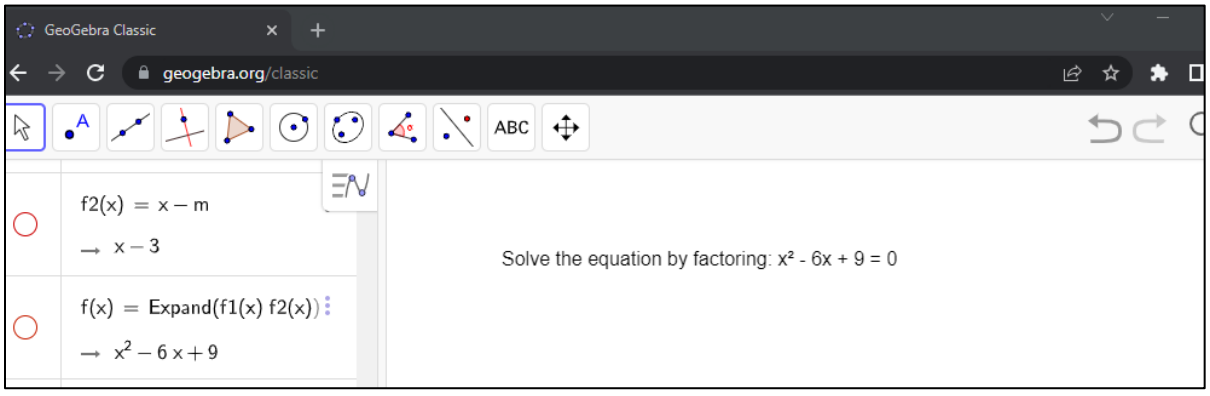

Figure 11. Screenshot with the problem stem in the Graphics view

Next, add the button to generate a new problem. To do this select the button tool, which is in the icon list with the sliders and text.

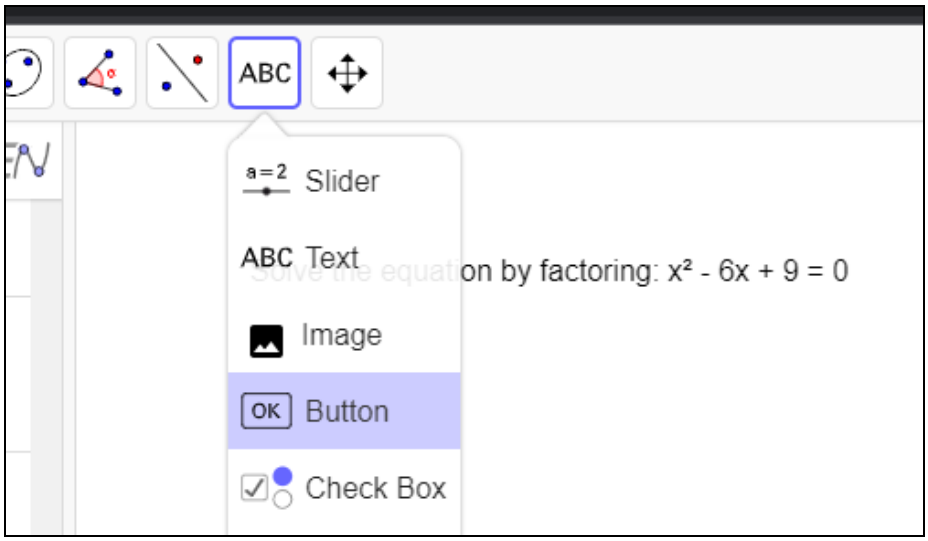

Figure 12. Selecting the Button tool

Then, mouse click where you want to place the button in the Graphics view. A dialog box will open. For the caption, type the text that you want to display on the button. In this case, New Problem. The GeoGebra Script is a command or commands that the button will execute once clicked. The command $UpdateConstruction()$; can be used to make GeoGebra refresh the construction and select new values for the random variables.

Figure 13. Setting the button's caption and GeoGebra script

Use the enter key on the keyboard or mouse click on "OK" to close the dialog window and create the button.

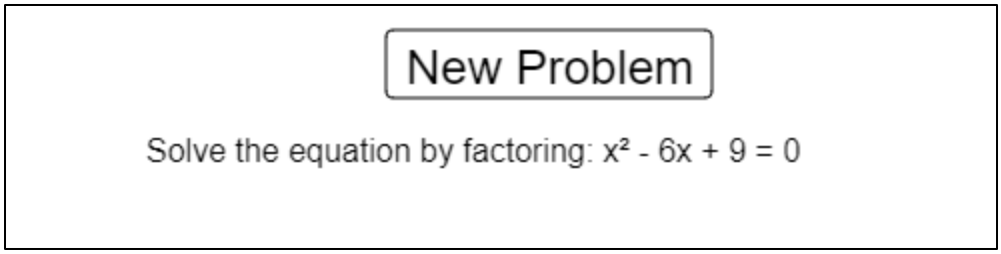

Figure 14. Screenshot with the problem stem and New Problem button

To add additional GeoGebra Script commands, right click on the button and select "Settings". Then, go to the "Scripting" tab. Add the command $SetValue(s, 0)$; so that the step counter variable s will be reset to 0 any time the button is clicked. After entering the additional command, click the "X" to close the settings. Now you should be able to use the "Move" tool and click on the button to generate new versions of the equation.

To finish, we need to add the feedback as a series of text strings and use a second button to increment the counter and make the feedback display step-by-step.

Use the button tool to create a second button with caption $Next\ Step$ and GeoGebra Script $SetValue(s, s + 1)$ to control the counter variable s.

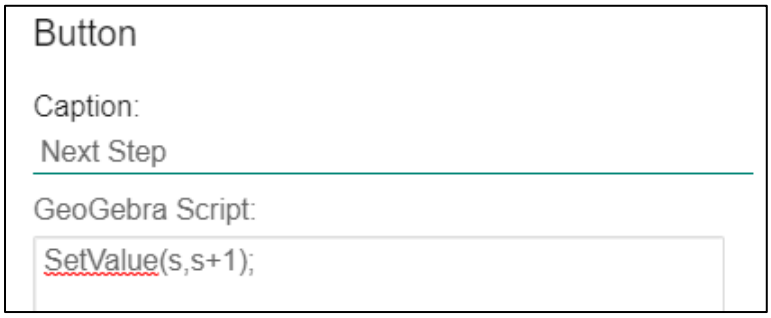

Figure 15. Setting up a button to advance a step counter s

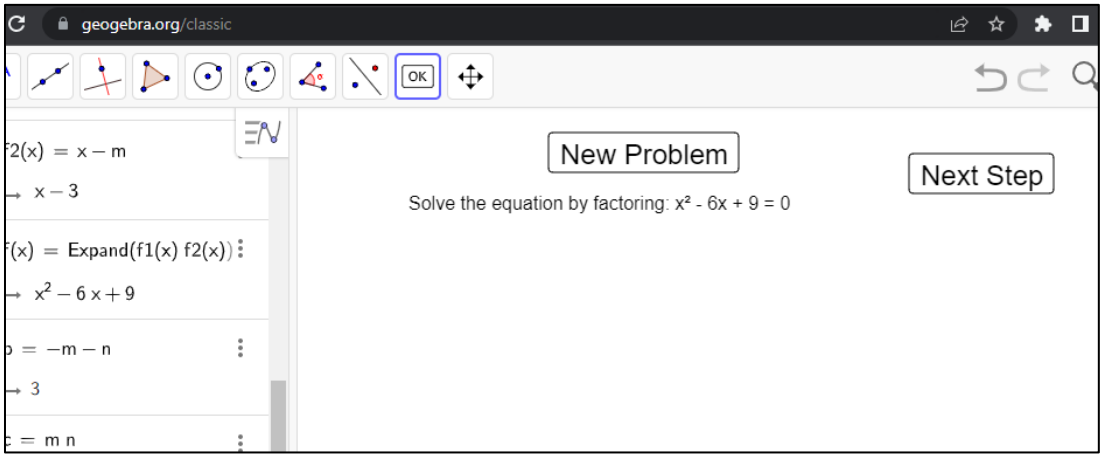

Figure 16. Screenshot with both buttons and the problem stem

In the following instructions, I will use the notation [object] to indicate a GeoGebra object that you need to select from the Advanced tab in the text dialog box. Note that if you want to do a computation on an object, you can click on any object once it is inserted in the text dialog box or select the "(empty box)" object. You can do any operation with objects in this box that you can in the Algebra input box. For instance, you can use $[-m]$ to get the additive inverse of m.

Figure 17. Combining text and a computation

Use the text tool five separate times to add the following text strings.

Feedback text 1: Find values of m and n such that mn = [c] and m+n = [b].

Feedback text 2: m = [-m] and n = [-n]

Feedback text 3: So, [f] can be factored as ([f1])([f2]).

Feedback text 4: To solve the equation, [f] = ([f1])([f2]) = 0,

set each factor equal to zero and solve for x.

Feedback text 5: [f1] = 0, [f2] = 0

x = [m], x = [n]

Once these text strings have been added, your GeoGebra screen should look similar to Figure 1, but all values will be based on the randomly selected values of m and n.

Finally, to control the step-by-step display of feedback, right click and enter the settings of the first feedback text string and under the "Advanced" tab and "Condition to Show Object", type $s > 0$ and enter. For the next text string set the condition to $s > 1$. Continue this, upping the count by one, through $s > 4$ for the fifth and final feedback text string.

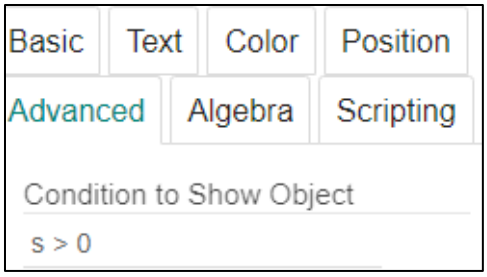

Figure 18. Setting the "Condition to Show" for the first feedback text string

After that, the construction is complete, and you can look under "View" in the "File" Menu and deselect "Algebra" to hide the Algebra view. Then, save your work by downloading the $.ggb$ file or by sharing to an online GeoGebra account.

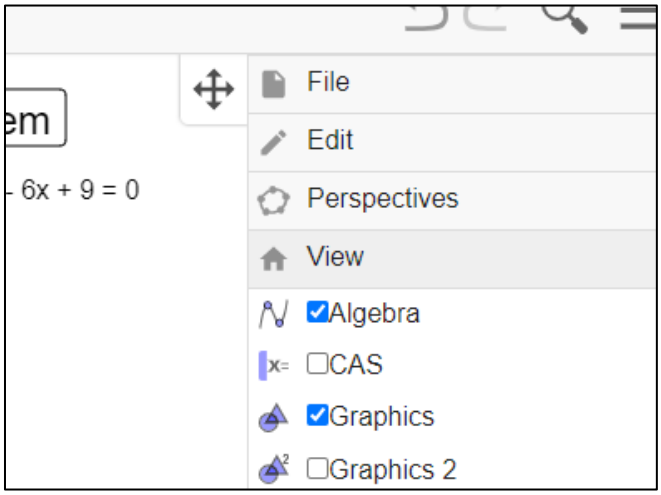

Figure 19. Screenshot of the View menu

Conclusion

Hopefully, this one example of solving a simple quadratic equation demonstrates the main idea that GeoGebra can be used to write practice problems for which users can generate new values and go through step-by-step feedback by clicking on the buttons. The more experienced a user is with GeoGebra, the more elaborate problems he or she can create. For example, I have written problems that randomly generate graphs with asymptotes, jumps, and removable discontinuities for my calculus students with feedback on limits that provides numerical answers and shades the appropriate portion of the graph to explore the answer. Having used GeoGebra for more than a decade, the thing that I find most impressive is that it provides tools for teachers and students to build endless constructions that are only limited by our own knowledge and imagination, and through the GeoGebra website users can share work with one another. As mentioned in the introduction, I have written many of the randomized practice problems that can be accessed from my webpage, and I encourage others to do the same.