

IMPLEMENTATION OF DYNAMIC GEOMETRY APPLETS TO ENHANCE STUDENT LEARNING IN ONLINE COURSES

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Abstract

A series of interactive geometry applets has been developed and embedded in the content of an online, asynchronous geometry course. Each applet includes suggestions to promote independent exploration and is followed by one or more short questions to assess understanding and gauge participation. This paper will provide an overview of the approach including detailed examples and implementation results.

Introduction

Many students enrolled in college geometry courses have difficulty visualizing geometric entities and understanding geometric relationships. Research indicates that inquiry-based approaches can lead to better outcomes [1]. These inquiry-based approaches encourage students to manipulate and interact with geometric figures. Contrary to traditional approaches where problems are solved using static figures, dynamic geometry applications invite students to manipulate figures and learn from this interaction. This inductive approach to learning supports and reinforces the deductive concepts they learn to apply to solve traditional problems.

In this work, a series of dynamic geometry applets was embedded into an asynchronous online course in order to address student difficulties and increase student comprehension. Specifically, the applets were designed to improve the students' ability to visualize and understand geometric relationships. Some applets were specifically designed to combat students' tendency to make assumptions that are not always true.

The remainder of this paper is organized as follows. First, the student population and previous approach are introduced. Next, an overview of the dynamic applets is provided including justification for the choice of technology and a synopsis of specific applets. Finally, conclusions and future work are addressed.

Student Population and Previous Approach

Student Population

The applets described were developed for an asynchronous online geometry course for future elementary educators. These students are usually in their third or fourth year and most have a gap of at least two years from the Algebra course that is a prerequisite for this course. Many of the students are returning adult learners who may be a decade or more

removed from their last formal mathematics course. This means that in addition to learning the new material students may spend a considerable amount of time reviewing the prerequisite material. In addition, many students are very anxious about mathematics in general and geometry in particular.

Previous Approach

In addition to assignments involving problem solving, two-column proofs, and constructions, this course requires students to complete assignments using a dynamic geometry visualization software. Currently, students complete five computer assignments using The Geometer's Sketchpad[2]. While these assignments are helpful, they demonstrate several shortcomings. First since there are five assignments throughout the semester, students are engaging in the inquiry-based approach promoted in these assignments at discrete times throughout the semester. It is desirable to supplement these assignments with inquiry-based activities that students engage with more frequently. Additionally because the students are learning to use the software, the assignments are fairly detailed in providing instructions and leading students to conclusions. Opportunities for more open-ended exploration would be a welcome addition to the course. Finally, The Geometer's Sketchpad is a standalone, proprietary desktop application requiring the students to engage with the software independently from the content of the course. It would be helpful to have visualizations that the students can explore while they are learning.

Implementing Dynamic Applets

In order to overcome the shortcomings discussed previously and promote inquiry-based learning, a series of ten applets has been developed and embedded directly into the content for an asynchronous online geometry course. Before engaging with the applet, students are provided with suggestions for interaction. They are then free to interact with the applet independently. Finally, one or more follow-up questions is posed and responses are collected using Google Forms [3] in order to assess comprehension and track participation.

Why GeoGebra[4]?

The applets were all developed using GeoGebra. GeoGebra is a free, open-source, cross-platform tool that is available for a variety of platforms including desktop, mobile, and web browsers. The applets can be embedded directly into a webpage which means that the geometry applets were able to be presented alongside the asynchronous course content. Additionally at the time of this writing, there were over 740,000 free applets available on GeoGebra's website. These existing interactive materials are open-source and can be modified to tailor them to illuminate a particular concept. They can also be used as a guide when creating your own applets which can help new users ease into more advanced features such as scripting. Finally, GeoGebra is not limited to geometry. In fact, there are tools for a variety of topics including algebra, graphing, calculus, spreadsheets, and statistics. That means that this work can be extended to courses in other disciplines.

Centers of triangles applet

The first applet (Fig. 1) discussed allows students to explore four of the centers of triangles and the lines that form them. Students can show or hide the angle bisectors, medians,

perpendicular bisectors, and altitudes along with their points of concurrency which are the incenter, centroid, circumcenter, and orthocenter, respectively. Additionally, there are calculations that show the relationship between the segments medians are broken into by the centroid. The inscribed and circumscribed circles for the triangle can be shown as well (Fig. 2).

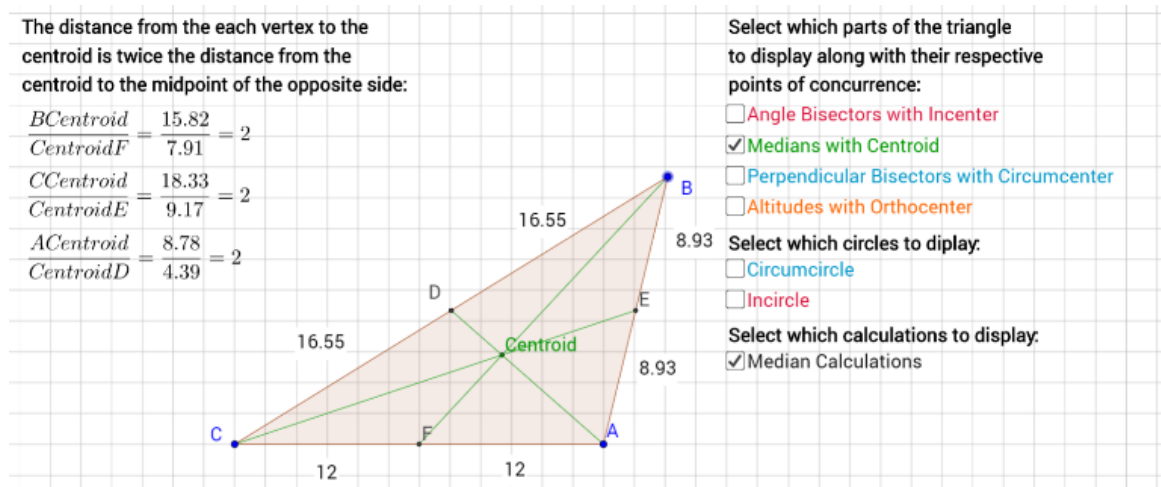


Fig. 1. An applet that allows students to explore how the centers of triangles behave for a variety of different triangles.

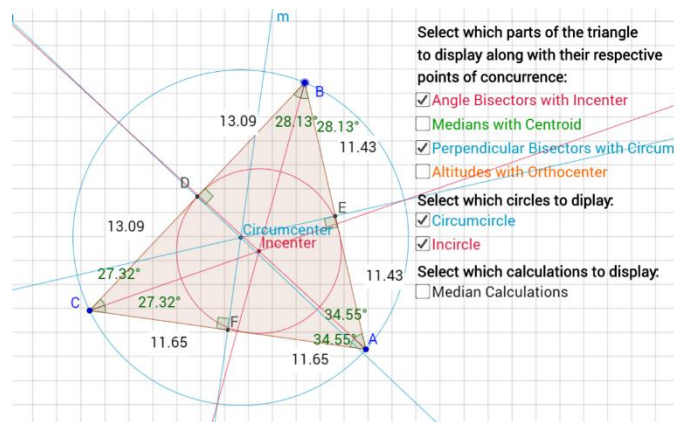


Fig. 2. The applet showing the centers of triangles can also show the inscribed and circumscribed circles for a triangle.

Use the applet above the answer the following questions.

For which type of triangle are the incenter, circumcenter, orthocenter, and centroid all located at the same point? * 0 points

- Scalene
- Obtuse
- Equilateral
- Isosceles

Fig. 3. Question students are asked to answer using the centers of triangles applet.

The power of these applets is difficult to convey in static images. Students can manipulate the vertices of the triangle to see what happens to the centers for different types of triangles. For example, they might notice that the incenter and centroid always remain in the interior of the triangle while the orthocenter and circumcenter move outside the triangle when it becomes obtuse.

After interacting with the applet, students are asked a follow-up question. The question that is paired with this applet is shown in Fig. 3. The first goal of this question is to clarify the misconception is that these centers of triangles are, in fact, four different points that happen to coincide for one special type of triangle. Then, students need to identify that the points coincide for equilateral triangles. The astute student will also notice that for isosceles triangles the points are collinear and lie on the angle bisector of the vertex angle.

Of the 42 students who responded to the question in Fall 2016 and Spring 2017, 86% answered correctly. Interestingly, the 14% that answered incorrectly all gave the answer isosceles. This is interesting because these points are all collinear for an isosceles triangle, rather than concurrent.

Triangle Inequality applet

Another applet was developed to give students a visual analog for the triangle inequality and the process of extending the Pythagorean Theorem to classify triangles by their angles (Fig. 4). In this applet, students can change the length of the blue and red sides of the triangle using the sliders. Once these lengths are specified, the location of the third vertex is automatically calculated (Fig. 4b) and students can manipulate points C and D to close the triangle (Fig. 4a). The applet shows the calculations for and conclusion from the triangle inequality and the inequality used to classify the triangle. If the student chooses lengths for which the triangle inequality is not satisfied, then the third vertex disappears and they can move points C and D to see why the triangle will not close. The questions paired with this applet gives the student two different sets of lengths for the sides of a triangle and asks them to determine if the triangle can be drawn and to classify the triangle. Students responding to this question in Fall 2016 and Spring 2017 determined whether or not the triangle existed correctly 92% of the time and classified the triangle correctly 79% of the time.

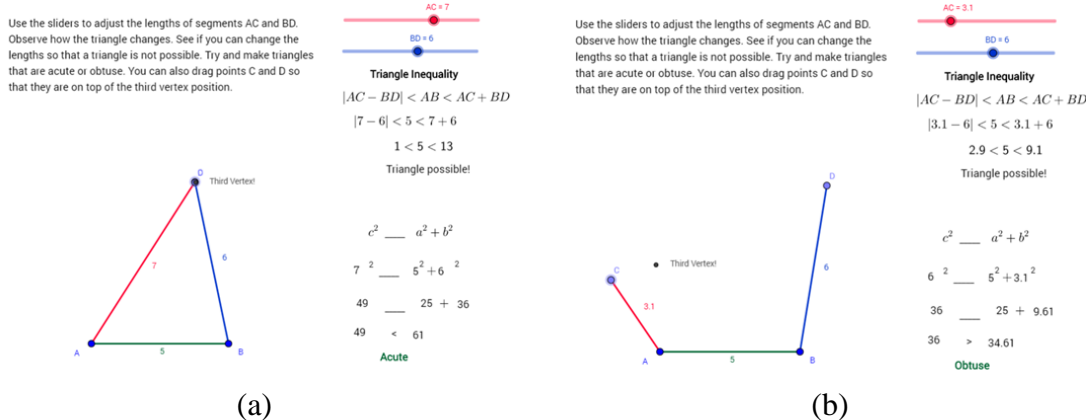


Fig. 4. Applet giving a visual representation of the triangle inequality.

Conclusions and Future work

While some of the questions were open ended and did not have a “correct” answer, for the questions that could be scored students who attempted them got between 75% and 92% on their first attempt. A consequence of placing the applets directly in the content and pairing them with questions was that it gave a quick and easy way for the instructor to determine which students were most engaged in the course content. The applets were placed randomly in the course modules based on where they best fit with the material. This meant that for students to find them all, they had to go through nearly every page of the content.

When comparing end of course grades for groups after the implementation of the applets and questions to groups prior to implementation who may have had access to a small numbers of the applets but no paired questions, there is an increase in the end of course test average. In order to make this comparison, a two sample t-test was conducted. The average increased to 82% ($n = 38$) from 74% ($n = 48$) for students who completed the course with $p = 99.8\%$ indicating that there is a difference in the means for the two groups. While there may have been other factors that influenced the increase in performance and the number of students is relatively small, these are promising preliminary results.

In the future, it will be interesting to further analyze the effect of the applets in the asynchronous course. Additional applets can and will be developed to help students understand challenging topics.

Acknowledgment

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References

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