Faculty Innovator Grant 2015
Center for Learning and Teaching

Final Report Form

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Project Title: (10 words or less)	Implementation of Dynamic Geometry Applets to Enhance Student Learning Outcomes

1. Describe the specific teaching and learning issues being addressed by the proposal.

Students learning geometry tend to have difficulty visualizing and understanding the relationships between geometric figures. Part of this issue can be attributed to the fact that traditionally we teach by drawing or presenting static figures. To truly understand how geometric objects are related, students need to be able to visualize what happens to various quantities and measurements as the figures change. This is especially difficult for students who do not have a strong background in mathematics. This project has focused on MATH 302 which is a geometry course for students studying to be elementary school teachers. These students frequently have a weak background in mathematics, but it is exceedingly important for them to have a strong understanding of the way geometric objects are related as they will be the first geometry teachers for children.

Previously in MATH 302, the above issues have been addressed by having students complete five computer assignments using a software called Geometer's Sketchpad (http://www.dynamicgeometry.com/) that allows them to create dynamic geometry worksheets. However having the students complete only these few assignments means that their interaction with these dynamic figures is limited to a few topics throughout the semester. Also, the software that is currently in use is not free to use and must be installed on a personal computer. This course is currently taught using face-to-face and web-based delivery. Dynamic visualizations are especially important for the online students to enhance their understanding of geometric.

2. Describe the revised specific teaching and learning issues being addressed by the proposal (if applicable):

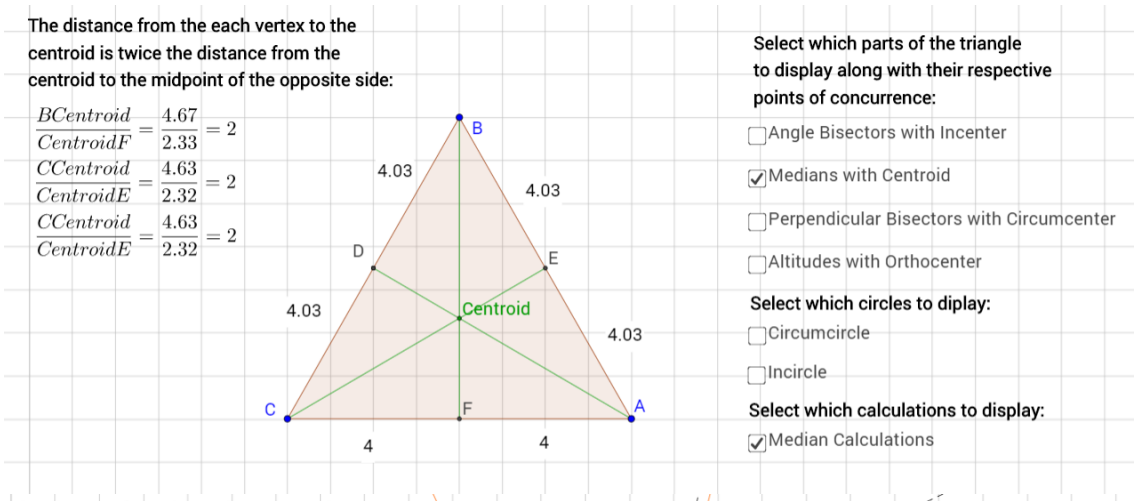
N/A

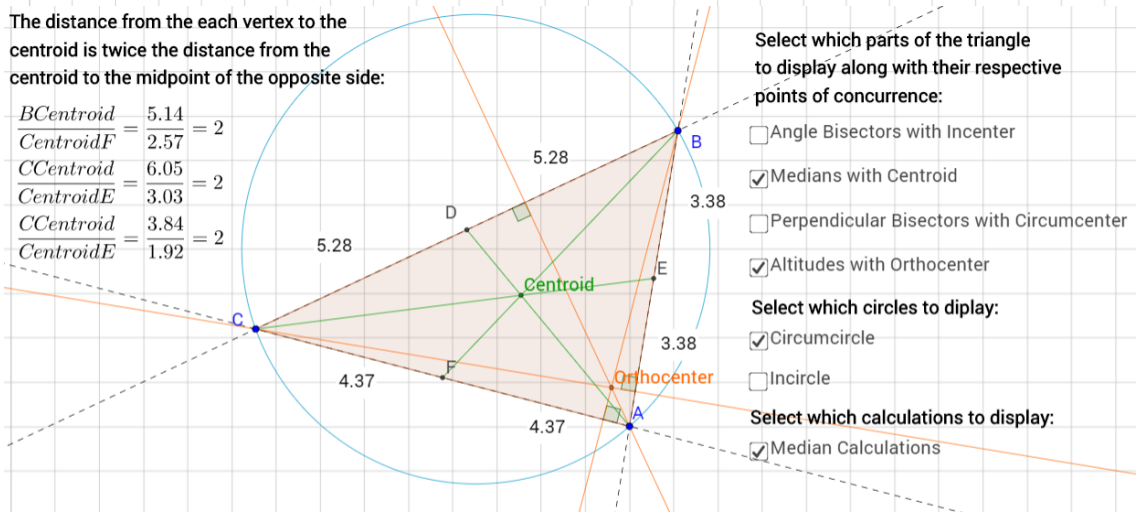
3. Describe the development activities involved addressing the learning or teaching issue.

In order to solve this problem, a free tool called GeoGebra (https://www.geogebra.org/) has been used to develop dynamic geometry applets that are embedded in a learning management (for face-to-face courses) or content delivery system (for online courses). The instructor uses these applets in class or in videos to demonstrate relationships between geometric objects. In addition, the students use the applets on their own to investigate these same relationships and develop a deeper understanding of the material. Questions are provided with each applet that requires independent exploration and student answers are monitored using Google Forms in order to track participation and understanding.

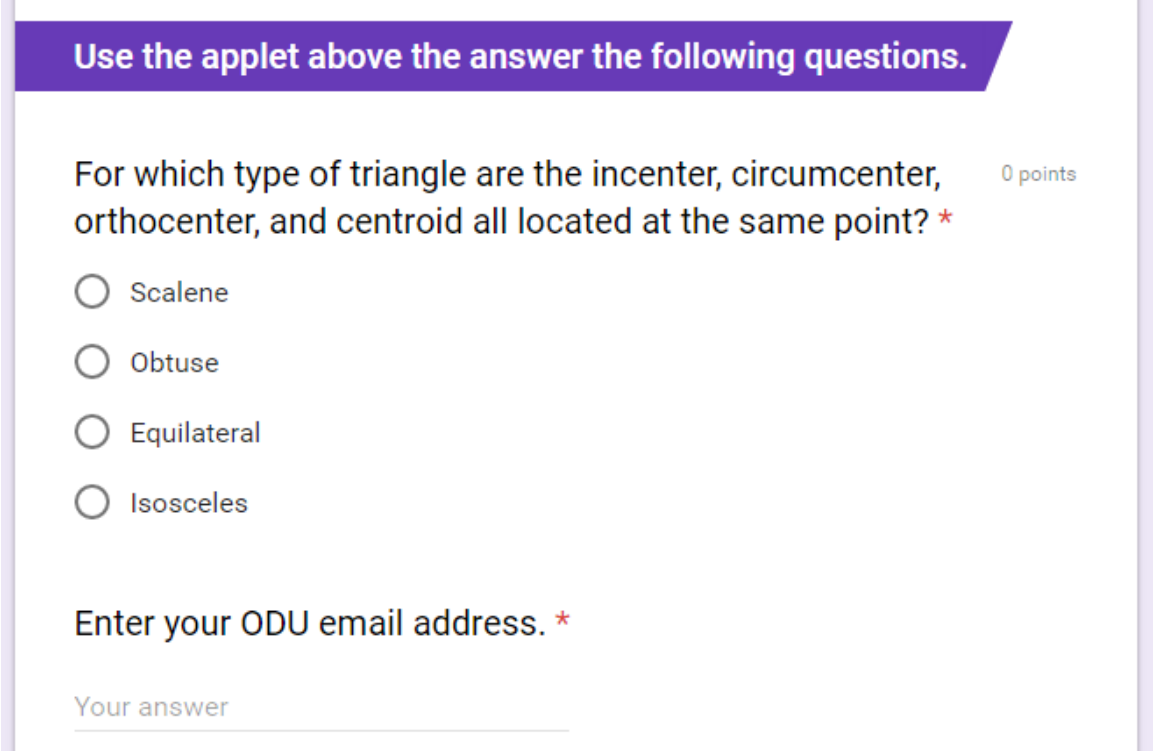
In addition to the proof of concept applet developed previously, ten additional applets have either been modified or developed from scratch. Each applet addresses a commonly misunderstood topic in the geometry curriculum. Two examples are described below while all applets are available at https://www.geogebra.org/k3smith.

The first applet helps students learn about the centers of triangles. Two screen captures are included to show the dynamic nature of the applet. Static images do not fully show the power of this tool, the link for the applet that was used to generate the captures is http://tube.geogebra.org/m/1969325.



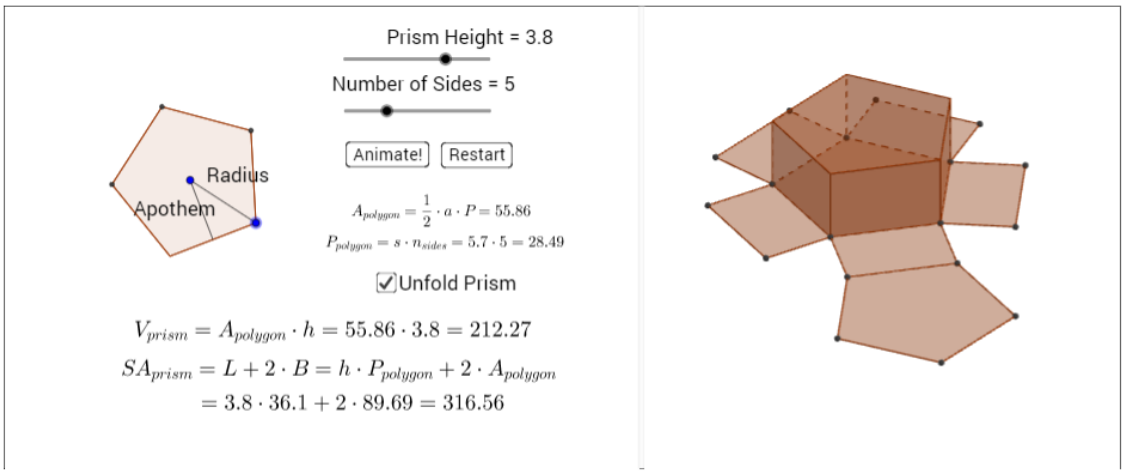


After interacting with the applet, students submit their answer to the following question using a Google Form:



Another applet helps students to understand how volume and surface area can be calculated to regular polygonal prisms with a given number of sides. Students can vary the height of the prism, radius of the polygonal base and number of sides. Additionally, they can view the prism folded flat to better understand the meaning on the surface area calculation. Two screenshots are provided below and the applet can be accessed at https://www.geogebra.org/m/UQeGnJs4.

Use the applet below to explore the volume and surface area of right, regular prisms. You can change the height of the solid and the radius and number of sides of the base.



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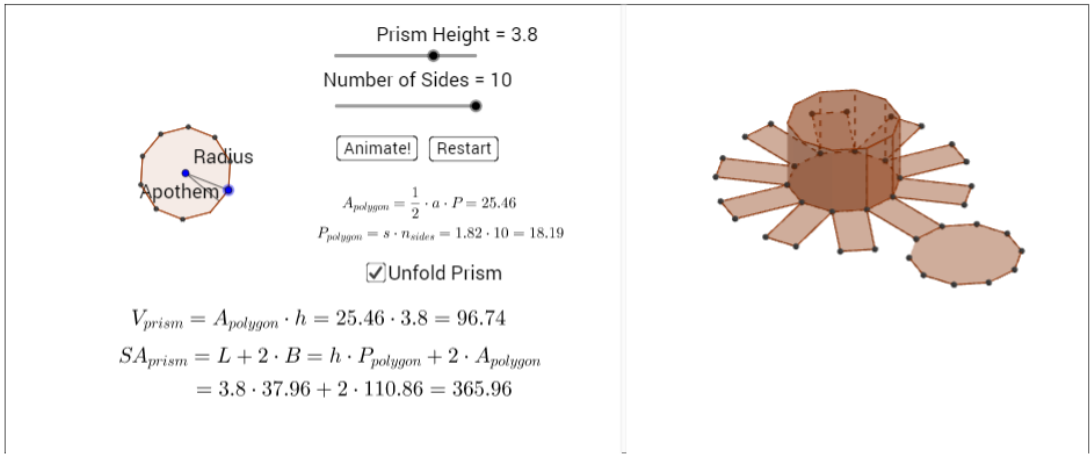


All applets can be accessed using a link or embedded in a content delivery system and viewed on any computer or mobile device with a web browser. There is also a free app available for iOS, Android and Windows and a free application that can be used on Windows, Mac OS X or Linux.

4. Describe the learning outcomes attained by the project.

The goal of this project is to enhance student understanding of geometry. Most students see geometry as a set of rules and theorems that are memorized and applied to static figures. Learning through independent discovery has been invaluable as these students understand geometric concepts at a deeper level. Instead of memorizing a set of rules,

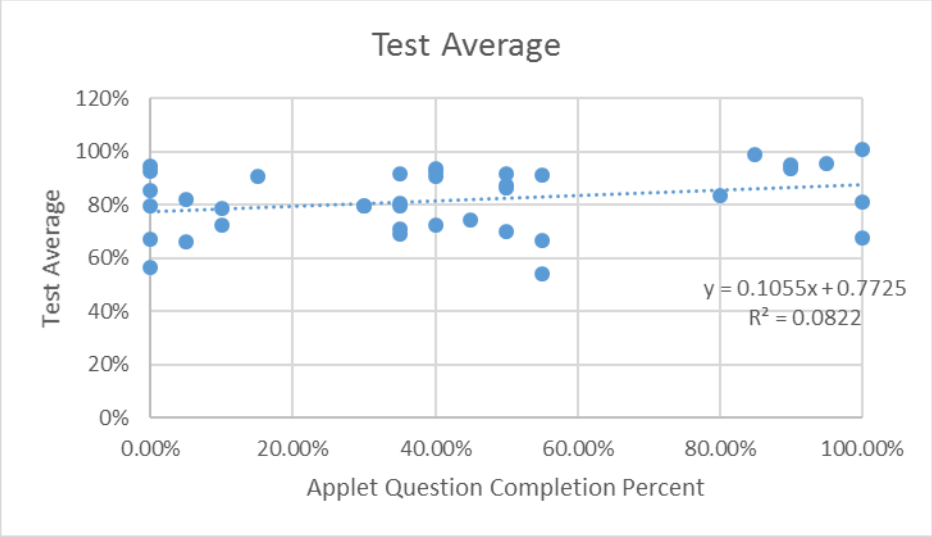
they are learning about geometric relationships by seeing how figures behave when the parts are manipulated. For example, they can see relationships between angles and arcs in a circle and view how one changes as the other is manipulated. This combination of inductive thinking with the deductive methods already present in the curriculum reinforces and enriches student learning. Students will be better equipped to explain similar, but simpler, geometric ideas to their future students. They will also be prepared to use similar methods of instruction to demonstrate geometric concepts to their future students.

Mean scores for the online asynchronous course were calculated prior to the full implementation of the applets (Spring and Summer 2016, 48 students) and after full implementation of all applets (Fall 2016, 38 students). The Spring and Summer classes had access to some of the applets, but not the accompanying questions. Only the final averages for students who completed the course, including taking the final exam, were considered when the two groups were compared. Since we were testing to see if the Fall course had a higher average than the Spring and Summer classes a one-tailed, two-sample t-test was performed. This test showed that the Fall 2016 scores were higher than the Spring and Summer 2016 scores with a confidence of 99.8%. The results are summarized in the table below.

Table 1. Two-sample t-Test comparing test averages for Fall 2016 students and the combined spring and summer 2016 group.

	Fall 2016 Class	*Combined Spring and Summer 2016 Classes*
Mean	81.67%	73.72%
Variance	1.40%	1.69%
Observations	38	48
t Stat	2.96	
P(T<=t) one-tail	0.00198	

While this allows us to conclude that students in the course with the applets fully implemented performed better than prior groups, it does not imply causality. Since it can be very difficult to show causality, the correlation between completing the questions that accompanied the applets in the PLE and test scores was investigated. The following plot shows this relationship.



The plot includes a trend line showing that there is a positive relationship between completing the questions accompanying the applets and a student's test average. While the r-squared value is not close to one, r-squared is a measure of how much variability can be explained by the linear model shown. Since there are many variables that influence a student's test average, it seems reasonable that 8% of the variability could be explained by applet questions completion percentage.

5. Describe unexpected outcomes, if any.

One unexpected outcome of this project was the ability to monitor student progress in an online asynchronous course that uses ODU's Personal Learning Environment (PLE). In the current iteration of PLE, instructors do not receive any information about how long students spent in the PLE reviewing course material or even which pages they visited. By embedding these applets directly in the PLE topics on various pages and collecting student answers, the instructor was able to determine which students were actively reviewing the material.

As a result of this discovery, similar Google Forms questions have been implemented in MATH 101M, which is another asynchronous online course developed by Ms. Smith. This has provided the ability to measure student participation in reviewing the course content through the PLE.

6. Describe the impact of the completed project on your colleagues, department, college, or community.

The applets created for this project are be available to all instructors in the department. In fact, the interactive worksheets are published on the GeoGebra website where they are freely available to anyone for educational use. Ms. Smith is available to present the work within the department and share all resources with any instructors who are

interested in implementing these or similar applets in their own courses. Because the applets are integrated into the online curriculum, any instructor teaching the online course has the applets automatically built into the course.

In addition to geometry, GeoGebra can be used for algebra, calculus, statistics and three-dimensional graphing, so any presentation to the department would include a discussion of how GeoGebra applets could be used to enhance other courses. In fact, Ms. Smith has also developed a statistics applet to accompany an activity in the online MATH 101M course at ODU.

7. Describe how the project can be a model, template, or prototype for use by other instructors.

Because the applets are integrated into the PLE for MATH 302 at ODU any other instructor teaching the course could use them with very little modification. The only change necessary would be to make copies of the Google Forms containing the questions. Then, the responses for these new forms would need to be directed to a Google Sheet that was owned by the instructor for that course. This set up should take less than an hour for each class.

If an instructor wanted to use the applets outside of the PLE, they could embed them in their Blackboard course, provide the students with links, or demonstrate them in a live class or video.

8. Describe the technology used to help address the issues described in the proposal.

The technology selected is an open source application that is free for non-commercial use called GeoGebra. GeoGebra is an application that can be accessed online, downloaded as an application for Windows, Mac OS X, or Linux, or installed as a free app on Windows, iOS, and Android mobile devices. The cross platform support and ability to access the application online without installing any software makes this technology a good fit for online students who are accessing course materials from a variety of mobile devices as well as personal computers. Materials developed using GeoGebra can be embedded in a web page or accessed on a variety of devices.

In addition to the ability to create interactive worksheets, GeoGebra offers scripting and animation capabilities. These capabilities can be used to have predetermined animations of figures that demonstrate a particular concept before students explore on their own. Scripting can also be used to enhance the interactivity of the worksheet.

9. Describe products, if any, that are a result of the project.

This project has resulted in a series of applets and accompanying questions. The applets are open source and freely available at https://www.geogebra.org/k3smith. Interested individuals can request copies of the questions from Ms. Smith by email.

Additionally, this work has resulted in the following publication:
Smith, K. “Implementation of Dynamic Geometry Applets to Enhance Student Learning in Online Courses.” Proceedings of the Twenty-ninth Annual International Conference on Technology in Collegiate Mathematics. March 9-12, 2017, Chicago, Illinois.

10. Describe the future plans for this project, if any.

The applets and questions developed as a result of this project will be used in the online asynchronous MATH 302 course for the foreseeable future. Additionally, Ms. Smith will continue to collect and compare data in future semesters to identify additional challenging topics that could be enhanced by an interactive applet and monitor student success because of applet use.

11. Attach a financial report with updated Budget Plan Matrix.

Final Budget Matrix

			Source of Funds	
Budget Item (equipment, personnel, software, etc.)	**Qty**	**Total Cost**	**Amount from FIG**	**Amount from Other Source**
Stipend for Ms. Smith	1	$1,500	$1,500	$0