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A Mathematical App for the Conceptual Understanding of Area and Perimeter

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Abstract: This paper discusses an app that was developed to build a strong understanding of the concepts of area and perimeter in students. An important feature of the app is the three-component feature which highlights progressive learning: *Explore,* designed for the learning of the conceptual understanding of area and perimeter; *Apply*, where area and perimeter concepts are applied; and *Create* intended for constructing representations to develop higher order thinking skills. The pedagogical basis for the creation of the app, the game design elements employed in the app as well as the integration of the app in the classroom will be presented.

Keywords: Mathematical app, area and perimeter, area, perimeter

1. Introduction

There is a longstanding and general consensus worldwide (Hiebert & Carpenter, 1992; Skemp, 2006) and in the Philippines (Department of Education, 2016) that mathematics must be learned relationally; that is, as an integrated network of connections between and among mathematical concepts. Teaching area and perimeter meaningfully entails going beyond the teaching of formulas or procedures so that students could justify these formulas and re-construct them in case they forget (Lithner, 2017). Toward this end, designing instructional materials to facilitate students' learning of area and perimeter is essential.

A problem arises in emerging economies whereby many schools routinely cater to ill-prepared students, which forces teachers to resort to rote-based strategies in teaching area and perimeter. In (Bansilal, 2011), classroom discussion facilitated by a teacher in South Africa focuses largely on helping her students remember the formula rather than on allowing her students to reason about the authentic performance-based assessment mandated by their national board of education. The reason for this teachers' actions was due to her learners' non-readiness for the task, preventing the students from engaging in more meaningful mathematical activity. In Taiwan, which has historically performed well in international assessments, there are teachers who present formulas directly instead of engaging their learners to explore the geometric basis for these formulas (Huang, 2017).

The potential of technological tools for teaching area and perimeter has been explored (Hwang et al., 2020). This paper discusses the *Area and Perimeter* app aimed to provide students the opportunity to understand the conceptual underpinnings of area and perimeter formulas. This app was designed in consideration of scholarly literature and was one of the outputs of a government-funded project in the Philippines (De Las Peñas et al., 2023). It was designed in a game-like environment to address particular learning competencies in mathematics. It is compatible with and runs efficiently in a wide range of Android devices (e.g., smartphones, tablets) and Windows PC (laptops or desktops) without the internet.

2. Pedagogical Basis

The *Area and Perimeter* app was designed based on the concrete-pictorial-abstract approach developed by Jerome Bruner (1996). The idea is to carefully sequence representations that would enable learners to transition from concrete to abstract (Ding & Li, 2014). As such, area formulas (which are abstract concepts) are strongly tied to geometric shapes (which are pictorial representations). The app also consists of three levels: *Explore*, *Apply*, and *Create*. By *exploring* geometric objects, students can think about area and perimeter using particular cases. By playing the app repeatedly, they can generalize, understand the conceptual basis for the area and perimeter formulas, and *apply* them to compute the area and perimeter of a given geometric figure. Finally, students are provided an opportunity to develop higher-order thinking by *creating* geometric objects given the area or perimeter. This sequence of *Explore*, *Apply*, and *Create* allows the student to develop relational understanding instead of relying solely on procedural formulas of area and perimeter.

3. The *Area and Perimeter* App

3.1 App Description

In the *Area and Perimeter* app, students have the option to choose the following topics: *Area*, *Perimeter,* or *Area and Perimeter*. The *Area* component includes the following subtopics: *Introduction to Area*, *Rectangle/Square*, *Triangle*, *Parallelogram* or *Trapezoid*. The app allows the student to investigate area properties of rectangles, triangle, parallelogram and trapezoid. The *Perimeter* component includes *Introduction to Perimeter*, *Rectangle* or *Rectilinear Figures.* Herein, a student can learn perimeter properties of rectangle or rectilinear figures. In the *Area and Perimeter* component, students find the area and perimeter of rectilinear shapes and construct rectilinear shapes of given area and perimeter.

There are three levels in the app, to reflect the pedagogical intention to enable students to develop deep understanding of area and perimeter, beyond knowing formulas by rote.

Explore. In this level, students learn the conceptual underpinnings of both area and perimeter. Under the topic *Area* and subtopics *Introduction to Area* and *Rectangle/Square*, students are shown a rectilinear shape then they are supposed to click on each unit square within the shape (Figure 1(a)) and are asked how many squares are enclosed in the figure. This way, they connect the idea of area to the measure of the surface inside the given enclosed region.

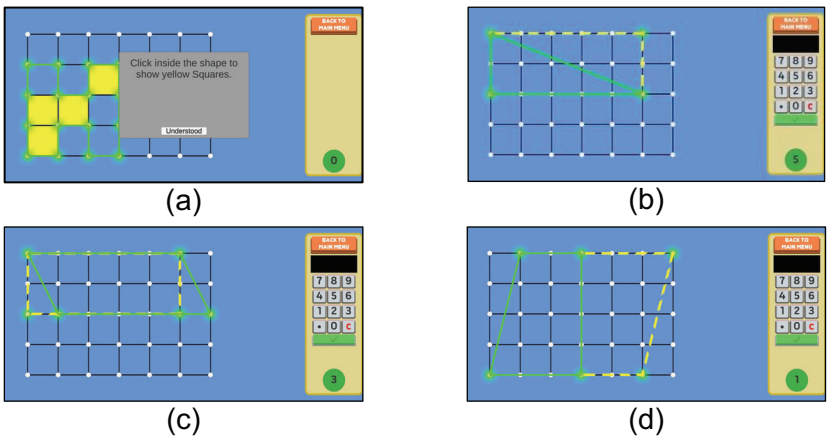


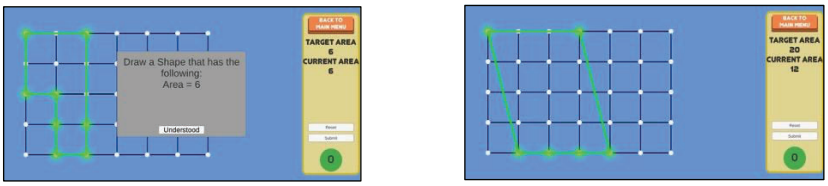
Figure 1. Screenshots of the app; Topic: *Area* and Level: *Explore.*

For the sub-topics of triangles, parallelograms, and trapezoids the aim of the *Explore* component is to allow students to learn the reasoning behind the area formulas. For example, for *Triangle*, a rectangle is first shown and then a diagonal is drawn (Figure 1(b)) to show that half of the rectangle is a triangle. This reinforces the idea that the area of a triangle is half the

area of a corresponding rectangle. For *Parallelogram*, an auxiliary line segment is shown (Figure 1(c)) to illustrate that translating the triangle at one end of the parallelogram to the other end would result in a rectangle. This reinforces the idea that the area of a parallelogram is the same as that of a rectangle with the same height and width. Finally, for *Trapezoid* (Figure 1(d)), a trapezoid (in green border) is shown and is duplicated (whole figure) and placed adjacent to the former so that the combined figure is a parallelogram. This reinforces the idea that the area of a trapezoid is half the area of a parallelogram with the same height and base. A score on the lower right corner of the screen allows the student to monitor his or her own progress and decide if he or she can choose another feature of the app.

Apply. Unlike the *Explore* level, in the *Apply* level, there are no extra steps, students are directly asked, "How many square units are in the figure?" At the *Apply* level, students use the ideas in the *Explore* component to determine the area of given geometric figures.

Create. In this level, students construct representations themselves, enabling them to develop higher-order thinking skills. Specifically, students are asked to draw a shape by clicking and connecting vertices to produce the required shape with a given area (Figure 2(a)). On the right side of the screen, the target area and current area are given. Thus, if a student constructs a shape with an incorrect area (Figure 2(b)), there is an instant feedback that provides an opportunity for the students to construct a new shape until they get one with the correct area.



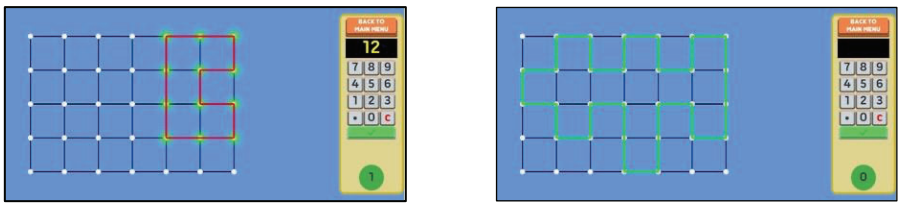
(a) (b)

Figure 2. Screenshots of the app, Topic: *Area* and Level: *Create*

Under the *Perimeter* option, the same levels (*Explore, Apply* or *Create*) are also available.

Explore. In this level, the students are asked to click on the edges of the shape and count the number of red edges such as in an example under *Rectilinear Figure* that is shown in Figure 3(a). When the correct answer is given, the app affirms that the shape has the given number as its perimeter. Through this, students connect the idea of perimeter with the number of edges around the shape.

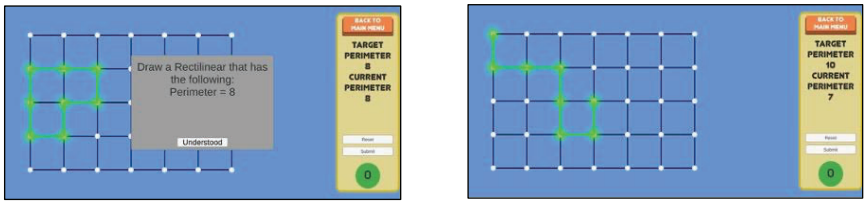
Apply. In this level, students must directly input the perimeter of the given shape (Figure 3(b)) using the ideas from the *Explore* component to be able to find the perimeter.



(a) (b)

Figure 3. Screenshots of the app, Topic: *Perimeter* and Levels: *Explore* (a), *Apply* (b)

Create. Here, students are tasked to construct a rectilinear shape with a given perimeter (Figure 4(a)). On the right side of the screen, both the target perimeter and the current perimeter are given. As the students add edges to form a shape, they will see that the current perimeter is updated, and this will guide them in constructing the correct shape having the desired target perimeter. For example, as shown in Figure 4(b), the target perimeter is 10 while the current perimeter is 7 and it is not possible to continue adding edges to construct a rectilinear shape having the target perimeter. Thus, students who meet such situations will construct new shapes until they successfully meet the target perimeter.

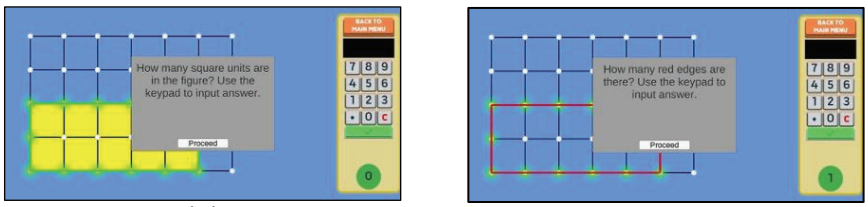


(a) (b)

Figure 4. Screenshots of the app, Topic: *Perimeter* and Level: *Create*.

When the topic *Area and Perimeter* is chosen from the Main Menu, students may perform tasks that involve both concepts, to help them attain the reasoning skills to distinguish between these two concepts (Huang, 2017).

Explore. Under the *Explore* level, students first click on each unit square within the figure to show yellow squares and then find the number of unit squares (Figure 5(a)). When the answer is correct, they now click on the edges of the shape to show red edges and then count them (Figure 5(b)). When the answer is correct, the app confirms that the area of the shape is the number of unit squares given and the perimeter is the number of red edges.

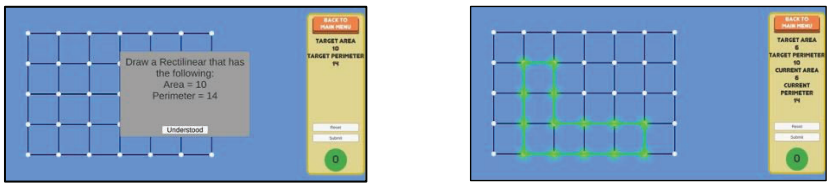


(a) (b)

Figure 5. Screenshots of the app, Topic: *Area and Perimeter* and Level: *Explore*

Apply. In this level, students directly input the area and perimeter of the given shape.

Create. In this level, students draw a rectilinear shape with the given area and perimeter (Figure 6(a)). There may be instances when students construct a rectilinear shape with the correct perimeter but incorrect area or correct area but incorrect perimeter (Figure 6(b)). The current area and current perimeter given on the right side of the screen provide the immediate feedback that will enable the students to construct new shapes until they successfully meet the target area and perimeter.



(a) (b)

Figure 6. Screenshots of the App, Option: *Area and Perimeter* and Difficulty Level: *Create.*

3.2 Game Design Factors

Creating an innovative instructional app in a game-like environment such as *Area and Perimeter* requires a sound framework on which its development can be based. Focusing on how the game is aimed at enabling players to make the leap from the concrete to the abstract, we used Shi and Shih's game-based learning (GBL) design factors (Shi and Shih, 2015) as a guide, apart from "sociality," which *Area and Perimeter* does not inherently feature as it is a single-player game.

The game goal is to develop an understanding of area and perimeter formulas. This is achieved via a combination of the abovementioned *Explore*, *Apply*, and *Create* difficulty levels, which constitute the game mechanism. The player interacts with the game by tapping squares to highlight areas, dragging between points to construct edges, and tapping a simple number

pad to provide answers to area questions. As mentioned above, players are free to select what concept (area or perimeter) and what shape to focus on; the *Explore*, *Apply*, and *Create* difficulties are also available for all these concepts from the beginning. Moreover, in the *Create* difficulty, players are tasked to construct any shape that has particular area and perimeter values, giving them autonomy and testing their creativity. Each concept, shape, and difficulty combine to form an inherently challenging level that requires the player to accomplish a task (e.g., highlight areas, tap edges).

While the *Area and Perimeter* app does not have a narrative by the strictest definition, it does feature a sense of progression through the various topics and difficulties. The game fantasy centered around an interactable grid, which is also the main medium with which the game provides sensation. The game's mystery arises from the variety of the topics and levels, as well as the randomness in the questions generated. These factors taken together give rise to the game value of *Area and Perimeter* as a learning tool for mastering abstract concepts such as area and perimeter formulas using concrete examples.

4. Integration and Use of the *Area and Perimeter* App

This section explores the use of the *Area and Perimeter* app as a pedagogical tool based on the RAT (Replacement, Amplification, Transformation) framework (Hughes et al., 2006). The app can replace the traditional approach of teaching area and perimeter without modifying the content or learning outcomes. For instance, teachers frequently ask students to calculate the areas and perimeters of hand-drawn figures of triangles, squares, rectangles and other quadrilaterals. These figures are now presented in the lattice configuration of the app. Finding the area or perimeter still must be done, but instead of doing it in a static way, geometric figures are now shown in a colorful and dynamic way. Teachers can use the app during drill and practice time.

Secondly, learning may be enhanced by the integration of the app since it can explain perimeter and area ideas with ease and efficiency. The lattice design accurately represents unit squares, which can help learners comprehend the conceptual underpinnings of area and perimeter calculations. This understanding is also possible since students engage in a variety of activities that the app can generate.

Finally, the app may be used to change instructional methods and the learning process. Teachers may conduct classroom activities that are more student-centered by using the app as a tool for group inquiry and projects that promote cooperation among students and provide a supportive learning environment. The *Create* option has the potential to improve student engagement and alter the way that students learn. Thus, teachers are encouraged to utilize this feature during class discussions and activity periods to expose students to questions about area and perimeter that aren't commonly asked.

Teachers can screencast to a smart TV or projector if students don't have their own devices. The proposed exercises can be completed by the entire class at the same time.

The app's three learning levels—Explore, Apply, and Create—can accommodate various learning demands of the students. While the levels on Explore and Apply can be utilized for remedial work, the level on Create is suitable for student enrichment activities.

5. Conclusion and Future Direction

This paper describes the features of the *Area and Perimeter* app designed to help students gain a better understanding of the notions of area and perimeter and help them make sense of the usual formulas associated with these concepts. The three levels of difficulty of the app leads students from basic exploration of the area or perimeter of polygons to application of these ideas in calculating these parameters, and finally to the creation of shapes with a given area or perimeter.

Efforts to improve numeracy and literacy among Filipino learners are even more relevant at this time considering the recognition by the Department of Education (DepEd) of

the Philippines that there have been setbacks in learning targets caused by school closures during the Covid-19 pandemic. The DepEd issued the *Adoption of the National Learning Recovery Program* (DepEd, 2023) to help address these setbacks. The *Area and Perimeter* app may be considered as a tool that can contribute to this recovery plan.

The *Area and Perimeter* app may be expanded to include the exploration of areas and perimeters of non-polygonal figures such as circles and other irregular shapes. This will further help students understand the concepts and not resort to sheer memorization of formulas. An avenue for future work would be the translation of the app into Filipino to make it more accessible to students in the Philippines. Finally, the authors plan to conduct further research to evaluate the effectiveness of the app in the learning of students.

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