Deployment of Mathematical Resources to a Philippine High School through a Community LTE Network

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Abstract: *In the Philippines, one challenge that continues to be faced by the Department of Education in bringing educational content in a blended learning modality is the lack of internet access of the learners. This paper discusses the distribution, through a community LTE network, of mathematical resources for Grades 7 to 10 to teachers and students of a particular high school in the Philippines. It also gives details on particular technological tools (mathematical applications) that were created to help the mathematical learning of students in a remote setting.*

1. Introduction

In the past two years of the Covid 19 pandemic, schools worldwide have adapted various modalities in teaching and learning. For the school years 2020-2021 and 2021-2022 in the Philippines, the Department of Education (DepEd) has called for a blended learning modality for schools in lieu of face-to-face instruction [1]. The problem lies in providing access to quality education to children who belong to households with limited or no access to the internet. In fact, based on the Philippine National ICT survey [2], only 17.7% of households have access to the internet. As such, the DepEd's blended learning approach focused largely on non-internet sources such as printed modules, radio, and television. Clearly, there is a need to explore alternative avenues for the delivery of information. Under a government-funded project *Mathematical Resources for Distance Learning Using Community LTE Networks* that started in April 2021, the authors collaborated with local DepEd school divisions to deliver mathematical content that included mathematical applications (apps), teaching guides/instructional videos, and performance tasks or activity sheets through community LTE networks.

Based on the literature, community LTE networks are small-scale local networks that are usually set up to address the connectivity needs in communities that are not reached by traditional telecommunication companies [3]. Community LTE networks have been successfully deployed in Bokondini, a mountainous region located in the Papuan highlands in Indonesia [3], and Oaxaca, an indigenous state in the southeastern part of Mexico [4]. In the Philippines, the possible use of community LTE networks has been considered and studied in [5]. More recently, community LTE network base stations have already been deployed in Philippine municipalities in Cavite, Rizal and Zambales [6].

There has always been a need to provide support for the mathematics education of Filipino learners. Even before the COVID-19 pandemic, the challenges in achieving the twin goals of mathematics education [7] are well-documented [8, 9]. To help ensure that distance learning takes place in the pandemic, the project carried out by the authors focused on designing mathematical apps, for dissemination, that showcased content on the following foundational concepts: place value, fraction number sense, and number sense strategies for Grades 1-6; integers, functions, geometry, trigonometry for Grades 7-10; and Statistics for Grades 1-11. The concepts are fully aligned with the official DepEd's Most Essential Learning Competencies (MELCs) [1] and with the existing literature on mathematical learning.

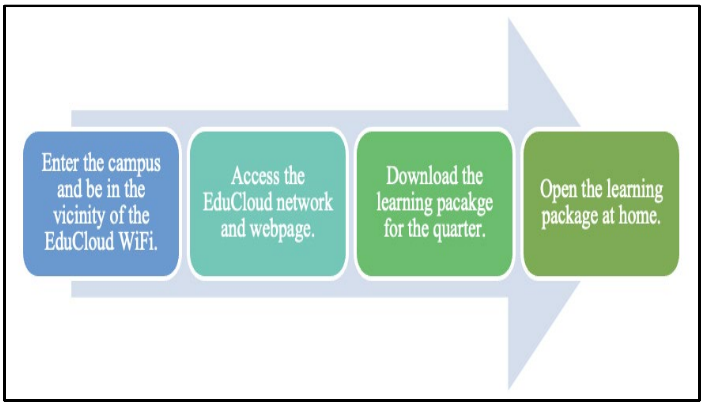
This paper documents the deployment of the mathematical resources of Grades 7 to 10 in school year 2021-2022 to a high school in Quezon City in the Philippines using a community LTE network.

2. A Local Network for Distribution of Educational Resources

During discussions by the authors with one school division in the country- DepEd Quezon City, it was agreed that for the deployment of the mathematical resources through a community LTE network, several factors will be considered in choosing a public school to set up the network. These factors were: i) there should be a substantial percentage of the student population that did not have ready access to the internet; and ii) faculty members and students would be ready for the adoption of the use of technological tools in teaching and learning mathematics, respectively. A choice was Lagro High School in Quezon City, within the country's capital region. In general, teachers in Lagro High School had experience in teaching with technology, such as google classroom (which was carried out in a small number of classes that had internet connectivity) and had exposure to some mathematical applications. Moreover, at the start of the pandemic, the Quezon City local government provided every public-school student of Quezon City with tablets for use to help them access educational materials. Given the circumstances and the set-up of distance learning in Lagro High School for the school year 2021-22, it was deemed beneficial to set up a local community LTE network at the Lagro High School campus.

The mobile cloud network architecture used is called *EduCloud* that has been developed by the Ateneo Innovation Center and that allows for a resilient distribution of educational content for remote asynchronous learning [10]. Initially deployed at Kaong National High School in Silang, Cavite in the Philippines, EduCloud "offers a low-cost, low technology requirement, easily deployable and wide range of compatibility systems for the distribution of open educational resources" [10, p. 402] and "initial performance tests show that the network architecture is efficient in data transfer and accommodating synchronized usage." [10, p. 402]. Collaboration of the authors with the EduCloud team, DepEd Quezon City, and Lagro High School led to an agreement of an installation process of one to two months before the start of the school year, in September 2021 (Figure 2.1(a)). As parents/students would go to school to get hard copies of modules and other learning materials at the start of every quarter of the school year, it was agreed that the mathematical resources would be organized by academic quarter and uploaded into EduCloud in preparation for the school visits. The general process followed by parents/students in accessing resources via EduCloud is shown in Figure 2.1(b).

(a)



(b)

Figure 2.1 (a) The EduCloud network setup in an office strategically located in Lagro High School for optimal use; and (b) the general process followed by parents/students when accessing EduCloud.

To guide the parents/students, signages were placed at appropriate locations (i.e., within the vicinity of the EduCloud WiFi) in the Lagro High School Campus. The signages contained instructions, in both English and Filipino, for accessing EduCloud, which involved two steps: (1) connecting to the EduCloud WiFi network using the provided password; and (2) opening the EduCloud webpage by typing in the provided address in any browser in the user's device. Once in the EduCloud webpage, a parent/student simply had to select the learning package corresponding to the correct grade level and quarter. The selected package would then be downloaded as a single compressed file, which reduced the time spent by the user compared to downloading files one at a time. In this way, personal interactions and possible COVID-19 transmissions between individuals who visit the campus could also be reduced.

Before the start of the school year, in August 2021, the authors conducted *Project A.L.A.M. (Ateneo-Lagro HS using Apps from Mathplus Resources)*, which was a capacity-building webinar for the mathematics teachers on the use of the technological tools. The webinar had parallel sessions per grade level where the mathematical resources were introduced. In addition to demonstrating how to play the apps and games presented in each grade level package, the authors offered suggestions on how to incorporate them in teaching and assessment. During the webinar, the EduCloud team also gave a talk on the EduCloud set-up in the school and how to download the resources in the math package. Shortly after, a separate webinar was also given by the teachers and school administrators for parents/students. When classes started, authors were assigned to different grade levels which ensured constant communication with the teachers to address their questions and other needs. Follow-up training and meetings were held as necessary which were also occasions for getting feedback from the teachers on the use of the mathematical resources. For newly developed apps, comments were solicited from teachers and students for the improvement of app functionalities.

3. Mathematical Resources

The mathematical resources deployed through the EduCloud system were selected and developed following the competencies identified by the Philippines' Department of Education [1]. Teachers from Lagro High School also specified least mastered skills for their students in the previous school years, e.g., 2020-2021. These are learning outcomes that proved difficult to achieve and provided valuable insight as to what topics required mathematical resources that could promote mastery and student engagement especially in remote learning.

The mathematical apps consisted of Android apps as well as Geogebra applets. These were organized into packages (i.e., a single compressed file) based on grade level and quarter (Figure 3.1). There were two versions of the packages, one for teachers and another for parents/students. In addition to the mathematical resources, guides (with English and Filipino versions) for installing apps and for running Geogebra applets were also made available (Figure 3.2). Moreover, some common apps (e.g., a scientific calculator) were included in each package. It was important that teachers were guided as to how to approach the subject matter with the use of the apps, so teaching guides and instructional videos accompanied the mathematical apps for the teachers.

An interested reader is invited to visit https://mathplusresources.wordpress.com/, the official website of the Ateneo Mathplus Resources Laboratory, where the mathematical resources can be downloaded through the internet. Some apps contained in the learning packages are described in this section to provide the pedagogical bases behind their design, and to highlight the important features available within the apps.

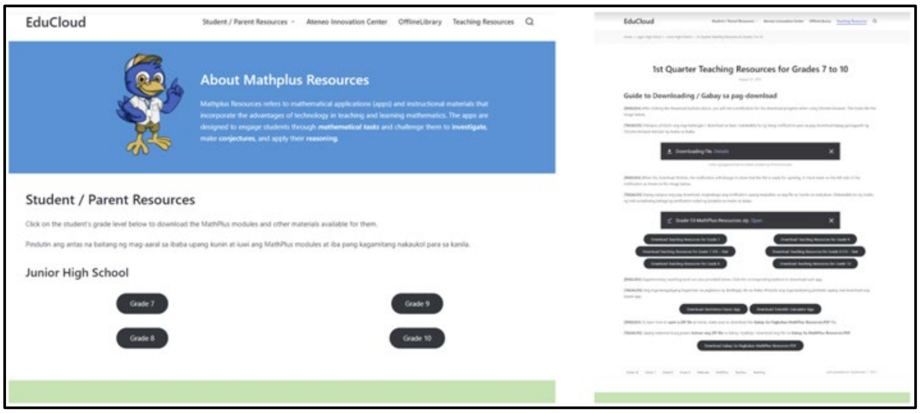


Figure 3.1 The EduCloud webpage showing organization of the mathematical resources

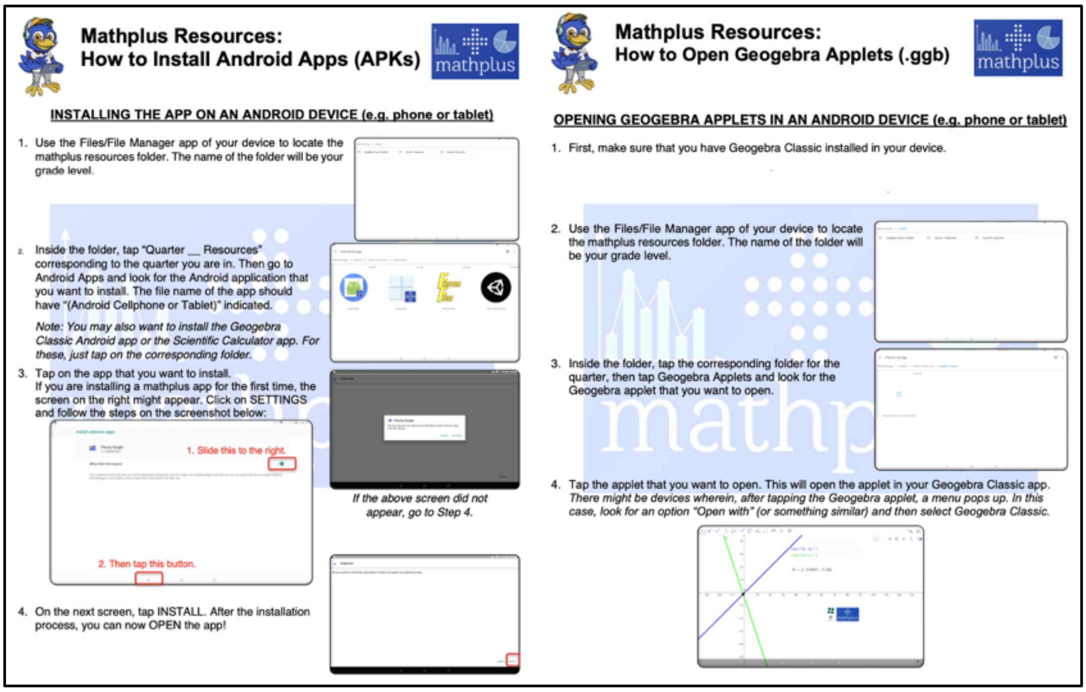


Figure 3.2 Sample instructional guides

One essential element was providing apps on number. A sense of number magnitude is a foundation for knowledge of the real number system [11]. The number line is a natural representation of each number as well as the sequential relationship between numbers [12]. Arranging real numbers on a number line is one of the basic learning competencies expected of high school students [1, 13]. To provide students with a variety of activities on the number line, two apps (*Catch the Carrot* and *Ordering Game*) were included in the package for Grade 7 (Figures 3.3(a)-(c)). In *Catch the Carrot*, a number is flashed on the screen and the player must estimate the location of this number on the number line (Figure 3.3(a)). There are options to work with whole numbers, fractions, decimals, integers, or irrationals. In *Ordering Game*, numbers appear one at a time on the screen. The player must drag each number to the line and the goal is to complete a row of ascending numbers (Figure 3.3(b)). Once a number is placed on the row, it cannot be moved anymore. A player may fail to complete the row if the next numbers would not fit in the vacant slots within the given number of moves shown at the bottom of the screen. In both games, the player must apply estimation skills and strategic thinking to complete the task within the time or number of chances given. Activities in the printed modules given to students by their teachers are supplemented by exercises using the two apps. For example, an activity in the Grade 7 printed module [13] asks students to estimate the location of the square root of a number on the number line. This has a parallel activity in the *Catch the Carrot*. Thus, students can keep on practicing using the game (Figure 3.3(a)).

The ability of high school students to factor polynomials is a “fundamental skill in solving problems in mathematics that scaffolds up leading to achievement in college level mathematics” [14, p. 116]. Many other math concepts such as simplifying or performing operations on rational expressions, and finding roots of polynomials or solving inequalities, rests on the ability of students to factor polynomials correctly. The use of technological tools to assist in developing the skill of factoring polynomials in an interesting and engaging way becomes even more critical in a remote-learning environment.

(a)

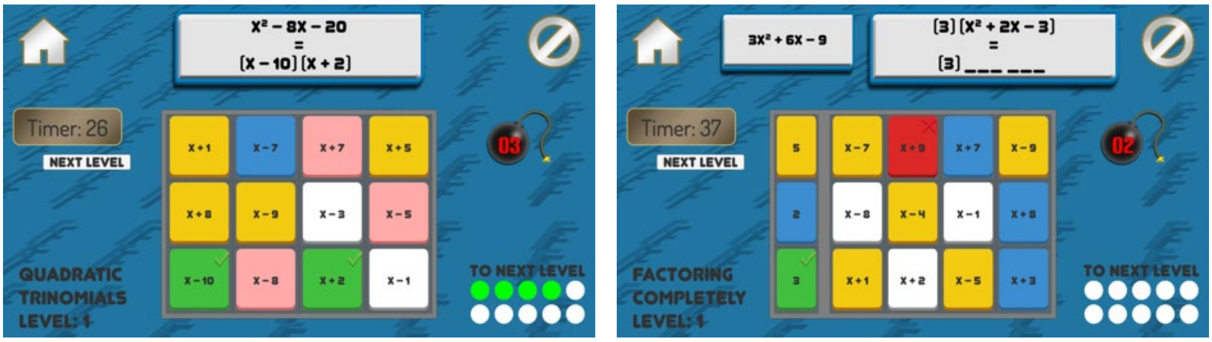
(b)

(c)

Figure 3.3 (a) Activity on number; screenshots of (b) *Catch the Carrot*, (c)-(d) *Ordering Game*

In view of the following learning competency "factors completely different types of polynomials (polynomials with common monomial factor, difference of two squares, sum and difference of two cubes, perfect square trinomials, and general trinomials)" [1, p. 230] for Grade 8 students, an app named *Factor Fuse* was developed. Students are given different types of polynomials to factor. The app contains tasks for factoring the highest common monomial factor, factoring a quadratic or cubic polynomial, or factoring a polynomial completely. Upon being shown a polynomial at the top part of the screen, a student chooses a factor of that polynomial. Sample screenshots of what appears when a student factors a quadratic trinomial or factors a polynomial completely are shown in Figures 3.4(a) and (b), respectively. A bell or buzzer sound rings depending on whether the student chose the correct factor or not. This feedback is important to a student who is still gaining the skill of factoring and needs some manner of prompting or direction on how to proceed. Upon hearing the bell sound, the student then chooses another factor from a table of polynomials. The student continues to do this until the polynomial is completely factored.

Factor Fuse is intended to be played by a student with minimal or no supervision by a teacher. Playing the app for practice even in a remote learning environment helps to strengthen a student's factoring skills.



(a) (b)

Figure 3.4 Screenshots on (a) factoring quadratic trinomial; and (b) factoring completely

In the needs assessment phase with teachers, it was determined that one of the challenging topics to teach was proving geometric theorems. It was very difficult for students to formulate parts of a two-column proof. Moreover, it would help to arrive at a technological tool that would allow the students to visualize the concepts behind every step of the proof and serve to assess learning remotely. For this reason, the authors designed apps for proving, such as *Two Column Proof-Parallelograms* (Figure 3.5(a)). This app addresses the following competencies for Grade 9: i) "understanding key concepts of parallelograms" [1, p. 236] and; ii) "determine the conditions that make a quadrilateral a parallelogram" [1, p. 236]. To navigate a proof, the student clicks the "Next" button (Figure 3.5(b)). A line of the proof appears, and the response is entered in the blank provided. To visualize a statement/phrase, the right arrow button is clicked; and an animation occurs. For example, for a proof that requires a reasoning involving the Side-Angle-Side (SAS) congruence, the side, included angle, side and the corresponding triangle are animated, as a guide to the students. The teacher may opt to discuss the proof of a theorem in synchronous class after the students have tried their hand on the proof, or perhaps use a theorem as an example, instead of giving it as an exercise.

In the *Two Column Proof* app, the student may save the answers to the proof. Once he/she has completed answering all the items, and saved the work, the answer key appears (Figure 3.5(c)-(d)). The student may opt to answer the activity again, even after he/she has viewed the answer key. Upon saving, there will now be another file saved. See Figure 3.5(e) where three files have been saved for one activity. The teacher can track (by asking the student to give a screenshot of this page of the app) if the student has practiced several times. When asking one proving question in an exam, the teacher can check from this screen if the student has more than one attempt in doing the exercise.

As the app on two column proof on parallelograms was quite helpful for the teachers and students, other similar apps were developed to address Grade 9 learning competencies on trapezoids and kites [1]. Figure 3.5(f) shows a sample proving activity on kites.

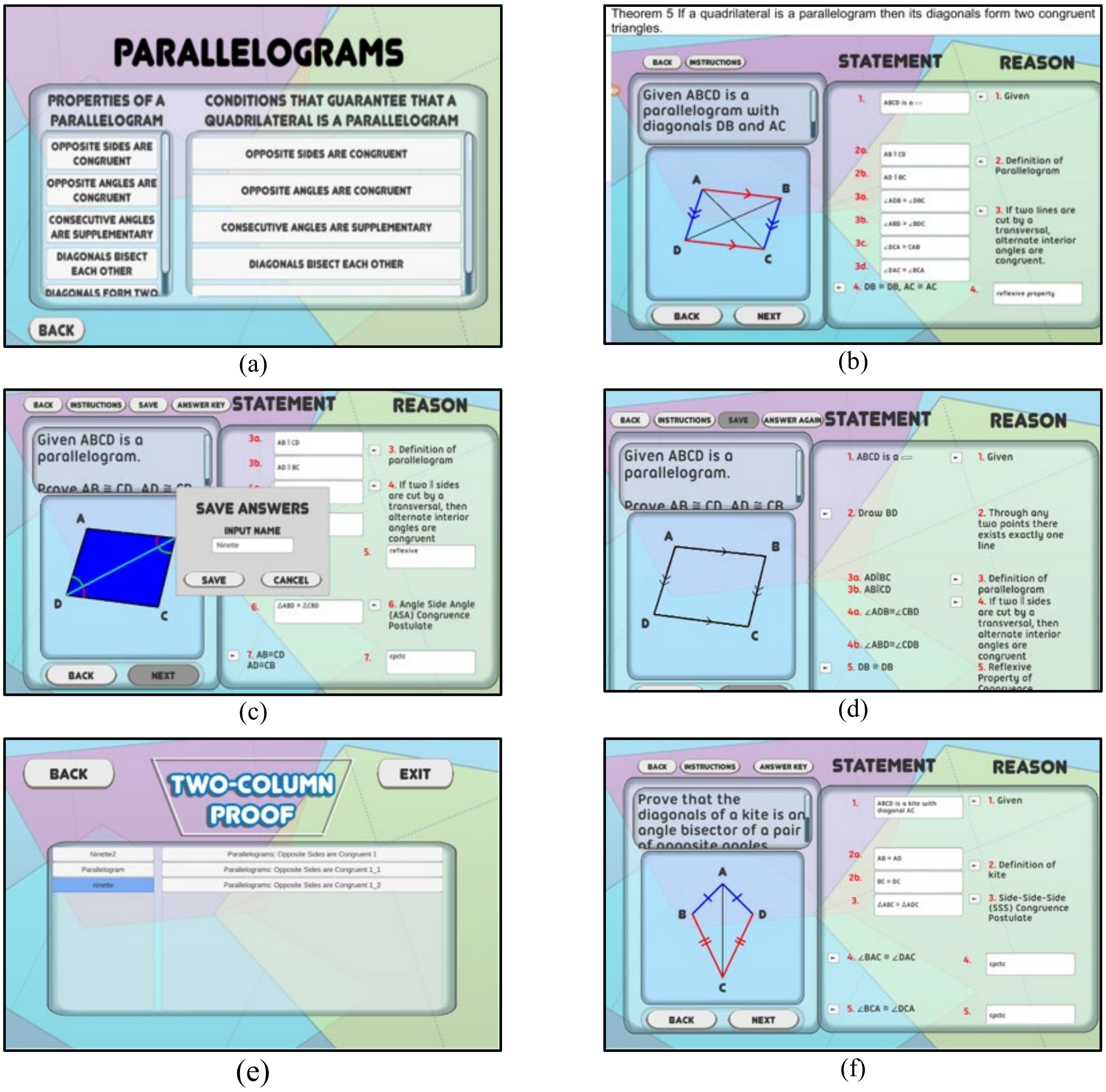
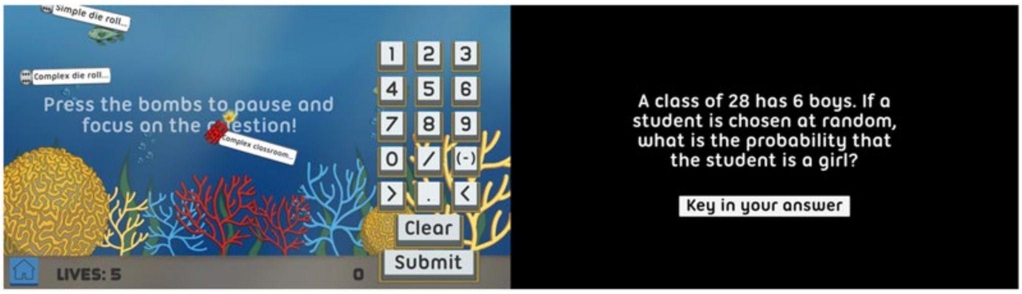
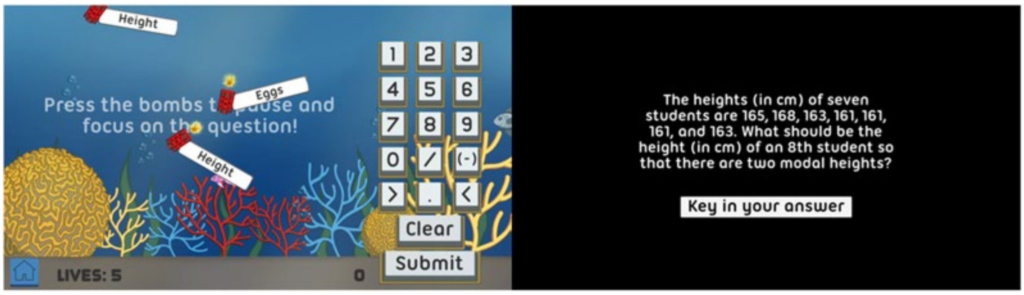


Figure 3.5 Screenshots of (a) menu on parallelograms; (b) sample proving exercise on a property of a parallelogram, namely, "the diagonals of parallelograms form two congruent triangles;" (c) when saving the proof; (d) sample answer key; (e) three different files showing proofs of the same theorem; and (f) sample proving exercise on kites

For Statistics, the least mastered skills included the computation of descriptive statistics, including measures of variability and central tendency, for grouped and ungrouped data. The authors decided to create two apps: *Just Keep Solving* for the mastery of concepts in probability and statistics related to the aforementioned topics, and *Statistics* for the computation of descriptive statistics for and the visualization of datasets. In *Just Keep Solving*, problems in probability and statistics are shown as banners falling towards the ocean floor. Tapping on a question banner pauses the movement of all banners on screen, allowing students time to carry out their computations. Banners will fall as students key in their answers, adding tension to the game and encouraging students to think quickly and recognize question patterns. The game interface and sample questions are shown in Figure 3.6. The app features two levels for probability and three levels for statistics, covering topics ranging from random variables and probability distributions to measures of central tendency and variability. The levels on probability are focused on the following learning competencies for Grades 8 and 11: i) “finds the probability of a simple event,” [1, p. 234] ii) solves problems involving probabilities of simple events,” [1, p. 234] iii) “illustrates a probability distribution for a discrete random variable and its properties,” [1, p. 540] iv) “computes probabilities corresponding to a given random variable,” [1, p. 540] and v) “solves problems involving mean and variance of probability distributions” [1, p. 540]. Meanwhile, the statistics levels cover the following competencies for Grade 7: i) “calculates the measures of central tendency of ungrouped… data,” [1, p. 230] ii) “uses appropriate statistical measures in analyzing and interpreting statistical data,” [1, p. 230] and iii) “calculates the measures of variability of… ungrouped data” [1, p. 230].



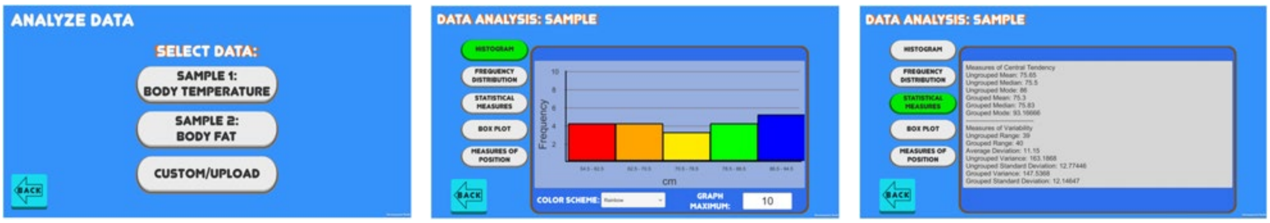
(a)



(b)

Figure 3.6 Screenshots of the *Just Keep Solving* interface and sample questions for (a) probability and (b) statistics

The *Statistics* app, meanwhile, provides tools for computing measures of central tendency and variability, as well as visualizing data. As shown in Figure 3.7, students can use either the app’s built-in datasets or their own. In addition to computed statistical measures for grouped and ungrouped data, analysis includes a frequency distribution table, a histogram, and a box plot.



(a) (b) (c)

Figure 3.7 Screenshots from the *Statistics* app showing (a) the data selection screen; (b) a sample histogram; and (c) computed statistical measures

The dynamic geometry feature afforded by the Geogebra software provides opportunities for students to explore, discover, prove conjectures and apply mathematical concepts. Learner's visual and conceptual abilities in mathematics are improved through explorations via Geogebra applets. Moreover, the color, graphics, and interactivity of GeoGebra applets can catch and hold the attention of the students and motivate them to learn and make meaning of their learning [15]. Because of these affordances, Geogebra applets were identified and provided for teaching particular topics. The Trigonometry applets shown here are examples. The applets provide dynamic worksheets and opportunities for exploration which support development of procedural and conceptual knowledge of trigonometric ratios.

One applet (Figure 3.8) allows students to determine the sine, cosine, and tangent of acute angles in the context of a right triangle. Given the sides of a right triangle, students input the values of the desired trigonometric ratio. Immediate feedback is given whenever the correct answer is given. Pressing the NEW PROBLEM button creates another problem to solve. Thus, the applet provides numerous practice exercises which facilitate mastery of the subject matter. Given this nature, it replaces the list of exercises that is normally given to students. It can conveniently be used as a formative assessment in class.

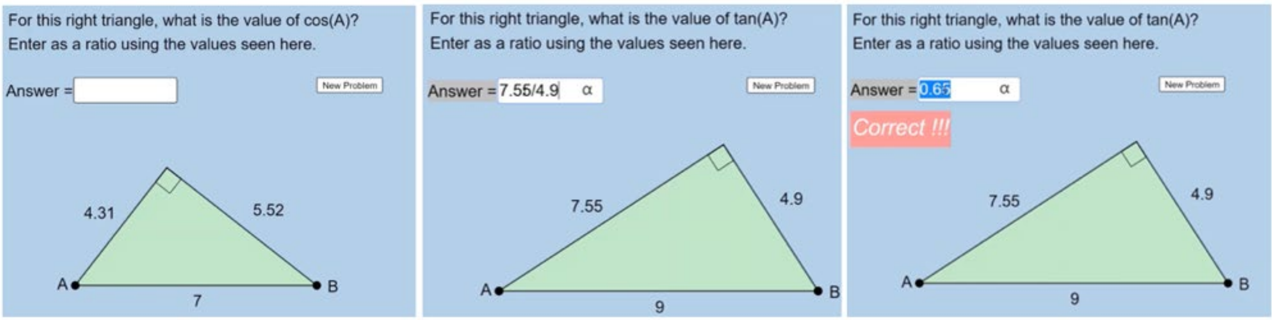


Figure 3.8 Screenshots pertaining to exercises on determining trigonometric ratios

The second applet (Figure 3.9) illustrates the conceptual meaning of the sine, cosine and tangent ratios when defined in the context of a right triangle. If the sine (or cosine) ratio button is pressed, an animation is activated showing the opposite side (or adjacent side) of the angle moving towards the hypotenuse. When it coincides with the hypotenuse, an explanation of trigonometric value is displayed at the upper portion of the screen. If the tangent ratio button is chosen, the animation shows the opposite side moving towards the adjacent leg. A similar explanation is presented at the end of the animation.

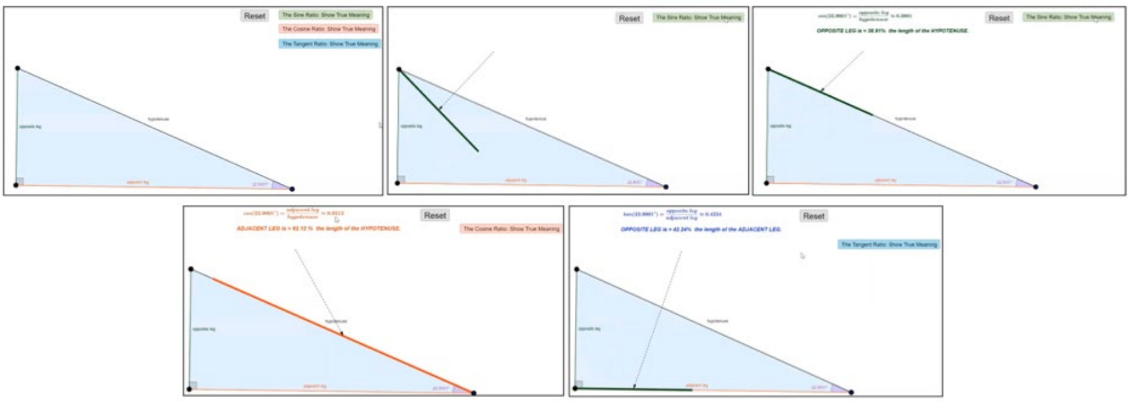


Figure 3.9 Screenshots: an animation of the conceptual meaning of the trigonometric ratios

Finally, the third applet (Figure 3.10) provides an exploratory activity for students to understand the definition and properties of the sine, cosine, and tangent ratios. It allows the student to create triangles of different sizes by dragging the vertices of the triangle. Moving point *A* (Figure 3.10(a)-(c)) adjusts the size of the triangle. In doing so, students can observe that the values of the trigonometric ratios do not change even if the lengths of the sides are different. This can lead them to understand that the values of the trigonometric ratios do not depend on the lengths of the sides if the angles of the triangle remain constant. However, moving point *C* (Figure 3.10(d)-(e)) transforms the triangle with different angles. The students can observe that the values of the trigonometric ratios are no longer constant. The affordance of dragging the vertex and creating dynamic transformations of the triangle provides opportunities for exploratory activities leading to visual discovery of the properties of the trigonometric ratios. It transforms figures which is not possible in the traditional paper-and-pencil approach [16, 17] (as cited in [15]). Such engagement with the applet can provide meaningful learning and deeper understanding.

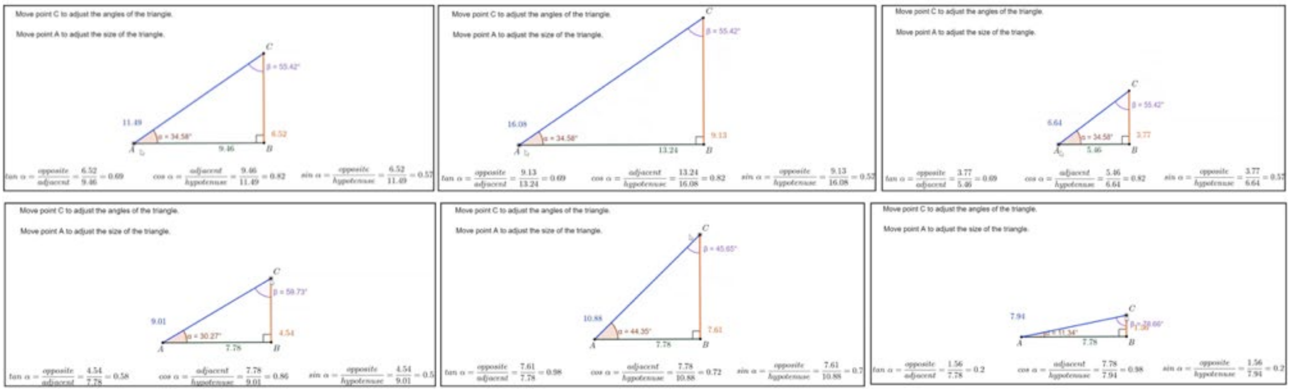


Figure 3.10 Screenshots: (a)-(c) Transformed triangles by dragging vertex *A* with constant values of the trigonometric ratios; (d)-(e)Transformed triangles by dragging vertex *C* resulting to different trigonometric ratios

4. Remediation Program

To help students who have difficulty in mastering mathematical concepts and skills, a remediation program named Academic Remediation on Operations on Numbers (ARON) was implemented in Lagro High School. Specifically, this intervention program was designed for Grade 7 students who have yet to gain mastery of computational skills involving fractions, decimals, and integers. These students were selected based on the results of a diagnostic test administered at the beginning of the school year. Through the community LTE network, three mathematical apps were deployed to the group of students and teachers involved in ARON: *Number Puzzles*, *Numberger* and *AlgeOps*.

Number Puzzles (Figure 4.1(a)-(b)) contains a series of problems involving the four fundamental operations. These problems involve numerical expressions with some unknowns. The expressions may involve whole numbers, integers and even polynomials. *Numberger* (Figure 4.1(c)-(d)) includes an option involving equivalent fractions. Set in a game-like environment, students identify which fractions are equivalent to a given fraction. These apps were chosen by the authors in coordination with Grade 7 teachers handling the remediation program. The teachers asked for apps that will provide more opportunities for students to practice and master the foundational mathematics skills. *AlgeOps* (Figure 4.1(e)-(f)) provides students with visualization of integer operations using two models: colored counters and number line. Positive and negative integers are represented by green and red counters, respectively. Students can relate the operations of addition and subtraction of integers by inputting an appropriate number of counters and seeing how the number of counters change because of the operation. The student then indicates the answer by moving a marker to an appropriate position on a number line.

A survey via Google Form that aimed to evaluate the apps in three areas was given to students and teachers: (a) ease of use; (b) gameful experience and (c) alignment with learning objectives. Results indicated a positive response from students and teachers. Majority of the students had no difficulty using the apps. Students found the app useful in understanding the lesson and solutions. The apps also helped them find the answers easily and quickly. They also noted that the apps provided a lot of opportunities for practice. Moreover, the teachers found the apps useful in helping the students stay motivated and engaged throughout the lesson. They also commented that the numerous exercises provided by the apps helped the students master the foundational skills in mathematics.

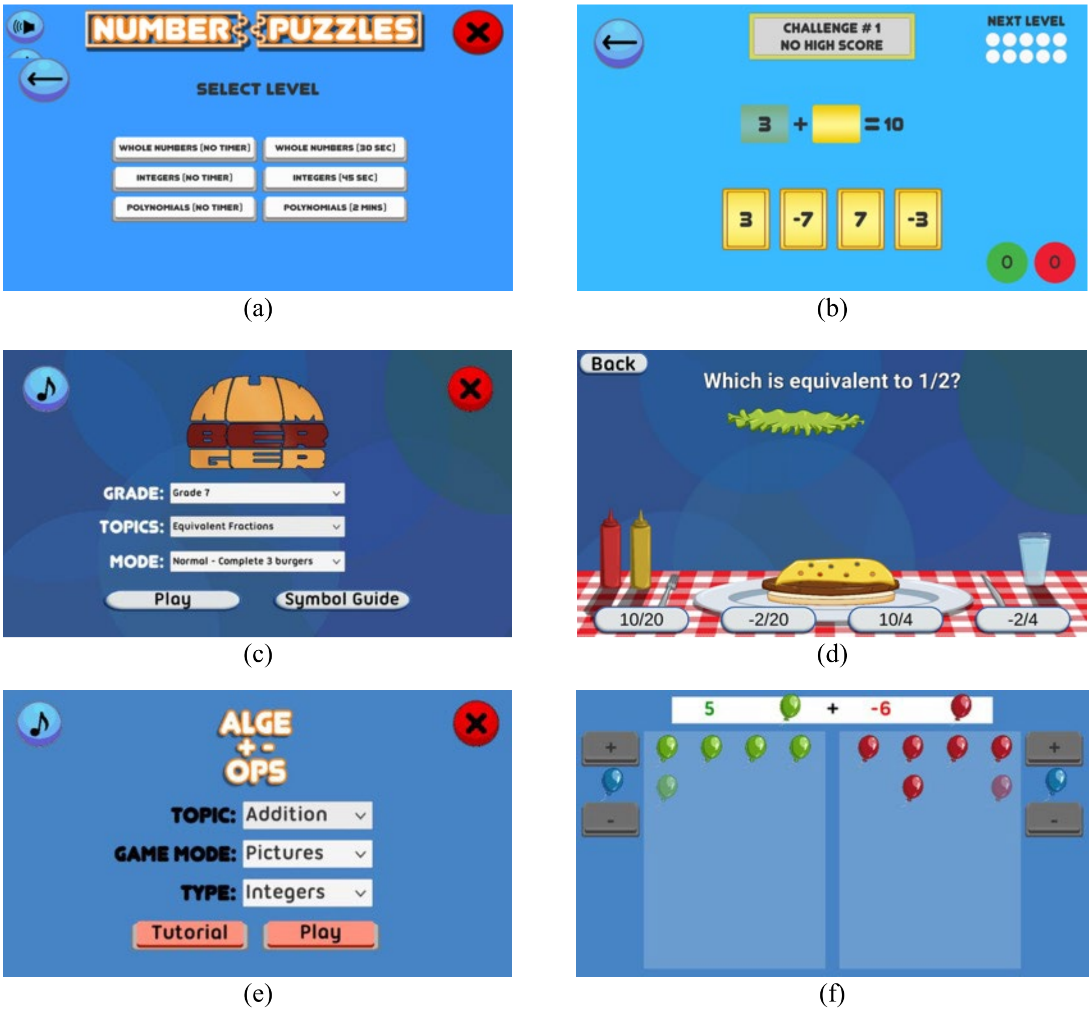


Figure 4.1 Screenshots from (a)-(b) *Number Puzzles*; (c)-(d) *Numberger*; and (e)-(f) *AlgeOps*

5. Challenges

The use of the community LTE network EduCloud was intended to offset some of the challenges associated with distance learning in the Philippines, where internet access is not guaranteed [2]. However, the implementation of EduCloud is not free from challenges.

The main challenge pertained to the process of downloading the files from the community LTE network. The IT team of DepEd Quezon City had earlier installed safety measures on the tablets, preventing students from downloading content from unlisted sources. The students' tablets had to be re-configured to allow access to the EduCloud network. A second reason was that the files in the learning packages were unfamiliar to parents and students. Parents who were more familiar with technology had more success and were better able to find solutions while others needed more guidance. While parents could successfully download the files from the EduCloud framework in the school premises, they could not install the files on their own. Many parents also had to be informed about the nature of files–GeoGebra vs Android apps, for example. Further, since some of the apps are available in PC or Android versions, there was a need to inform parents to install the correct files in their device. Teachers had to create detailed instructions and infographics to guide parents and students, especially on downloading and installing the Geogebra apps.

A second challenge was due to physical access to EduCloud in the network site amidst protocols related to the pandemic during some of its peaks, such as in January 2022. During such times, parents could not access the materials and it was also difficult for IT school personnel to assist, given strict health safety protocols. Fortunately, when COVID-19 cases leveled off or decreased, safety measures were eased, and parents could travel to the network site and download the packages. Further, since the packages were organized according to academic quarters, then parents needed to access the materials only four times in a year.

A third challenge related to the apps themselves. Since this is an ongoing project, new apps are undergoing preliminary testing, and feedback from users (teachers, parents, and students) continue to be gathered. For example, feedback on the Proving apps in geometry showed that the apps provided helpful visualizations of the proving process, but additional markings in the diagrams could clarify some of the given statements in the proving tasks.

6. Conclusion and Future Direction

Achieving the goals of mathematics education is a perennial challenge [9], and this has been made even more difficult due to the sudden shift in learning modalities due to the pandemic. Inconsistent access to stable internet forced teachers and students to utilize non-Internet sources such as printed modules, radio, and television. However, mathematical technological tools cannot be deployed through such media. This project demonstrated that through a community LTE network, mathematical apps can be shared even without the internet. To maximize the learning potential of these apps, they were organized according to academic quarters to help the users select the important apps they needed to learn the expected competencies. Further, the apps came with teaching guides and clear instructions for downloading so that teachers and parents could rightfully guide the learners even in a remote setting.

Proper deployment of the material was achieved through a combination of research-based content and the commitment of DepEd school divisions, IT personnel, and teachers. The dedication of parents in making sure the material got to their children was also a big factor in success of deployment. These were needed to address challenges that would normally arise in such projects. The authors would continue collaborating closely with schools to generate more feedback and gather empirical data on the extent to which the apps affect student learning.

There are more challenges to face in the coming school year. One is on further remediation, as DepEd has identified more students who had not met the learning competencies required of their grade level in the past two years of the pandemic. Moreover, even as more schools expect to offer onsite classes, there are students who would continue remote learning modality due to health issues. Discussions on how the mathematical apps as well as the community LTE network will be used to help address these challenges are ongoing with the authors and particular DepEd school divisions.

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