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Development of a mobile ten frames app for Philippine K-12 schools

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Abstract: This paper reports on the *Quick Images* app, whose design framework is informed by research on ten-structured thinking and gamification principles. Inclusivity was also a major consideration, especially in the context of a developing country. Thus, the app was made freely available and required only moderate system requirements. Pilot studies revealed that the app has the potential to promote children's ability to see two-digit numbers in relation to tens and ones, which is a major goal of elementary school mathematics. Collaborations with the Philippine Department of Education to ensure the app's sustained use are also discussed.

Keywords: Mobile math apps, mobile technology, ten frames

1. Introduction

Current mathematical education research emphasizes the importance of critical thinking and problem solving, and these form the twin goals of Philippine mathematics education (Department of Education [DepEd], 2016). However, Filipino children in the elementary grades often gain only a superficial understanding of mathematics (Verzosa, 2015a). Mathematics is learned by memorizing rules or procedures, with little understanding of number sense, which is a prerequisite for learning more advanced mathematical concepts (Siegler & Lortie-Forgues, 2014). Additionally, elementary school teachers even with training in elementary mathematics, may not be able to immediately translate such training to the classroom (Verzosa, 2015b). A team of mathematicians and mathematics educators with the support of the Philippine Department of Science and Technology - Philippine Council for Industry, Energy and Emerging Technology Research and Development (DOST-PCIEERD), came together to create mathematical mobile applications (apps) for Grades 1 to 6 Mathematics to address the aforementioned issues and concerns (De Las Peñas et al., 2020).

The apps integrate current mathematics education research in its design. These tools were based on what had been learned from cross-national large-scale research projects (Bobis et al., 2005). Further, the representations in the app were digital versions of concrete materials that had already been pilot-tested in classrooms, using traditional (paper) materials (Verzosa, 2015a, 2020). In this intervention, elementary school pupils who were exposed to number sense ideas over 8-10 two-hour informal sessions posted gains in place value knowledge. It is anticipated that a more frequent and sustained exposure to number sense ideas using these digital tools would lead to larger gains.

In addition to the aforementioned solid pedagogical and empirical basis, the apps were designed to be easy-to-use and easy-to-play; and are engaging and interactive. Thus, the apps can be used even with minimal supervision, and are very apt for student-centered or remote learning. Moreover, through constant play and exposure to the apps, students' understanding of mathematical concepts is enforced. By playing the game, children develop a better understanding of the math principles involved. To make the apps accessible to public and private school children and teachers all over the country, the apps were made free and were created to run on mobile technology with moderate system requirements.

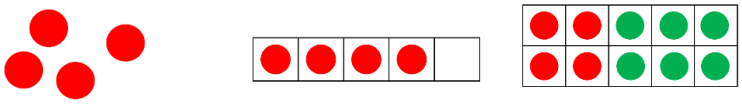
This paper presents a focused look on the development of *Quick Images*. This app aims to promote mastery of addition and subtraction facts, which is an official learning outcome in the early elementary grades. Moreover, even Grades 5 or 6 children who have poor number sense may also benefit from the visual representations offered by the app (Young-Loveridge, 2002). Its design was

informed by a framework based on ten-structured thinking, which is an essential conceptual advancement in the elementary grades (Fuson, Smith, & Lo Cicero, 1997).

2. Ten-structured Thinking

Ten-structured thinking, or the ability to think of 2-digit numbers in terms of tens and ones, is one of the major objectives in elementary mathematics (Fuson, Smith, & Lo Cicero, 1997). It is a "big idea" because it is connected to and is a foundation for many other mathematical concepts, and provides an organizational structure (Siemon, Blecky, & Neal, 2012). Unfortunately, many children continue to rely on counting by ones even in the upper elementary grades (Verzosa, 2015a; Young-Loveridge, 2002).

A child may conceptualize a number, say four, as a set of dots (Figure 1a), but this conception does not elucidate a number's relationship to five or ten. A stronger conceptualization occurs when a number is anchored on five or ten, and this is naturally demonstrated by five-frame and ten-frame manipulatives (Figure 1b and 1c). Here, it becomes clearer that four is one less than five (Figure 1b) or that four and six make ten (Figure 1c). In a study by Young-Loveridge and Bicknell involving children of ages five to seven, it is reported that the use of five- or ten-frame structures help in identifying groups of ten. (Young-Loveridge & Bicknell, 2016). Indeed, these aids have been recommended as effective visual materials for promoting ten-structured thinking among young children (McGuire, Kinzie, & Berch, 2011; Murata & Stewart, 2017), supplement intervention for upper elementary grade children who had not mastered the basic addition and subtraction facts. These manipulatives were the primary instructional material utilized by the app described in this paper.



(a) (b) (c)

Figure 1. A sample arrangement presented (a) randomly, or through a (b) five-frame or (c) ten-frame manipulative

3. The *Quick Images* App

A teaching strategy that can maximize the potential of the five-frame and ten-frame framework is called "quick images" (Clements, 1999). A picture of five frames or ten frames is shown quickly, while children call out the number shown. Because the images are flashed quickly, children are trained to naturally develop counting by tens (or groups) instead of by ones. Some apps that display ten frames already exist. However, in most of these apps, the ten frames remain shown on the screen and children can count the dots one by one, so the development of more sophisticated strategies is not promoted. There is one GeoGebra app (Ulbright, n. d.) where ten frame patterns are flashed on the screen. *Quick Images* improves on this app by flashing ten frames and other dot patterns through a sequence of tiered difficulty levels that develop addition and subtraction strategies.

3.1 Pedagogical Design

Broadly, *Quick Images* presents some dots on the screen (Figure 2). The dots disappear after 0.5s, 1.5s, or 2.5s, depending on the speed option chosen by the user. The goal is to determine the number of dots shown, and to answer as many tasks as possible within 30 seconds. *Quick Images* offers 66 levels or challenges whose sequence is determined pedagogically. In the most basic levels, pictures of objects are shown (Figure 2a). Next, five frames with pictures of objects are presented (Figure 2b), followed by the more abstract five -frame (Figure 2c). The next set of challenges includes ten frames (Figure 2d), double ten frames (Figure 2e) and numerals (Figure 2f).

Aside from the increasing complexity of the visual representations, the sequence of questions follows a developmental approach as well, with each level focusing on a specific strategy. For example, one challenge focuses only on doubles patterns (Figure 3a). The goal is to help children master the doubles facts so that they can apply this knowledge to answer near-doubles facts (Figure 3b). Thus, *Quick Images* is intended to facilitate a strategy for answering a near-doubles fact such as 6 + 7 by applying a doubles fact: (6 + 6) + 1 (Van de Walle, Karp, & Bay-Williams, 2015). The general goal is to prompt students to develop thinking strategies especially because mathematics education in the Philippines is often characterized by imitative or superficially learned strategies (Van den Berg, 2009).

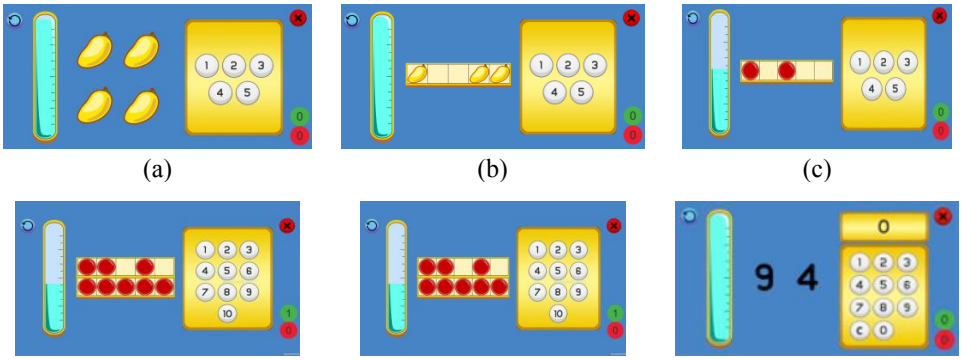


Figure 2. Increasing abstraction in ten-frame tasks.

Figure 3. Doubles and near-doubles strategies developed by *Quick Images*.

3.2 Gamification Features

Playing video games remains to be a popular entertainment activity, especially among the youth. In the Philippines, it is estimated that there are around 40 million gamers, 75% of whom play games on a mobile device (Elliot, 2020). Coupled with the sudden shift to online or distance learning due to the COVID-19 pandemic, it is valuable to use the widespread popularity of gaming to enrich the learning experiences, especially asynchronous ones, of students.

Quick Images had been designed to gamify the experience of learning through the five -frame or ten-frame framework. Moreover, as previously mentioned, the potential of this framework is maximized by adapting the strategy of "quick images." To develop an effective and successful educational game, it is important to balance the input of educators or pedagogy experts and the input of game designers (Hirumi & Stapleton, 2008). To ensure this, the development of *Quick Images* involved detailed and comprehensive discussions of a team composed of educators and game developers.

Moreover, the development of *Quick Images* adheres to the Educational Games Design Model proposed by Ibrahim and Jaafar (2009). This model consists of three factors: Game Design, Pedagogy, and Learning Content Modelling. Table 1 shows how *Quick Images*, which was based on ten-structured thinking (Fuson et al., 1997) and a strategy proposed by Clements' (1999), also adheres to Ibrahim and Jaafar's (2009) gamification model.

On the factor of pedagogy, the previous section details how *Quick Images* addresses the learning outcomes pertaining to ten-structured thinking. In addition, it features a scoring system which

presents a natural motivation for the user who may want to improve one's own top score and/or who may initiate a friendly competition with his/her peers. Moreover, *Quick images* is ideal for independent use and student-centered learning since its mechanics are clear and straightforward. When advancing to more difficult levels, for example, the user performs problem-solving rudiments to develop more efficient strategies to determine the number of dots flashed on the screen.

Table 1. *Game Design of Quick Images*

	Element	Implementation
Usability	Satisfaction	The color theme, font types and sizes, object designs and sizes are catered to its target audience (i.e., grade school students). The app features different modes and difficulty levels for more diverse experiences.
	Efficiency	Through the use of quick images and strategically designed and tiered difficulty levels, the app allows the users to naturally develop and master counting and arithmetic techniques.
	Effectiveness	The app is designed based on the five-frame and ten-frame framework; and gamifies the use of quick images to maximize the potential of the framework.
Multimodal	Multimedia	The app uses a combination of texts, figures, designed objects, and sound prompts.
	Interaction	The app features an interactive game that mainly takes user input through button presses. There are sound prompts for correct and incorrect answers.
Fun	Challenge	The challenge lies in achieving the highest score possible within the given time limit. There are different levels of abstraction, different speeds (slow, medium, fast), and different levels that allow for customization of the difficulty level.
	Clear goals	The goal is simple and clear: to count the number of dots flashed on the screen and to maximize the number of correct answers within the given time limit.
	Uncertain outcome	The number of dots flashed on the screen is random but strategically planned, depending on the level. The user's score within the time limit is dependent on his/her skill level.
	Self-esteem	The user's self-esteem is developed as s/he progresses through the tiered difficulty levels and the different modes/speeds.

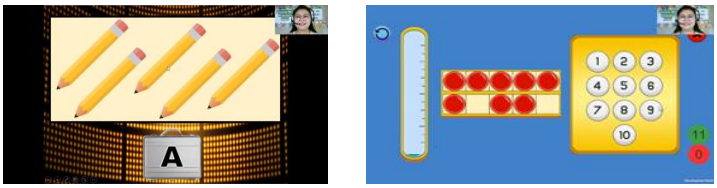
Finally, on the aspect of learning content modelling, *Quick Images* was designed so that it is aligned with the most essential learning competencies for Grade 1 (DepEd, 2020) set by DepEd in their Curriculum Guide. These competencies include: i) visualization, representation, counting of numbers 0 to 100 using a variety of materials and methods; ii) identification of the number that is one more or one less from a given number; iii) regrouping of sets of ones into sets of tens and sets of tens into hundreds using objects; iv) visualization and addition of two one-digit numbers with sums up to 18 and three one-digit numbers; v) visualization, representation and subtraction of one-digit numbers with minuends through 18 (basic facts), one to two-digit numbers with minuends up to 99 with and without regrouping; and vi) subtracts mentally one-digit numbers from two-digit minuends without regrouping using appropriate strategies. *Quick Images* also serves as a review tool to facilitate the learning of competencies of higher grades (Grades 2-6).

4. Integration of Quick Images into an online or blended classroom

Since *Quick Images* is mapped to specific learning competencies, its integration in the classroom, a learning management system, or a blended learning environment can be conceivably achieved. Its

design and functionalities allow it to be utilized as a practice tool to enrich a student's ten-structured thinking, or as an assessment tool to gauge the student's level of development in the said skill.

Several Grades 1 to 6 teachers prepared video lectures on number identification. These videos were posted in a School Division's portal and may be used by other teachers in their online classrooms. Shown in Figure 4 are screenshots of a 5-min video lecture (Mathematics Teachers Association of Mandaluyong, 2020) of a Grade 1 teacher demonstrating *Quick Images* as a complementary activity to a lesson on number identification. In the first half of the video (Figure 4a), the teacher reviewed the counting numbers from 1 to 10 through pictures of familiar objects. Using different sets of static images, the teacher guided the students in identifying the number of objects shown.



(a) (b)

Figure 4. Screenshots of a video lecture of a teacher demonstrating the use of the *Quick Images* in an online classroom.

The second half of the video shows the teacher using *Quick Images* to practice or enrich the students' quick number identification skills (Figure 4b). The teacher introduced *Quick Images*, explained its interface, how it is played, and its important features and options. The simplicity of *Quick Images'* design allowed the teacher to discuss its features in less than 30 seconds. This is important since the attention of the students must be focused on the practice activity provided by the app rather than on the app itself. Afterwards, the teacher engaged the students to play *Quick Images* with her. Occasionally, she clicked on the "show again" button to redisplay the objects in case some children might need to see the objects again. Towards the end of the video, the teacher encouraged the students to independently play with the app and send her a screenshot of the page which displays their score.

Teachers who created the videos and integrated *Quick Images* into their lessons answered some feedback/evaluation forms. They found the app easy to use and integrate in lessons. Some commented that *Quick Images* is very helpful and adaptable into a blended learning setting because it offered a strategy to make mathematics interesting and accessible when the teacher is not always present as in a physical classroom setting. Moreover, one teacher commented that the "advantage [of] *Quick Images* is [that it is] interactive and the students can play it over and over again while at the same time learning the mathematical concepts, which will be difficult to achieve in static worksheets." Pilot studies with 6- to 9-year-old children also demonstrated that the app was enjoyable to use. Even after just one session with the app, some children learned new strategies, such as determining the number of dots by looking at the number of empty boxes.

5. Conclusion and Future Direction

This paper gives a detailed look into one of the mathematical mobile applications designed and created for the teaching and learning of mathematics in Grade 1 to 6, the *Quick Images* app. It discusses its gamification features as well as the theoretical framework and the mathematical pedagogies that form the basis of its creation. *Quick Images* showcases how mathematical activities in the traditional classroom setting can be transformed and framed in a gamified environment through a mobile app for elementary mathematics. The gamified version also offers a feature that is not possible when using concrete materials—in the app, the dots disappear after a fixed amount of time, which discourages learners to count by ones. Additionally, elementary school teachers who may not be able to apply the knowledge gained in in-service trainings (Verzosa, 2015b), can readily apply the new teaching strategy integrated within the app. *Quick Images* is currently being integrated by teachers into the lessons for

Grades 1 to 6 Mathematics in blended learning for the school year 2020-2021. While *Quick Images* shows much potential in mathematical learning evidenced by the positive feedback from teachers and the learners who have used it, the next few months will entail the study of its efficiency in improving the performance of selected classes in public schools through learning-related questionnaires and microgenetic interviews.

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References

Bobis, J., Clarke, B., Clarke, D., Thomas, G., Wright, R., Young-Loveridge, J., & Gould, P. (2005). Supporting teachers in the development of young children's mathematical thinking: Three large scale cases. *Mathematics Education Research Journal*, *16*, 27-57.

Clements, D. H. (1999). Subitizing: What is it? Why teach it? *Teaching Children Mathematics*, *5*(7), 400–405.

De Las Peñas, M. N. et al. (2020). *Technology innovations for mathematical reasoning, statistical thinking, and assessment: Year 1 terminal report* (pp. 1-36, Rep.). Manila, NCR: DOST-PCIEERD.

Department of Education. (2016). *K to 12 curriculum guide: Mathematics*. Retrieved June 1, 2020, from https://www.deped.gov.ph/wp-content/uploads/2019/01/Math-CG_with-tagged-math-equipment.pdf

Department of Education. (2020). *K to 12 most essential learning competencies with corresponding CG codes*. Retrieved July 12, 2020, from https://commons.deped.gov.ph/K-to-12-MELCS-with-CG-Codes.pdf

Elliott, R. (2020). *The Philippines' games market: data and insights*. Retrieved from https://newzoo.com/insights/articles/data-and-insights-on-the-philippines-games-market/#:~:text=Share%3A,Southeast%20Asia's%20overall%20games%20market.

Fuson, K. C., Smith, S. T., & Lo Cicero, A. M. (1997). Supporting Latino first graders' ten-structured thinking in urban classrooms. *Journal for Research in Mathematics Education*, *28*, 738-766.

Hirumi, A., & Stapleton, C. (2008). Applying pedagogy during game development to enhance game-based learning. In Z. Pan, X. Zhang, A. El Rhalibi, W. Woo, Y. Li (Eds.), *Technologies for e-learning and digital entertainment: Third international conference: Edutainment 2008, Nanjing, China, June 25-27, 2008, Proceedings* (pp. 509-517). Germany: Springer Verlag Berlin Heidelberg.

Ibrahim, R., & Jaafar, A. (2009). Educational games (EG) design framework: Combination of game design, pedagogy and content modeling. In *Proceedings of the 2009 International Conference on Electrical Engineering and Informatics, ICEEI 2009* (pp. 293-298). doi:10.1109/ICEEI.2009.5254771

Mathematics Teacher Association of Mandaluyong. (2020). *Pagbibilang mula 1 hanggang 10* [Video file]. Retrieved from https://www.facebook.com/watch/?v=354568545569833&extid=LBsxn6IpsNATl4zx

McGuire, P., Kinzie, M. B., & Berch, D. B. (2011). Developing number sense in Pre-K with five-frames. *Early Childhood Education Journal*, *40*, 213-222.

Murata, A., & Stewart, C. (2017). Facilitating mathematical practices through visual representations. *Teaching Children Mathematics*, *23*(7), 404-412.

Siegler, R. S., & Lortie-Forgues, H. (2014). An integrative theory of numerical development. *Child Development Perspectives*, *8*(3), 144-150.

Siemon, D., Bleckly, J., & Neal, D. (2012). Working with the big ideas in number and the Australian curriculum: Mathematics. In B. Atweh, M. Goos, R. Jorgensen, & D. Siemon (Eds.), *Engaging the Australian national curriculum: Mathematics* (pp. 19-46). Adelaide, Australia: MERGA.

Ulbright, J. (n.d.). Arranged Ten Frames. Retrieved June 29, 2020, from https://www.geogebra.org/m/cb4CSBMj

Van de Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2015*). Elementary and middle school mathematics: Teaching developmentally*. Boston, MA: Pearson.

van den Berg. E. (2009). *A case study of pedagogical content knowledge and faculty development in the Philippines*. Retrieved from https://www.iederkindeentalent.nl/wp-content/uploads/2012/06/4-A-case-study-of-pck-and-faculty-development-in-the-Philippines.-Van-den-Berg1.pdf

Verzosa, D. M. B. (2015a). Developing the number knowledge of low-attaining first- to fourth- graders. In C.

Vistro-Yu. (Ed.) *Proceedings of the 7th ICMI-East Asia Regional Conference on Mathematics Education* (pp. 217-224). Quezon City: Philippine Council of Mathematics Teacher Educators (MATHTED), Inc.

Verzosa, D. M. B. (2015b). The effectiveness of short-term in-service training in the context of teaching mathematics for understanding. *Intersection*, *12*, 5-15.

Verzosa, D. M. B. (2020). Community math stations as a learning opportunity for preservice teachers. *Primus,* 1-28. doi:10.1080/10511970.2020.1809040

Young–Loveridge, J. (2002). Early childhood numeracy: Building an understanding of part–whole relationships. *Australasian Journal of Early Childhood, 27*(4), 36-40. doi:10.1177/183693910202700408

Young-Loveridge, J., & Bicknell, B. (2016). Developing early place-value understanding: a framework for tens awareness. *Mathematics Education Research Group of Australasia.* Retrieved from https://files.eric.ed.gov/fulltext/ED572346.pdf