

MATHIC: A Gamified Computer-Aided Instruction for Elementary Students

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Abstract: The use of mobile phones has increased in recent years compared to now. As a result, the students' academic performance suffers, and they wind up spending more time playing than learning. Recent research has demonstrated that trying to teach children using the conventional pen, paper, and speech methods is insufficient and more difficult, particularly during the Covid-19 pandemic. Given these circumstances, the researchers developed "Mathic", an educational app for Android that is intended to give students in Grades 1-3 an enjoyable, gamified arithmetic learning experience with the aid of interactive components, star awards, and a content management system to create computer-assisted training and customized quizzes for teachers. The Department of Education's modules for the 2020–2021 academic year were used for the app content. The researchers followed Agile model in developing the app. The program was created using Unity Game Engine with C# as the programming language. Google Firebase and Unity Built-in PlayerPrefs System was utilized for the database. The application underwent functionality and compatibility tests. Mobile Application Rating Scale (MARS) was used to evaluate the app which yielded a total average mean of "3.79" and a Standard Deviation of "0.05", interpreted as "Highly Acceptable". The evaluation results proved that the application was useful to engage children towards learning Mathematics and as a useful supplementing tool for teaching.

Keyword: Computer-Aided Instruction, Gamification, Mathematics, Teaching Methods.

I. INTRODUCTION

In today's time, mobile phone usage has increased compared to recent years. As cited in the study [1], a huge number of children now have access to the devices and use it to play games. Children that used to spend time playing in the dirt have now transitioned into doing it digitally through adventure games. With the younger generation's faces glued to their gadget's screens, educating young ones has become harder to accomplish. This results in the pupils' studies becoming affected, making the time dedicated to studying spent on playing. A study [2], revealed that in children aged 6-12 years, there has been a decline in concentration and a higher percentage of students' academics were waning. Trying to teach children, through the old methods of pen, paper, and talking, is not enough. A method for educating the younger generation must be created, which utilizes what has been a distraction, a smartphone.

Considering the abovementioned situations, the researchers developed the application entitled MATHIC: A Gamified Computer-Aided Instruction for Elementary Students that enable the elementary students to enjoy and learn mathematics in a fun way. The app includes lessons from the first to third graders. The lessons were delivered in a three-step method and included different minigames to ensure student engagement.

A. Project Context

Mathematical mastery of concepts is essential in the 21st century [3]. The Philippines has ranked second to the last in 2018's educational achievement test by the Program for International Student Association (PISA). Thus, more research into the improvement of teaching methods for students is needed, especially with Mathematical concepts such as arithmetic, algebra, and the like.

Classical and modern education have become very different with the rise of technology [4]. Technological assistance has become prevalent. However, schools that do not have computer access are being avoided. This rings true today; with the pandemic, classes have become online. Not only that, now the subject of mathematics has become harder to understand. This results in students outright not attending the classes or failing the activities. With students losing more interest, the subject has become more complex and more challenging in their eyes.

Employing mobile applications to teach mathematics courses in open learning systems is highly recommended. The study [5] examined opinions on mobile learning for mathematics instruction in open educational environments. 57 male and female students who were enrolled in the mathematics course in the Department of Educational Studies at the Arab Open University/Jordan for the academic year 2016/2017 made up the study's sample. The study's findings revealed that 80% of students had favourable attitudes regarding adopting mobile applications. The ratings for mathematical reasoning (75%), motivation for achievement (76%), the development of social and emotional abilities (77%), and application technology (96%), are all listed in ascending order.

Moreover, several recent studies [4, 5, 6], both local and foreign, on different courses or subjects suggested that the use of mobile application as a tool makes learners more engage and interested. Nonetheless, several studies [7, 8, 9, 10] on the development of mobile application in Mathematics context have been proven effective.

In line with these, the researchers developed an application that can be used as a supplement by teachers and an alternative for students in the Philippine education set-up in teaching Mathematics. The project can help with the pupils' cognitive and academic development. The project can also be a big help to teachers that serves as an alternative tool in teaching Mathematics. In general, educational institution will also benefit in planning more effective learning activities to develop and empower the mathematical skills of the students.

B. Project Description

The project aims to assist primary educational institutions by giving students exciting learning material to explore and enhance the students' skills. A supplementary learning tool is designed for children, especially those who have trouble learning through the math modules. By gamifying the learning process, the application can help students discover that learning mathematics is fun and enjoyable. The application would be aligned with the lessons and topics that elementary students currently study. This ranges from basic arithmetic to solving worded problems. The entire system was built in one application that users can install on their android phone. In addition, the system also includes a content management system. Teachers could personalize the app by giving students customized questionnaires that are suited to the current lessons.

The system was developed according to the grade level of the students' capabilities in mathematical topics. The Department of Education Math modules for Academic Year 2020-2021 was the basis for the content of the developed app. The project was developed alongside a consultant, who played a role in testing the application to see if the application is effective in teaching students.

C. Objectives of the Project

Generally, the researchers developed an android application named Mathic: A gamified computer-aided instruction for Elementary Students. Specifically, the project aimed to:

1. Design a learning environment with the following features:
 - a. Account registration module.
 - b. Log-in screen that identifies the users as teachers or students.
 - c. Grade level screen where the application asks the grade level of the student with no account.
 - d. Student Interface that displays the lessons that the students will be able to access.

- e. Teacher's interface which enables the application to be used as a teaching aide by teachers.
 - f. Lessons panel where the students can access the lesson provided by the application.
 - g. Scoring system wherein students are given stars if they completed a lesson.
 - h. Quiz creation panel where teachers can create quizzes and can choose between creating personalized quizzes or use the built-in one.
 - i. Lesson content aligned with the current modules used in the K-12 curriculum of the Department of Education of the Philippines particularly in the field of mathematics for Grade 1-3 level.
 - j. Content management features where teachers can personally create customized and specific questions that the students can access with the code given to the user.
2. Create the project using Affinity Designer, Canva, Adobe Photoshop, Unity Game Engine Canvas, and Scenes as frontend. Unity Engine C# scripting as backend with Google Firebase and Unity Built-in Player Prefs System, for the database.
 3. Test and improved the developed system, using functionality and compatibility tests.
 4. Evaluate the acceptability of the system and measured it based on MARS Standards for Mobile Application Development, namely:
 - a. Engagement
 - b. Functionality
 - c. Aesthetics, and
 - d. Information Quality

D. Scope and Delimitation of the Project

The target users of the system are elementary students, specifically Grades 1 – 3, or children of ages 6-10 years old, together with the teachers of the said grade levels. It is aligned with the current year levels and corresponding modules that the Department of Education of the Philippines supplied in K-12 Academic Year 2020-2021. The developed app provided a Content Management System (CMS) where teachers can create personalized quizzes.

In creating a class, teachers can no longer edit the list once saved. The quiz codes that are supplied when the teacher creates the quizzes are different every iteration, it is only accessible to those with the specific quiz code. The quizzes are limited to ten (10) items multiple-choice questions only and would only have three (3) choices per question. The personalized quizzes have dedicated placeholders or text fields for questions and options. It is limited to texts and would not support images or any other media. Quiz scores may be saved or downloaded in .TXT format only.

The application is available in the English Language. It runs on android phones from version 7-11 and have a screen ratio of 16:9. The initial release of the application would only display the selected lessons per grade level. This is to ensure that the quality of the lessons have not degraded. The following lessons would be added as future updates as part of the proponents' recommendations. The developed app does not cater topics that are higher than Grade 1 – 3 mathematics. It is limited to arithmetic and basic algebra and not include Grades 4 – 7 and high school level mathematics.

II. METHODOLOGY

This section contains the conceptual framework of the studies generated from the review of related literatures and studies made. In addition, several diagrams and representations are also included to presents the methods used in developing the project.

A. Conceptual Framework

The project's input restrictions and conditions, process, outcome, and assessment approach are all depicted in the conceptual framework. Figure 1 shows the conceptual framework of the project. The input box includes all considerations that the researcher used in developing the system such as knowledge requirement which includes knowledge on computer-aided

instruction, mathematics, gamification, content management system, gadget use of children, design considerations, C# programming [11], database management [12], and evaluation. Software requirements includes the use of different application both frontend and backend. Unity game engine [13, 14], with assets created in Affinity Designer and sounds edited in Audacity together with Adobe Photoshop was used as front-end programs. The backend of the application was developed with the use of Firebase as the database. Using the hardware requirements on both PC and android devices, the app was created using the minimum system requirements identified and the application was tested on android versions 9,10, and 11.

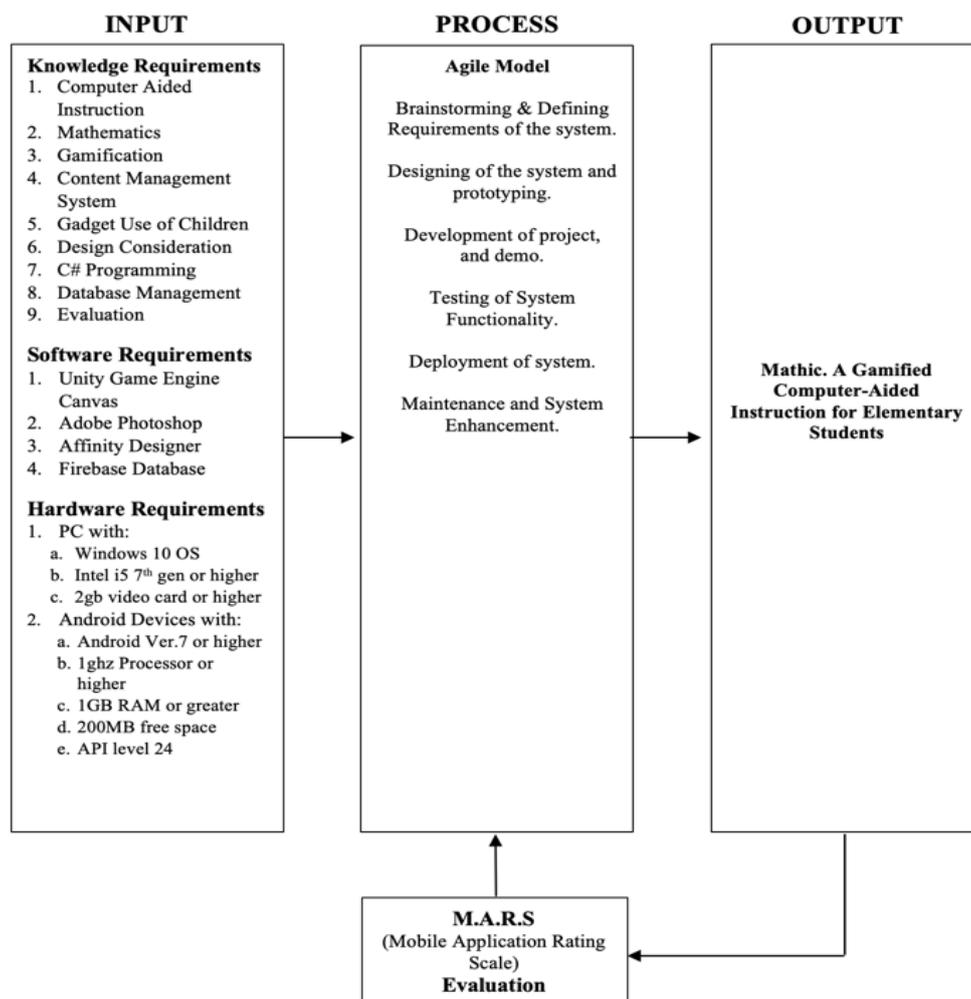


Fig. 1. *Conceptual Framework*

The process phase required the proponents to utilize the Agile Model [15]. The first phase is the brainstorming phase, or the requirements gathering phase. In this phase, the requirements are defined. This phase is where the planning takes place. The next phase is the Design phase. This phase is where flowcharts, use case diagrams, context diagrams, wireframes, and storyboards are created. The next phase is the Development phase, wherein the system is created. The next phase is the Testing phase, wherein the quality of the system would be checked. The last stage is Deployment, where the intended users use the product. With the Agile Model, the phases continued but with a working model delivered after every cycle. This model allowed the group to comply with the new set of requirements depending on the feedback of the consultant and adviser.

The output phase is the final product or version of the system. It produced “MATHIC: A Gamified Computer-Aided Instruction for Elementary Students”. Lastly, Mobile Application Rating Scale (MARS) was used to evaluate the system. The rating scale used is a simple evaluation tool designed to test the capabilities and effectiveness of applications.

B. Design

Defined by the IEEE [16] design is the process of determining system’s component structure, configurations, interfaces, and other characteristics. The Process Model and Object Model are discussed here, a flowchart and an activity diagram were used to illustrate the models. Figure 2 illustrates the system flowchart of MATHIC. Initially when opened, the application displays the splash screen, followed by an introduction video of the application. To grant approval from parents for students to use the app, the verification screen appears that only teachers and parents can answer. To know more about how to use the app, the user may download the app’s manual. If the question has been answered incorrectly, the application will ask the question once again. If the answer to the question is correct, the application will display the agreement for users, which will prompt users to press the “read more” button that would show the terms and conditions of the application. Reading until the end of the terms will enable the back button, where the user can proceed by checking the checkboxes that signify that the user has read and agreed to the terms and conditions. The continue button will be enabled if the user has checked the boxes. Tapping the back button will lead the user back to the agreement page, which will lead to the next screen.

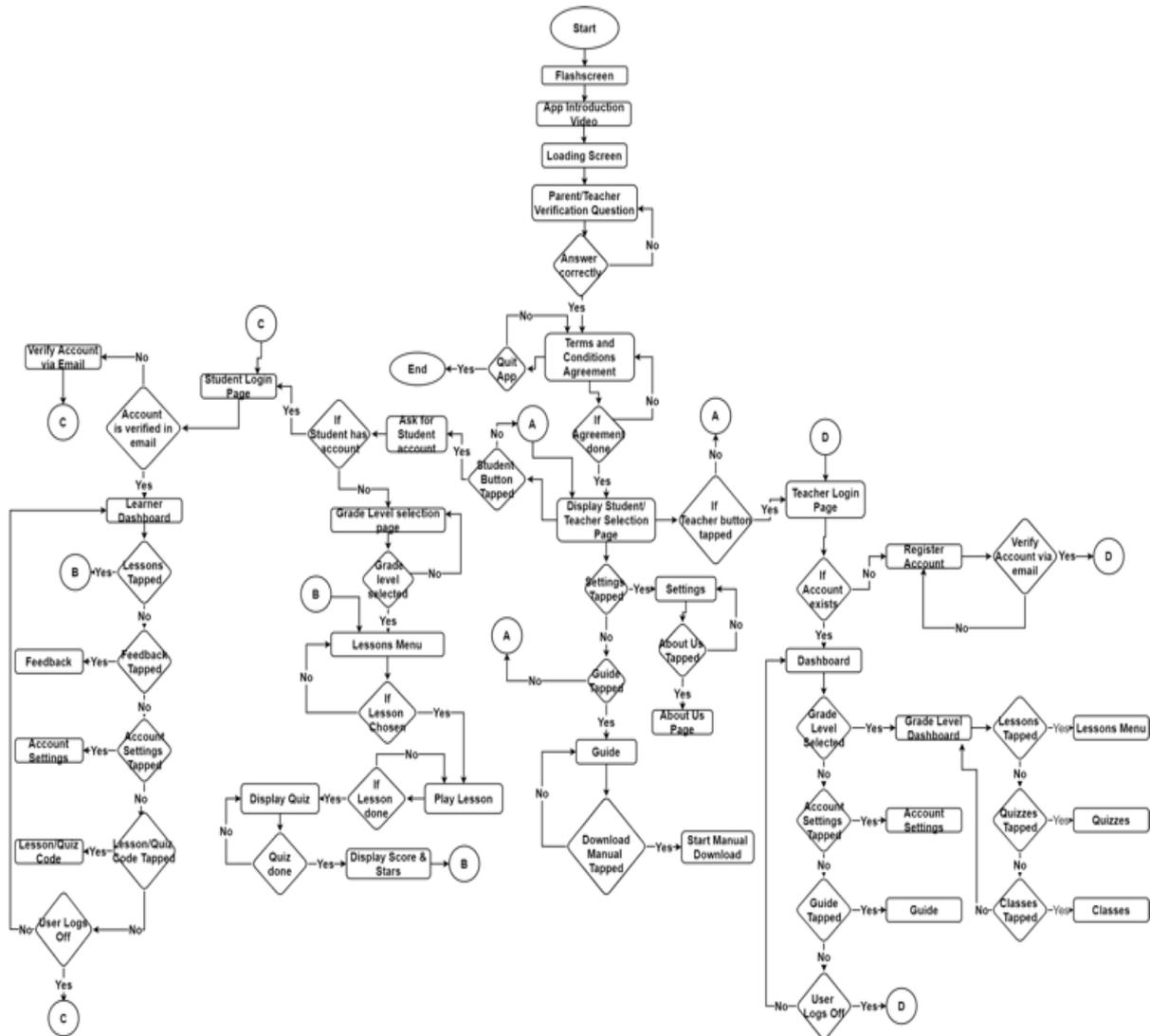
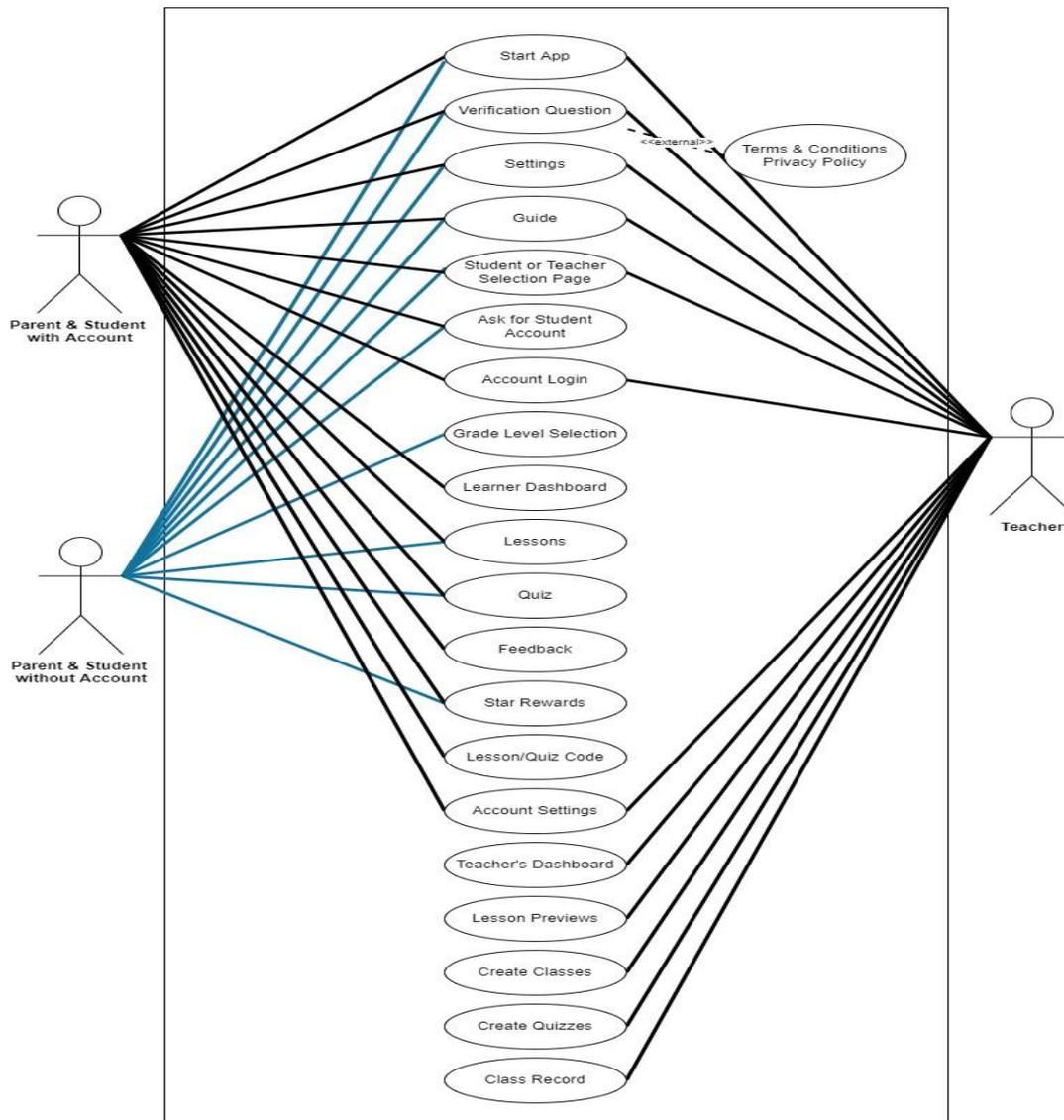


Fig. 2. System Flowchart

Clicking the continue, the screen will ask if the user is a student or a teacher. Pressing the teacher button will prompt the teacher into logging in with their account. After logging in, the teacher will see the teacher’s dashboard, where teachers could create quizzes, view lessons, and create class lists. If the register button is selected, it will prompt the teacher to create an account used in the application. If the student button is pressed, the application will ask the student for an account, which can be answered by tapping the Yes or No button. Selecting the Yes button will prompt the student to log in while going with the No button will lead the user to the lesson menu.



The project has three (3) primary users: A student and parent without an account, a student and parent with an account, and a teacher. Initially opening account will be able to access the lessons and quizzes that accompany the said lesson. The users without accounts can also view the stars that are collected. If the user were given an account, the application would then ask for the student's login details, which the teacher will provide. Once logged in, the student with an account will be able to access the selected lessons and quizzes that the teacher has created. The students will also be able to view the number of stars collected from the lessons. All kinds of users can access the settings, where users can change the volume of the music and sound effects. The users can also view the about us page and read about the terms or conditions once again. the application, the user must agree to the terms and conditions of the application before continuing to use the system. After agreeing with the terms and conditions, the user will be asked if a student or a teacher. If the user selects the teacher, the user will be prompted to log in. Following the login, the teacher will be able to access the teacher panel where lessons are available for viewing, create quizzes, and to be able to add classes for the account creation of students. If the user selects the student, the application will ask if the student has an account or not. If the student does not have an account, the application will redirect the users to the grade level, displaying the corresponding lessons. Students without an account will be able to access the lessons and quizzes that accompany the said lesson. The users without accounts can also view the stars that are collected. If the user were given an account, the application would then ask for the student's login details, which the teacher will provide. Once logged in, the student with an account will be able to access the selected lessons and quizzes that the teacher has created. The students will also be able to view the number of stars collected from the lessons. All kinds of users will be able to access the settings, where users can change the volume of the music and sound effects. The users can also view the about us page and read about the terms or conditions once again.

C. Test Plan

The primary purpose of this phase entails testing the application and identifying if the intended functions of the system are accomplished. The functionality test respondents includes one (1) Technical adviser, two (2) end-users such as, one (1) Teacher/Consultant, one (1) Student and two (2) IT Experts as the primary end-users. Compatibility testing, which tests the software's capabilities to work on different environments and various specifications was also performed. The application was tested using android mobile devices and android emulators with Android Operating System with version 9 (Pie) to Android 11.

Test Procedure. The test activity was conducted using the following steps:

1. The required documents were prepared and a preliminary meeting discussing the test was conducted.
2. The discussion of the project and the purpose of the project were discussed after the approval of the appointment.
3. The test instruments that will be used were explained and disseminated.
4. Each module or function was checked to identify if the said module or function was working properly and bug free.
5. Connecting with the end-users and testers was done with Messenger, Gmail, and Zoom Meeting. (<https://zoom.us/meeting/75913593308>).
6. Test sheets were filled-up and submitted.
7. Recommendations about the software improvements were documented.
8. Results were tallied and comments were collected which would be applied in the application.

Test Instrument. The test instruments acceptable to the application's functions guided this activity. Functionality and Compatibility tests are suitable evaluation methods used. The functionality test was used to check if the modules or functions of the application were working as intended. The compatibility test was conducted after the functionality test to ensure that the application works in various versions of android and different devices.

D. Evaluation Plan

The evaluation tool used was based on the Mobile Application Rating Scale or MARS. Ten (10) end-users comprised of five (5) elementary teachers, (5) elementary students, and five (5) IT experts were called upon for the completion of the evaluation.

Evaluation Procedure. The evaluation phase was successfully done with the following steps.

1. Evaluators were scheduled for an appointment based on their availability. Connecting with the evaluators was done with Messenger, Gmail, and Zoom meeting.
2. Once the approval of the evaluators is met, the evaluation will proceed.
3. The development team explains the relevance of the application, parts and functions were also explained.
4. The evaluation instrument, criteria, and sub-criteria were discussed.
5. The evaluators were given time to explore the application.

Evaluation Tool. The evaluation instrument utilized for the project was the Mobile Application Rating Scale or MARS. The instruments were used to accurately assess the application's quality. Criteria such as engagement, functionality, aesthetics, and information were assessed and evaluated.

TABLE I: SCORING SYSTEM

Numerical Rating	Equivalent
4	Highly Acceptable
3	Acceptable
2	Fairly Acceptable
1	Unacceptable

Table I shows the scoring system used in quantifying the results of the evaluation made. Four (4) is the highest or highly acceptable, and One (1) the lowest or unacceptable.

$\bar{x} = \frac{\sum x}{N}$ <p>Where: \bar{x} = Mean Σ = "Summation of" x = Score of proper weight N = Total number of respondents</p>	$SD = \sqrt{\frac{\sum(x - \bar{x})^2}{N - 1}}$ <p>Where: \bar{x} = Mean Σ = "Summation of" x = Score of proper weight N = Total number of respondents</p>
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Fig. 1. Mean and Standard Deviation Formula

Statistical Treatment of Data. A total of ten (10) end- users, and five (5) IT Experts evaluator-respondents provided data for the study. The data gathered were validated and computed using the weighted mean and the calculation for the standard deviation. Figure 4 shows the mean and SD formula.

TABLE II: LIKERT SCALE

Numerical Rating	Equivalent
3.26 – 4.00	Highly Acceptable
2.51 – 3.25	Acceptable
1.76-2.50	Fairly Acceptable
1.00-1.75	Unacceptable

Likert scale. The researchers used the Likert scale to identify and quantify the acceptability level of the respondents from the questionnaires. A corresponding interpretation depending on the range of the calculation of the mean and standard deviation was used to determine their acceptability. Table II shows the Likert scale use to interpret the result of the evaluation made.

III. RESULTS AND DISCUSSION

A. Test Results

Test cases used for the system include Functionality and Compatibility Tests. The functionality criteria tested the functions with regards to the design specifications as well as the performance of the software. Compatibility criteria examined the capability of the software to run on Android OS versions 9.0 Pie, Android 10.0, and Android 11.

TABLE III: FUNCTIONALITY TEST RESULTS

Test Respondents	Pass	Fail	Test Criteria	Percentage
Technical Adviser	32	3	35	91.43%
Teacher/Consultant	35	0	35	100%
Student 1	35	0	35	100%
IT Expert 1	35	0	35	100%
IT Expert 2	34	1	35	97.14%

Table III presents the results of the functionality test made. The test instrument has 35 criteria tested; the technical adviser resulted to 32 out of 35 test criteria resulting to a 91.43% passing rate. One of the IT experts resulted to a 34 out of 35 in the test criteria with a 97.14% passing rate. Other testers resulted to 35 out of 35 in the criteria, with a 100% passing rate. Other users did not encounter any issues with the testing, while the technical adviser encountered problems with the quality of the guide used, as well as an unregistered user appearing on another section module, and the close quiz feature not able to work. The IT expert also encountered the problem of the guide being unreadable. The issues were fixed before moving to the evaluation phase.

TABLE IV: COMPATIBILITY TEST RESULTS

Test Respondents	Pass	Fail	Test Criteria	Percentage
Technical Adviser	4	0	4	100%
Teacher / Consultant	4	0	4	100%
Student	4	0	4	100%
IT Expert 1	4	0	4	100%
IT Expert 2	4	0	4	100%

Table IV shows the compatibility test results. All test participants passed the compatibility test with 100% passing rate from the four (4) test criteria. The test results demonstrated the capability of the application running in various Android OS versions, specifically 9.0 Pie, 10.0 and 11 as well as smoothly running in 16:9 ratio or 1920x1080 resolution.

B. Evaluation Results

The evaluation instrument used was Mobile Application Rating Scale (MARS) and was evaluated by five (5) IT experts, one (1) consultant, and ten (10) end-users.

TABLE V: EVALUATION RESULTS SUMMARY

Criteria	Mean	SD	Interpretation	Rank
Engagement	3.81	0.05	Highly Acceptable	3
Functionality	3.88	0.08	Highly Acceptable	2
Aesthetics	3.60	0.06	Highly Acceptable	4
Information	3.90	0.03	Highly Acceptable	1
Average Mean and SD	3.79	0.05	Highly Acceptable	

Table V shows the overall result from ten (10) end-users comprised of five (5) elementary teachers, (5) elementary students, and five (5) IT experts. Engagement has a mean of "3.81" and a standard deviation of "0.05," Functionality achieved a score of "3.88" mean and "0.08" SD. Aesthetics scored a "3.6" mean and "0.06" SD, while Information obtained a mean of "3.9" with a "0.03" standard deviation. The ten (10) end-users and five (5) IT experts resulted to an average mean of "3.79" and a SD of "0.05" and the interpretation is "Highly Acceptable". Information ranked first, with it being the most important aspect of what the application offers. The delivery of the information satisfied all the respondents, stating that the target users of the application will learn from it. Functionality ranked second, with all the intended functions of the app working, with recommendations from the experts about minor details and the screen resolutions. Engagement ranked third with the users finding the minigames enjoyable and playable. Aesthetics ranked the lowest, with the evaluators recommending that UI can still be improved.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

The developed application, MATHIC was designed to be a supplementary tool to help the students and teachers in terms of knowledge enrichment for the former and of interactive teaching tool for the latter. The application offers methods to instruct students with engaging lessons and quizzes. Using the content management features, teachers can disseminate customized quizzes to students and track their performance. The students can keep track of scores as well as get customized quizzes from teachers. The project was created and designed with Affinity Designer, Adobe Photoshop, Adobe Premiere Pro, Unity Game Engine and C# while the data and information are handled in Firebase database. The android application is only applicable for users who have android smartphones that run the operating system of android version 7.0 Nougat (API level 28) and above. The application was tested according to functionality and compatibility test cases. Functionality test yielded 91.43% passing score from the adviser and 97.14% from one of the IT experts and 100% for the end-users. The app was improved based on recommendations of the test-respondents. Compatibility test yielded 100% passing scores for all the testers. The test proved that the application runs on Android version 9.0 Pie, 10.0, and 11.0. Evaluation yielded an average mean of "3.87" and a Standard Deviation of "0.10" with the interpretation of "Highly Acceptable". Based on the evaluation results, the end-users, IT experts, and the consultant recognized the application as effective in engaging children to learn Mathematics and as a supplementary tools for basic Math teachers.

B. Recommendations

The following are list of recommendations that the researchers suggest for future improvement of the developed application:

1. Create an application that has a more consistent screen resolution.
2. Provide more lessons and more mini games to keep the children more engaged.
3. Create an application of the same purpose but with Filipino as the main language.
4. Create a way to edit the section once added.
5. Create a way to enhance the personalization of the create a quiz function.
6. Embed the manual of the application in the user interface, making it easier for the user to see the manual.
7. Include voice-over on all the topics covered by the application, not only on the demo parts.
8. Include an option to download the scores of the students in different file types like xlsx (excel), PDF, and more.
9. Sets method for the students to download the grades obtained in the quizzes; and
10. Create a port of the application for Apple's iOS.

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