

## RESEARCH ARTICLE

# Students' evaluation and learning experience on the utilization of Digital Interactive Math Comics (DIMaC) mobile app

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**Abstract:** Mobile phones are prevalent worldwide, and today's learners utilize this technology for instructional purposes. This educational design research aims to evaluate the developed interactive mobile application. This instructional material contributes to today's 21<sup>st</sup> century or digital native learners' needs to engage students in the teaching-learning process. The app is aligned with mathematics instruction, balancing visuals and Math content. Employing the Instructional Material Development for Non-print Materials instrument shows that the developed mobile app is acceptable for the Grade 11 students. Students reported a positive experience and noted an increased interest in Mathematics when using the app. Further research is needed to explore the integration of this app in the mathematics classroom.

**Keywords:** interactive app, digital comics, mathematics classroom

## 1 Introduction

Today's learners live in an image-saturated environment, given that communication relies on highly visual components (Kędra & Žakevičiūtė, 2019; Statton et al., 2018; Association of College and Research Libraries, 2011). This fact reinforces the argument that the world consisting of text is irreversibly dead (ArtsEDNet, 1997; Goldfarb & Kondratova, 2003). Today's learners are exposed to digital technology and are used to various media for pleasure or learning (Crăciun & Bunoiu, 2019; Kirchoff, 2017). Throughout learners' education, they engage with images and visuals (ACRL, 2011). Kane and Pear (2016) contend that views of an article or advertisement depend on available images, as page posts with visuals receive 94% more engagements. Visual images in the teaching-learning process are essential in achieving the learning objectives set for a specific lesson. Teaching or reinforcing visual literacy to students to utilize and evaluate such an image is essential (Vidakis et al. 2019). A visually literate person can understand visual information, a necessary skill for communication in the 21<sup>st</sup> century. In a classroom setting, technology for visual tools is primarily utilized (Duncan et al., 2015; Katsaris & Vidakis, 2021).

Employing technology in the classroom is one way to increase students' engagement in the teaching-learning process, and it has grown dramatically in recent years (Orlando, 2014; Francis, 2017; Vassallo & Warren, 2018). Today's digital native learners are prepared to use these new technologies (Stošić, 2015). The new technologies increase their engagement in learning (Papadakis, 2020; Schindler, 2017). Effective utilization of these technologies improves the productivity of instructional processes (Erişti et al., 2012), enhances and enriches the teaching and learning process (Duhaney, 2000), and makes the instruction more enjoyable (Raja & Nagasubramani, 2018).

Today's learners live in an environment with technological access to an abundance of information on an extraordinary scale. The National Education Association P21 framework (2009) incorporates a set of competencies for 21<sup>st</sup> century skills in the teaching and learning process. The framework utilizes a different intervention to improve learning outcomes, enhance student engagement, and prepare them for employment (remakingchange.org).

One of its competencies is proficiency in utilizing Information and Communications Technology (ICT), which is also utilized to aid teaching-learning (Papadakis et al., 2020). Modern technologies like computers, class websites and blogs, digital microphones, smart interactive whiteboards, online media, online study tools, and mobile devices are used in the classroom (Ramey, 2012). Moreover, ICT development also shifted printed texts to digital ones, including various platforms that combine texts with visual elements like digital comics (Crăciun & Bunoiu, 2019; Papadakis & Kalogiannakis, 2019).

A technology that serves as one of the platforms for these visual images is the mobile device. It plays a promising role in instruction (Poultsakis et al., 2021). Smartphones are rapidly growing,

containing novel features that can be widely used in various contexts (Halaweh, 2017; Lazarinis et al., 2022), and it is widely used worldwide (Papadakis, 2021). Mobile and online learning are widely employed in teaching and learning processes (Drigas & Pappas, 2016; Sincubaa & John, 2017). It positively impacts students' learning outcomes, like improving students' learning achievement and behaviour (Supandi et al., 2018; Etcuban & Pantinople, 2018; Alkhateeb & Al-Duwairi, 2019) and helps develop creative thinking (Rudyanto et al., 2019). Several mobile applications have already been developed for instructional purposes. For example, *Sketchpad* by Nicholas Ackie in 1991, *GeoGebra* designed by Markus Hohentwrtler in 2002, *Math4Mobile* platform by Yerushalmy et al. (2007), Mobile Mathematics Tutoring (MoMT) introduced by Zhao and Okamoto (2009), and many typical mobile applications are utilized in the classroom.

One of the latest initiatives that use mobile technology as a [user] platform is digital comics. Digital comic is a multimodal textual-visual form of literature (Cook, 2017), and they can be effective pedagogical tools (Scott, 2015). According to Kirchoff (2017), digital comics can be delivered via remediated, ergodic-hyper, multimedia comics.

Several comics have already been developed for instructional purposes (Lazarinis et al., 2015), as comics provide pedagogical opportunities (Berkowitz & Packer, 2015). Comics have been created for different subjects like Filipino (Cabiles & Espina, 2015), multiplication material in Math (Rahmawati & Salam, 2019), and Geometry (Pardimin & Widodo, 2017), and Algebra (Sepriyanti & Tapia, 2018). These developed comics acquired very favourable ratings from the evaluators. Areas like comic structure, content, organization, presentation, writing, language, and readability were favourably evaluated as suitable for students' use in instruction. Comics are also used to promote science literacy (Olson, 2008), improve vocabulary (Zimmerman, 2008; Tejwani, 2012) and reading comprehension (Liu, 2004), enhance understanding of the symbolism in algebra (Toh, 2009), motivate students (Yang, 2003), and improve academic performance (Shin et al., 2013). These advances in educational comic book use occurred because comics are encouraging, visual, permanent, intermediary, and popular (Yang, 2003), and image utilization improves learners' memory benefiting the learning process (Kędra & Żakevičiūtė, 2019).

Comics are among the top 10 read non-school books in the Philippines (National Book Development Board, 2017). This study's purpose aligns with the Department of Education's key thrusts to utilize Information and Communications Technology (ICT) in the classroom and develop, implement, and evaluate local and contextualized instructional materials for students (Official Gazette of the Republic of the Philippines, 2013). The presented literature on the positive effects of comics on students' learning outcomes and the importance of visuals in teaching a subject matter were the reasons for developing this Digital Interactive Math Comics (DIMaC) mobile app.

DIMaC is a mobile application where math content and a storyline with available visuals on the comics' characters, plot, and emotions are illustrated. The DIMaC has a sequential art form, visual communication of mathematical messages to develop students' general mathematics' competencies. The developers created this DIMaC app with experts in Mathematics education.

This app is supplemental instructional material for senior high school students in General Mathematics. The app contains questions that students must answer before proceeding to the following exciting scenes, making the app interactive. Specifically, this research sought answers to the following questions:

- (1) What is the students' evaluation of the Digital Interactive Math Comics (DIMaC) acceptability for classroom use?
- (2) What are the students' learning experiences using Digital Interactive Math Comics (DIMaC)?

## 2 Methods

### 2.1 Research design

The researcher utilized educational design research, designing and developing an educational intervention. It includes instructional strategies and learning materials to solve complex problems in education and advance our knowledge about the characteristics of these interventions (Mckenney & Reeves, 2013). These interventions can be products, processes, programs, or policies. This research utilized the ADDIE model with five stages of DIMaC app development: analysis, design, development, implementation, and evaluation.

### 2.2 Analysis

The study's first analysis phase included 425 randomly selected grade 12 Senior High School students in the seven public High Schools of Baybay City Division, Baybay City, Leyte, Philippines. During the assessment phase, the researcher administered the 80-item test and a survey questionnaire on students' preference for the Math comics' characters and themes. The former was utilized to assess the least learned competency of the students. Before assessing the least learned

competencies, a letter asking permission from the Division Superintendent was completed to ask for a time/schedule to administer the 80-item competency test.

The 80-item researcher-made competency test comprised items from the three main topics of General Mathematics, namely, functions and their graphs, business mathematics, and logic. Each item developed followed the syllabus stipulated by the Department of Education. A learning competency of a specific mathematics topic taught for one hour has one question on the questionnaire, and a competency taught for 3 hours has three related questions with different difficulty levels. The 80-item questionnaire is based on the researcher's Table of Specifications (TOS). Fifty questions are adapted from the resources provided by the Department of Education (DepEd) and the Commission on Higher Education (CHED), while 30 items were original. The test is a multiple-choice type of four choices and was pilot tested on senior high school students. Eight experts in Mathematics and Assessment and Evaluation validated the face and content validity test. A Cronbach's alpha value of 0.788 was computed, indicating an acceptable internal consistency value. This test was used to determine the students' least learned General Mathematics skills that needed to be integrated into the mobile application.

The assessment results indicate that three topics from the logic area, two from functions and their graphs, and one from business mathematics were the students' six least learned topics. Including only six least learned topics were the researcher's decision, experts, illustrators, and programmers. The more topics included, the more illustrations needed. It could take up to a year to finish. A consensus decision of having the top 6 least learned was pursued.

The second instrument was a questionnaire on students' character preferences and the math comics themes during the assessment phase. This questionnaire sought responses as to what will constitute the theme and makeup of characters of the math comics. This questionnaire was validated by experts in mathematics education and assessment and evaluation. These experts are PhD degree holders who have developed various Instructional Materials in their respective subject matter. Results showed that characters like Superman, Wonder Woman, Tony Stark, and other superheroes were the students' chosen casts. Since they may cause a problem in the copyright, the researcher decided on the characters involved in the story. The characters were purely from the researcher's imagination. Only the "love story theme," the top choice of the students, was followed.

### 2.3 Design and development

After the assessment phase, students' least learned or the lowest scored topics in General Mathematics and the "love story" theme for the comics' storyline were solicited. The design and development phase followed. The first step done in this phase was scriptwriting. The main challenge was the seamless integration of Math content and the love storyline in this phase. That is why; the researcher reminisced about his experiences in high school for the storyline. The help of a few senior high school students in the flow of the storyline was also asked for. They suggested the climax and end of the story. Their suggestions were also based on their own or friends' love experiences. For integrating the Math contents, the researcher, adviser, and panel of experts contributed. Experts validated the first draft of the storyline for the Math contents and the flow of the story. The experts suggested storyline improvement, which was integrated to refine the final script. The script was then submitted to the illustrators so that the electronic illustrations of the storyline's different scenes could be created. The researcher contributed to the scene, including the story's characters' features. Revisions of the illustrations were also made to fit the characters' emotions and the comic's plot based on the script. Scott (2015) emphasized that developed digital comics are effective pedagogical tools combining narratives, ICT, and visual art.

Finally, the programmer used the drawings to develop the mobile application. Suggestions on the flow and functionality of the mobile app were the researcher's ideas. The researcher has expertise in mathematics education with research interests in assessment and evaluation and instructional material development. Mathematics education and information technology experts commented on the drafts for its improvement before the app's final output was developed. The developed mobile app (DIMaC) can be used via Android phones and be shared via the SHARE-it mobile app. The followings are the screenshots of the mobile application with its descriptions.

Figure 1 shows the preliminaries of the DIMaC. Screenshot *a* is the logo of the app. The fist in the logo indicates that it is comics because we usually compare comics to heroism. The Math symbols denote that the comics contain mathematical content. The sunrays below the first illustration symbolize that the user will be the 21<sup>st</sup> century learner; hence, it is an interactive Math comic. Below the logo is a "START" button that students will press to begin the story. Screenshot *b* is the password section. It is made to use the app in the class simultaneously. After providing the password, the app leads the students to the "About Section". This section explains what the app is all about. Instructions are also provided in the about section, and the nature of the buttons is explained.

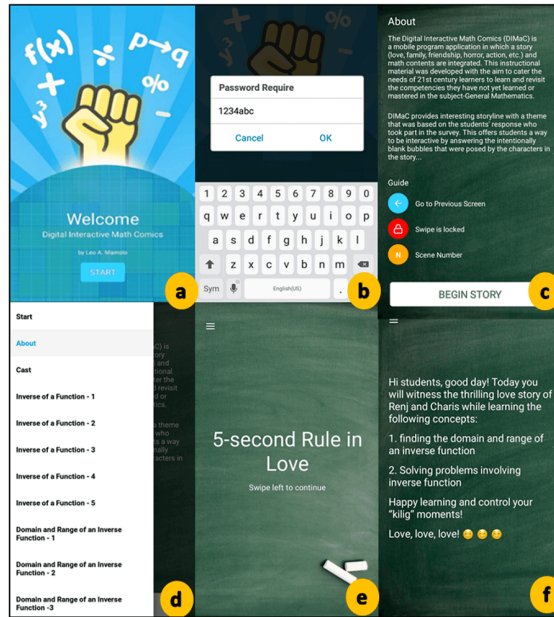


Figure 1 Preliminaries of DIMaC application

Swiping from the left-right will show the topics on Mathematics (screenshot d). These are the least learned topics integrated into the love storyline. Every Math topic has scenes and plots. The “Cast section” can also be found in this section, followed by the title section. The chosen title of the comics is “5-second rule in love”. Senior high school students also decided on this title. Then, the lesson’s objectives per topic were presented (screenshot f). Putting the objectives sets the students that they are in a classroom setting. They may be using mobile phones and reading comics; they should learn the lesson objectives of every topic.

This DIMaC app has a love story/romantic comedy theme chosen by the Senior High School Students. The story revolved around the love story of the main cast, Renj and Charis, who were classmates from Grade 7 to college. Figure 2 highlights the beginning scenes of the comics. The figures above show that the first scenes are “frustrated” wedding scenes. It was executed to keep students’ interest and make them continue reading the next stages. After this, flashback scenes followed, showing the main characters’ puppy love in the classroom setting.



Figure 2 Introductory scenes of the storyline of the DIMaC application

Figure 3 presents the style of Mathematics content integration in the DIMaC. Topics like finding the inverse of a function (screenshot c) are integrated into the characters’ conversations. Challenging topics that need explanation were integrated into the storyline and are posted per

scene (screenshots d, e, and f). The way it was done was like tutorial sessions. Characters asked about the concepts, and then the topic and explanations were posted. The researcher made sure to explain the idea as smoothly as possible. There is a balance between Mathematics contents and the love storyline in the app. The DIMaC is established in a “Math-Love-Math-Love” flow. After mathematics questions are posed, a love storyline follows, and then another Math problem solving is posed, continuing with the storyline. The researcher ensured a seamless connection between the two areas aiming to balance the math and love storyline.

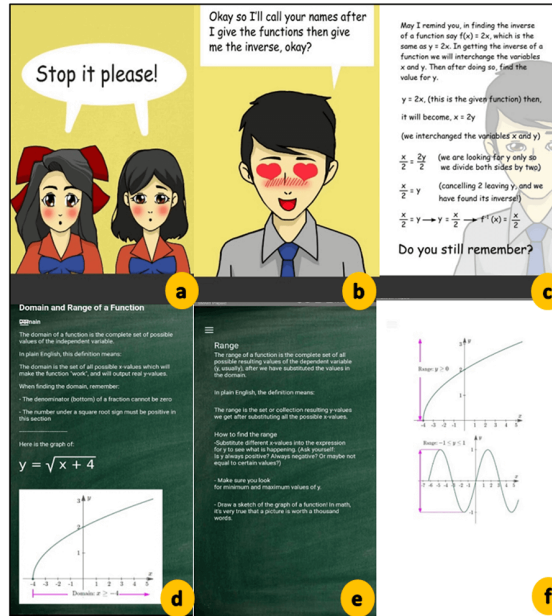


Figure 3 Math content integrated in the DIMaC application

Figure 4 shows the screenshots of the interactivity features of the DIMaC app. Screenshots b and f have a red button below them. This button means that the scenes are locked, and it indicates that students will not be able to proceed to the next slide/scene until they correctly answer the question posed. The same screenshots have “Tap to answer” words in green texts. It is where the interactivity of the Math comics comes in. Students must click/press the bubble with the “Tap to answer” feature to lead them to the sections to supply the answers. Screenshots c and e are the sample illustrations of the next step. Fill in the blanks or supply type, multiple-choice, and bonus true-or-false questions were integrated throughout the app.

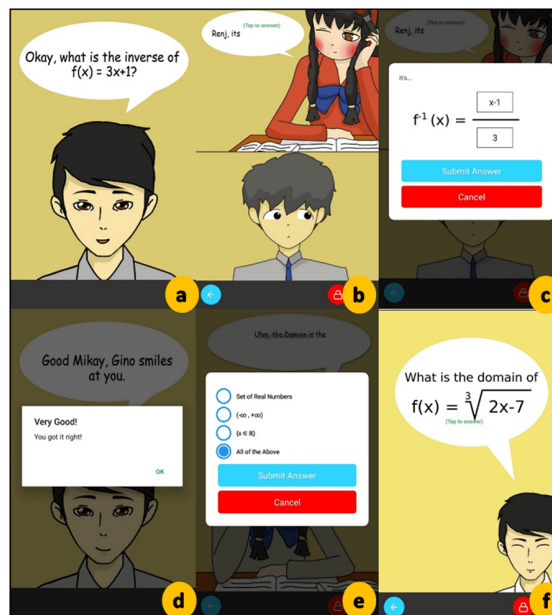


Figure 4 The interactivity of the DIMaC application

Students are given three tries to answer the supply-type questions. In the first wrong answer, the

application will inform the students' answer is wrong. This means that students need to recompute and recheck their solutions. The second wrong answer, the app will give a hint. This hint is maybe a variable or a constant that will lead the students to get the correct answer. This clue would be of help for the students to get the correct answer. In the third wrong answer, the app will notify the students, "Sorry, it is time to ask your teacher." This time, the teachers should clarify the concepts discussed. Thus, in the third try, students must see to it to get the final correct answer after the two attempts to proceed to the comics' other scenes without interruption. Screenshot *d* will appear if the students will supply a correct answer. All solutions must be written in their notebooks.

## 2.4 Implementation and evaluation

The implementation of Digital Interactive Math Comics (DIMaC) was administered to grade 11, STEM strand, composed of 38 students at West Visayas State University Senior High School. The teacher handling the General Mathematics class was the one who utilized the DIMaC in the classroom. The implementation took five sessions. After this, students evaluated the application's acceptability using an Instructional Material Evaluation Form C for Non-Printed Materials. This instrument is a standardized instrument of West Visayas State University. It is the primary tool utilized in evaluating developed Instructional Materials that are non-print. The university conducted validation of the said instrument. Before the tool was used, permission from the Instruction and Quality Office was asked. Also, the instrument was reviewed by Mathematics and IT experts for the tool suitability. After a few minor corrections and validations, the instrument was utilized. The instrument includes eight criteria; content, instructional quality, technical quality, storyline, interactivity and feedback, presentation and organization, accuracy and up-to-date information, and assessment. The interpretation and description of the application are shown in [Table 1](#).

**Table 1** Acceptability rating description and interpretation

Score	Description	Interpretation
3.51 – 4.00	Very Acceptable	All aspects of instruction and work are adequately covered, and the quality of work is superior.
2.51 – 3.50	Acceptable	Significant aspects of instruction and work are covered, and the quality of work is above average.
1.51 – 2.50	Moderately Acceptable	The significant aspect of instruction and work are covered with minimum acceptability.
1.00 – 1.50	Barely Acceptable	Significant aspects of instruction and work are hardly covered, and the work quality is below-average.

Journal entries were utilized on the students' experiences on the DIMaC app. Students shared their thoughts and answered the guide questions. Two mathematics education and one assessment and evaluation experts validated the instrument. After the five sessions, the journals were collected, and students' responses were consolidated. It was then analyzed using thematic data analysis, precisely an inductive approach. [Braun and Clarke \(2006\)](#) define thematic analysis as identifying, analyzing, and reporting recognized themes within data. This method helps researchers to describe and organize the gathered data in a detailed manner. This qualitative data analysis method is accessible, flexible, and increasingly popular ([Braun & Clarke, 2012](#)).

This study executed the compilation and organization of data from journal entries. Qualitative data were analyzed to report patterns/themes about students' experiences using the app. The participants checked their findings to confirm whether the analyzed data corresponded with their information. It was done to guarantee the accuracy of the data captured ([Brantlinger et al., 2005](#)).

## 3 Ethical procedures

The researcher observed all ethical procedures for the whole duration of the study. A letter of permission was asked first from the Director of the Integrated High School of West Visayas State University to implement the DIMaC application and gather the students' experiences of its use. The participants were assured that all data collected was confidential and only used for research purposes. Moreover, all participants were not subjected to any harm. In this study, pseudonyms were used; students 1-38.

## 4 DIMaC in the classroom

The Digital Interactive Math Comics (DIMaC) was used in the lesson discussion. The DIMaC app was distributed via a SHARE-it application to all the students in the class. After the teacher reviewed the last topic and presented the drills and lessons motivational activities, the DIMaC was utilized. A specific learning objective took 45 minutes to one hour of the class session. The teacher allotted time for every learning competency to read and interact with the DIMaC. There were intentionally left bubbles for some information to be answered by the students. After the third try, the teacher facilitated the students who could not give the correct answer. After the allotted

time, if some students were not finished with the topic, the teacher explained the remaining part on the board or called some representative students who could complete the task to provide the solutions. It was implemented for the other students to advance to the next task in the DIMaC. The teacher facilitated the lessons.

This application can be used by just “swiping left” to advance to the next scene or conversation. The question posed in the DIMaC must be first answered correctly before moving to the next scene. If students answered incorrectly, they could not proceed to the next stage.

## 5 Results and discussion

After five sessions of implementing the DIMaC application, the 38 students who gained first-hand experience with the app rated its acceptability in the classroom. Table 2 presents the evaluation of the students on the DIMaC’s acceptability on the eight criteria. Results show that the content, instructional quality, technical quality, storyline, interactivity and feedback, presentation and organization, the accuracy of the information, and assessment features of the application were acceptable. It means that all significant aspects of instruction and work were covered. Also, the quality of the application for classroom use is above average, as perceived by the students. The highest among the criteria is Assessment ( $M=3.44$ ,  $SD=0.54$ ). It could have happened because, per observation by the teacher during the implementation, students were engaged in answering the math questions posed. The lowest in the criteria is Technical quality ( $M=3.08$ ,  $SD=0.60$ ). It could have resulted from some bugs and errors the app incurred in the implementation. The students’ suggestions for the betterment of the app may support this rating.

**Table 2** Students’ Evaluation on the Acceptability of DIMaC

Dimensions	N	SD	M	Description
Assessment	38	0.54	3.44	Acceptable
Presentation and Organization	38	0.50	3.37	Acceptable
Accuracy and Up-To-Datedness of Information	38	0.54	3.36	Acceptable
Storyline	38	0.47	3.33	Acceptable
Instructional Quality	38	0.52	3.32	Acceptable
Interactivity and Feedback	38	0.51	3.26	Acceptable
Content	38	0.49	3.25	Acceptable
Technical Quality	38	0.60	3.08	Acceptable
Total	38	0.53	3.30	Acceptable

**Note:** 3.51-4.00: Very Acceptable; 2.51-3.50: Acceptable; 1.51-2.50: Moderately Acceptable; 1.00-1.50: Barely Acceptable.

Results show similarities with [Nurdin et al. \(2020\)](#) study, where the students rated the contextually based comics above the practicality criteria. The authors concluded that comics could be an effective medium for mathematics learning. This confirms the study of [Marianthi et al. \(2001\)](#). Almost all the student-teachers held positive views about comics’ value as a teaching approach, and those interactive comics show positive student responses ([Rahmawati & Salam, 2019](#)). Similar results were found by [Sepriyanti and Tapia \(2018\)](#), where comics for topics on linear equations and inequalities were valid and very practical as rated by the students and teachers; hence, comics can be a medium of instruction in Mathematics. The use of comics in the teaching-learning process can motivate students ([Berkowitz & Packer, 2001](#); [Yang, 2003](#); [Toh, 2009](#)) and develop analytical and critical thinking skills ([Versaci, 2001](#); [Yang, 2003](#); [Rasiman & Pramasdyahsari, 2014](#)). It also supports the findings of [Farinella \(2018\)](#), who highlighted that digital comics help learners with no background knowledge of the subject matter. Finally, integrating narrative, ICT, and visual art present in the DIMaC with an element of multimodal nature can enhance readers’ engagement and facilitate learning ([Eilam & Poyas, 2010](#); [Farah et al., 2014](#)).

### 5.1 Students’ experiences on DIMaC

According to the students’ responses in their reflective daily journals, the DIMaC is genuinely an interactive mobile Mathematics application providing exciting visuals that supports their mathematics learning. Moreover, the following themes emerged about the DIMaC application; a) an interest booster, b) a well-thought instructional material, c) genuinely interactive and educational, and d) commendable for other learners.

#### 5.1.1 An interest booster

Using the DIMaC app in their class, students pointed out that it played a vital role in learning mathematics concepts. They highlighted that the app appeals to the youth, is convenient to use, and makes learning fun and enjoyable because of its entertaining value with challenging activities. Moreover, a relatable storyline made the DIMaC exciting and motivating to read and learn. Some of their responses are the following:

Student 5 said, “The app is exciting! It provides fun in learning. At the same time, it teaches the user about math lessons with fun and challenging activities. Aside from the learning, I could get, I was entertained and satisfied with the app.”

Student 16 emphasized, “In my opinion, the use of DIMaC as an educational medium was quite intriguing. It gave me the feeling of challenge and excitement to look forward to the story’s happenings by overcoming the given equations and queries in the application. I had to try my best to answer the obstacle in reading the given mathematical problems to know the protagonist’s love story flow in his high school life.”

Student 12 stressed, “It is fun to read about the story, no matter how simple. It has an excellent motivation to answer the questions, making it not dull. It has many exercises needed to understand the lessons better. Also, I find DIMaC interesting because it uses a different approach than the usual math lectures. It uses comic strips of vivid illustrations and exciting storylines to which the present learners will surely relate.”

Student 30 shared, “It was adorable and relatable with the game’s plethora of diverse characters and personalities, contributing some more spice, drama, or comedy to the story.”

Some of them pointed out that since it is interesting to use the app, they can use it anywhere during their spare time. Moreover, the material is suitable for reviewing Math concepts. Most of them said, “I find it interesting since I could learn math in a fun way without stressing myself out. I could also use it during my free time. Therefore, I can still study on my way to school or wait for my teachers to arrive”. “It can help us review. Also, the story is exciting and would be an excellent way to bond with friends while answering the questions.”

### 5.1.2 A well-thought instructional material

The students in the implementation phase lauded the DIMaC app because of its uniqueness. It does not just contain Math content but has a blend of an exciting love story. Some were even intrigued to know what the app was all about. The following were some of their responses:

Student 1 said, “I think it is an innovative procedure in learning mathematics, especially among 21st-century learners inclined to use technology. It is a unique experience. I have never seen this kind of game: a combination of a quiz game and webtoons. Probably, it is the first of its kind. I cannot wait to play more, especially with my friends.”

Most students pointed out that the app development is well-planned, with excellent graphics and design pleasing to the eye, appropriate content, and function doing what it is designed to do. Five of the students shared that, “It has good content. The topics are well-planned and placed in the story. The illustrations, layout, and design are of high quality, and it is not too distracting or too much. The designs are simple but enjoyable enough to help the student gain interest.”

The same experience by student 26, who emphasized, “The illustrations were cute and very anime-like. Each character was unique and looked like typical Filipino students, making them more attractive and relatable. The layout was simple but effective; there was just enough dialogue, and the designs were catching but not exceptionally so as not to distract the readers. All in all, it was an outstanding balance.”

Furthermore, student 38 commented, “It was easy to swipe, tap, and manoeuvre the panels in the game. The things to click on were self-explanatory and easy to figure out.”

### 5.1.3 Truly interactive and educational

Students in their journal entries emphasized that using the DIMaC app as an aid in the discussion is genuinely interactive. While they are interested in the storyline, they are more excited to answer the part where they will supply the correct answer to proceed to the next page/scene for them not to be left hanging on the thrilling plot. Students highlighted the following:

Student 20 shared, “I like how it is all right to make mistakes in the answers in the game. It encourages interaction between the student and mathematics, and it is fun to feel like a part of the story.”

Student 32 supported saying, “I had fun interacting with the app because it has more to offer than just plain solving; it has a story. It is a convenient and creative way to allow students to learn and practice. Moreover, it is very interactive since it added various elements to make it fun while learning instead of just a regular game.”

Furthermore, students noted that using the app for Math lessons is educational. It provides facts so students can understand the experience at a gradual level of difficulty. Some noted the following:

Student 4 highlighted, “It helped me understand the math concepts better by teaching me the lesson rather than giving me exercises to test what I’ve learned.”

Student 12 emphasized, “I think DIMaC helps students understand the concepts in Math because they see to it that they read the story so that they can proceed to the next level. Also, it incorporates notes with a reasonable explanation in the content.”



The same experience by student 21, “Though the storyline is page by page, there is a step-by-step guide on approaching the item to be answered. The app also tells you whether your answer is right or wrong and allows you to try again until you get the answer right. Therefore, it makes way for a broader understanding of the concepts through the repetitive answering of questions from a particular topic while holding you in suspense about what will happen next. That is why; DIMAC helped us understand the math concepts because the storyline provided notes and explanations before giving users questions (which is interactive).”

#### 5.1.4 Commendable for other learners

As students noted, the app is exciting and has a love storyline, appropriate content, and working interactivity; hence, they would like to recommend it to others like their peers. They further emphasized that their peers will also like it, especially those who hate Mathematics. Some of their responses were:

Student 2 said, “We all know that students sacrifice learning and productivity involving school work, and this app allows the students not to sacrifice any of these by incorporating entertainment and learning. I would recommend my friends the use of DIMAC in their math class because it is a less annoying way of learning, so that will surely keep the students enjoying it while at the same time being productive.”

Student 6 shared, “I would recommend it to my friend since we have loved the mobile devices in our generation. If we cannot eradicate this problem, we can at least divert our mobile devices from social media to interactive learning apps like DIMAC.”

Finally, student 22 stressed, “I would recommend it because not all of us can understand math easily, like the others, and DIMAC can make the students interact while learning. It can also be a way to make math enjoyable for the students to pique their interest in the story while learning simultaneously.”

Students’ favourable view of DIMaC as an interest booster, well-thought instructional material, interactive and educational, and commendable for other learners supports [Cleaver \(2008\)](#). Teachers consider comics as potential educational tools to arouse students’ interest in academic subjects ([Cleaver, 2008](#)). According to [Marianthi et al. \(2001\)](#), digital comics is an innovative instruction tool. The approach was interesting based on the student teachers who used it because they can learn through playing. Also, when students create their comics about mathematical concepts, they are engaged in artistic processes, supporting the development of problem-solving, representation, and communication skills ([Francis et al., 2009](#)).

[Silva et al. \(2016\)](#) emphasized that comics presentation as a teaching strategy enhances competence development, develops innovation and flexibility, and reduces the gap between theory and practice. It could be why the students are engaged in the teaching-learning process. The use of comics can improve students’ academic performance ([Cervesato, 2011](#)), class participation in Mathematical discourse ([Halimun, 2011](#)), and critical thinking skills ([Versaci, 2001](#); [Rasiman & Pramasdyahsari, 2014](#)). Furthermore, this acceptable rating may support that of [Sengül and Dereli \(2010\)](#). They have reported that cartoons in comics decrease students’ mathematics anxiety, resulting in the emotional connection between students and the characters of a comic’s story. Because of this emotional involvement, learning can improve the memory essential to recall the subject matter ([Hima et al., 2016](#)). Finally, researchers have presented that visuals are remembered longer than words because visuals support the emotional impact ([Barianos et al., 2022](#); [Kimball & Hawkins, 2008](#); [Kostelnick & Roberts, 2010](#); [Schafer, 1995](#); [Schriver, 1997](#); [Tuft, 2003](#); [Statton, 2018](#)). It further reinforces that verbal statements with images promote concentration and concretization ([Xezonaki, 2022](#); [Uzuner et al., 2010](#); [Özkubat & Ulutaş, 2017](#)).

## 5.2 Students’ feedback for the betterment of DIMaC app

As stated by the students in their journals, some considerations for the betterment of the DIMaC were solicited. Students pointed out that future researchers may develop better versions of the app considering the following attributes. Technical issues must be fixed, like lags, bugs, and crashes, before the final distribution of the DIMaC app. It must also be compatible with many phone operating systems, including laptops, so that everybody will get a chance to explore it. A little music/audio would help and could make it more appealing. A more colourful and better representation of graphics and real-life examples should be illustrated. Another genre of storylines should be included to have a surprising turn of events. Putting animations and providing even more Math examples to aid in better understanding must also be addressed.

## 5.3 Suggestions

Future researchers and mobile application developers may use this study as a reference if they are to pursue a related study. They can modify the processes and make their versions of DIMaC,

like considering other story genres, adding sound effects and animations, and different ways of usage/implementation. Finally, it is highly recommended to determine the DIMaC's effectiveness in improving students' academic performance, motivation, and problem-solving skills.

## 6 Conclusions and recommendations

The study aimed to ascertain the students' evaluation and learning experience on the developed interactive mobile application in Mathematics, the DIMaC App. The developed DIMaC application was acceptable for the students in all eight instructional material development criteria for non-print materials. Digital Interactive Math Comics (DIMaC) solicited positive experiences because the app is unique and caters to 21<sup>st</sup> century learners who are considered digital Natives. It may indicate that the way DIMaC was presented from the exciting storyline, appropriate contents, smooth interactivity, pleasant use of graphics, up-to-date information, and engaging assessment techniques were well-thought and indeed an exciting novel instructional material. Thus, the DIMaC application conformed to the standards of instructional material development.

The positive results of students' evaluation and learning experience indicate the DIMaC's acceptability for classroom use. The DIMaC could help motivate learners to acquire mathematical concepts interestingly. It is also possible that students' mathematics performance would improve when they utilize the DIMaC in the classroom. This research's primary goal was to contribute to today's digital native learners to engage in the teaching-learning process.

The developed Digital Interactive Math Comics (DIMaC) has contributed to positive experiences for the students who utilized it in their math class. They further emphasized that the visuals' availability with an engaging storyline helped them learn the concept quickly and with interest. The pleasant use of graphics/visuals aided in the concept acquisition. It supports the Cognitive Theory of Multimedia Learning by Mayer (2005). This principle is also known as the multimedia principle. It states that people learn faster when using words and pictures than just words alone—using the DIMaC application in the classroom adhered to the principle. The learners are provided with texts discussing the math contents and exciting visuals. Furthermore, the positive learning experiences that the students acquired in the app strengthen the fact that with pictures and words, learners learn more deeply.

It is recommended that the need for more ICT-integrated instructional material like Digital Interactive Math Comics (DIMaC) in classroom instruction may be the top priority of policymakers and all school stakeholders in the country. Teachers should consider using DIMaC and find more ways to engage the students in the teaching-learning process. They need to remember that learners dealt with are 21st-century learners or digital natives. Finally, students' differences must be catered to (Ycong et al., 2021) by providing varied instructional opportunities to all students (Sugano & Mamolo, 2021) to achieve optimum learning.

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## Conflicts of interest

The author declares that they have no conflict of interest.

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