Journal of Education and Learning (EduLearn)
Vol. 20, No. 1, February 2026, pp. 590~599
ISSN: 2089-9823 DOI: 10.11591/edulearn.v20i1.22776

DIMenGeComS in action: evaluating its effectiveness on Mendelian genetics education

Azriel P. Barrientos[1], Monera A. Salic-Hairulla[2], Sotero O. Malayao Jr.[2], Saddam C. Bazer[3], Joy B. Bagaloyos[4]
[1]College of Education, Department of Secondary Education, Caraga State University, Butuan City, Philippines
[2]College of Education, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines
[3]College of Education, University of the Philippines Diliman, Quezon City, Philippines
[4]Integrated Developmental School, Department of Science and Research, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines

Article Info

Article history:

Received Jul 15, 2024
Revised Feb 20, 2025
Accepted Mar 19, 2025

Keywords:

ADDIE approach
Comic-based learning
Conceptual understanding
Digital interactive comic stories
Mendelian genetics
Normalized gain

ABSTRACT

The primary goal of this study is to improve the understanding of Mendelian genetics among Grade 8 students through the use of digital interactive Mendelian genetic comic stories (DIMenGeComS). This research contributes to the field of education by providing an innovative and engaging method to teach complex genetic concepts. Utilizing a sequential explanatory mixed-methods research design, this study involved pretests and posttests to measure the effectiveness of DIMenGeComS. The key findings indicate a significant improvement in the students' comprehension of Mendelian genetics as specified by normalized gain scores in sections such as Linnaeus (0.57), and Sampaguita (0.69), all of which were medium to approaching high-class gain and had significant probabilities ($p<0.0001$) less than 0.05 level of significance. These results suggest that DIMenGeComS can be a valuable tool in science education, offering the potential for further research into its application in other areas of the curriculum.

Corresponding Author:

Azriel P. Barrientos
College of Education, Department of Secondary Education, Caraga State University
Butuan City 8600, Philippines
Email: apbarrientos@carsu.edu.ph

1. INTRODUCTION

The Philippine education system continues to face obstacles, such as low scores on international exams and persistent difficulties integrating digital interactive resources and instructional methodologies into the K-12 curriculum, particularly in science education [1]–[3]. Despite the importance of Mendelian genetics in biology instruction, students encounter significant cha llenges due to common misconceptions and difficulties comprehending fundamental concepts [4]. In addition, the comprehensive needs assessment of grade 9 students and science teachers which was carried out as part of this study's topic analyses [5] and several studies have illuminated important obstacles, experiences, and problems related to teaching and learning Mendelian genetics [6]–[11]. This project aims to bridge a major gap in genetics education by investigating the effectiveness of digital interactive comic novels as a cutting-edge teaching tool [12]–[18]. It focuses on phenotypic trait prediction based on straightforward inheritance patterns, a topic that has not gotten enough attention in the Philippine setting. Specifically, the results of a study [19] on the least mastered competencies in biology revealed that the learning competency "Predict phenotypic expressions of traits following simple patterns of inheritance," had a mean of 2.23 (SD=0.84) which was interpreted to have low mastery (LM). According to students' responses to open-ended questions, some of the causes of the students'

low mastery are inadequate conceptual understanding, lack of motivation, inadequate discussion, poor retention, inadequate prior understanding of the subject matter, and dislike of science classes [19].

However, Samosa [18] taught biology using comics as a tactical intervention strategy. The respondents, who had difficulty understanding photosynthesis, were specifically chosen by the researcher from a secondary school in the San Jose del Monte Bulacan Schools Division. The results demonstrated that there was a significant difference between the students' pretest and posttest scores when it came to teaching biology concepts, particularly photosynthesis. Following their exposure to the developed content, the pretest mean score was lower than the posttest means scores. Additionally, following their exposure to the material, the students gave excellent feedback regarding studying biological ideas.

Furthermore, a study in 2021 [20] on the use of comic-based learning modules in physics found that it improved students' conceptual understanding and motivation toward learning physics. Similarly, comic-based learning offers a lively and captivating method of imparting difficult scientific ideas to pupils, encouraging their understanding and excitement [20], [21]. In addition, Enteria and Casumpang [22] carried out research locally in which they created comic strips and used the materials to examine how well an educational resource taught particular science ideas. The students who received assistance in creating comic strips outperformed the control group, according to the data. They had spoken about how science topics may be effectively taught using comic strips as a developed teaching tool. Additionally, the professional assessors thought that the created comic strips had great potential for usage in a teaching environment.

While it is well established that instructional comics can enhance students' understanding and engagement in various scientific subjects [21], digital interactive comic stories have not yet been utilized to teach Mendelian genetics in the Philippines. This study has anchored its objectives to the dual coding theory (DCT) [23], which contends that combining verbal and visual information improves learning by using both mental imagery and linguistic representations. Using this idea, digital interactive Mendelian genetics comic Stories (DIMenGeComS) improve students' understanding and memorization of Mendelian genetics by emphasizing trait phenotypic expression prediction. This strategy is supported by multimedia learning theory [24], which highlights the value of fusing words and images to promote deeper learning.

These interactive comic stories aim to provide a user-friendly platform for studying Mendelian genetics by addressing the challenges teachers face when integrating new technologies into their lesson plans. This study aims to: i) evaluate the effectiveness of DIMenGeComS in enhancing students' understanding of Mendelian genetics, particularly in predicting phenotypic expressions of traits and ii) explore the potential of DIMenGeComS in addressing challenges faced by science teachers in integrating new technologies into their teaching methodologies. By addressing these objectives, this research seeks to contribute to the development of research-based instructional resources that enhance biology education, ultimately improving students' conceptual knowledge and learning outcomes [4]. This study intends to increase the quality of science education and improve conceptual knowledge and understanding among high school students especially in the Philippines by integrating cutting-edge digital interactive tools with traditional teaching methodologies.

2. METHOD

2.1. Research design

In this study, DIMenGeComS were developed and evaluated using the ADDIE approach, as previously outlined in 2011 [25]. At Iligan City National High School-Main Campus (ICNHS-Main Campus), the DIMenGeComS was integrated into the curriculum during the implementation phase. Instructors received training on how to integrate the newly created digital interactive resources into their Mendelian genetics lesson. Pretests, posttests, and teacher and student feedback were used to gather data during the evaluation phase. This allowed us to determine how well DIMenGeComS was able to improve students' comprehension of Mendelian genetics and make the required adjustments to improve the quality of education.

2.2. Research subjects

The research subjects of the study were two sections of grade 8 students of ICNHS-Main Campus who were selected through purposive sampling. The inclusion criteria for the subjects are: i) currently enrolled in grade 8; ii) have not undergone any formal lessons on Mendelian genetics; iii) have no medical or learning conditions that may affect their ability to learn; iv) have secured the consent of their parents or guardians; and v) with mobile gadget/phone. Excluded from the study would be: i) grade 8 students who have previously undergone structured instruction in Mendelian genetics; ii) those with medical or learning disorders affecting comprehension; and iii) those lacking parental or guardian consent.

2.3. Data gathering procedure

Using the analyze, design, develop, implement, and evaluate (ADDIE) paradigm as a guide, the DIMenGeComS intervention was carefully designed to address needs that were found during the analysis phase

of the assessment. By combining concepts from inheritance, probability, and practical applications, the goal is to increase students' understanding of the fundamental ideas of Mendelian genetics. Using the ADDIE model's analysis phase as a guide, the researcher created the DIMenGeComS's narrative and design. This made it clear to the researcher where attention should be paid to the DIMenGeComS content. After the researcher established the storyline, various experts in the field (1 biology education expert and 1 English expert) checked for the validity of the content including grammar and suggestions on the storyline's improvement. The story then went to the illustrator for the sketches with the experts' comments and suggestions.

Subsequently, the designed illustration was sent to a programmer who coded and programmed it for usage on mobile devices, enabling interactive functionality as intended. The programmer finished writing the DIMenGeComS app's code in two weeks. The adviser, researcher, and panel experts reviewed the final product. All feedback was incorporated into the DIMenGeComS until the validity was confirmed by the experts. The programmer upgraded the application ten times in total during the project.

The DIMenGeComS intervention was then implemented in 2 sections (Linnaeus and Sampaguita) of grade 8 students at ICNHS-Main Campus. Pretests and posttests, consisting of a validated and reliable 30-multiple choice researcher-made achievement test, were administered to measure changes in students' conceptual understanding of Mendelian genetics. The DIMenGeComS intervention was accessed through the developed mobile application. It was shared through either a share-it app, Bluetooth, Easy Share, Nearby Share, or any other channels whichever is applicable.

The teacher handling the subject facilitated the implementation procedure with assistance from the researcher. She administered the pretest questionnaire before the intervention to her grade 8 students. After answering the pretest, the teacher then allowed the students to open the DIMenGeComS app through their mobile devices, assessing the intervention's impact. A posttest was then given after exposure to the intervention.

2.4. Data analysis

The Experts' Evaluation Ratings were examined by mean calculation and standard deviation in the meantime, providing a numerical viewpoint on comprehension, interest, aesthetic appeal, interactivity, and overall efficacy of the DIMenGeComS while the paired samples t-test, frequency count, mean, standard deviation, percentage, and normalized gain score were used to interpret the results from the achievement tests.

2.5. Normalized gain

In this study, the normalized gain was employed to assess students' conceptual understanding of Mendelian genetics, particularly about the prediction of phenotypic traits based on simple inheritance patterns. First introduced by Hake [26], normalized gain is a widely used measure of educational effectiveness and conceptual knowledge growth. It is currently the recognized metric for reporting concept inventory ratings derived from research-based evaluations. The normalized gain is a useful metric that sheds light on how well the DIMenGeComS intervention supports students' conceptual understanding. This metric provided a detailed assessment of the impact of the intervention on the learning outcomes of the students by quantifying the relative increase in their understanding of Mendelian genetics principles. The amount of the increment is the normalized gain value. A positive increase would equate to low, medium, and high gain from pretest to posttest [27]. Negative gains would suggest that the intervention was ineffective or even detrimental, whereas zero gains would point to a stable response. By using normalized gain, the researcher can better understand whether learners require additional attention based on their gain score or determine whether the intervention is effective if there is no negative gain.

3. RESULTS AND DISCUSSION

3.1. DIMenGeComS evaluation results

Table 1 presents the evaluation findings for the DIMenGeComS from seven specialists in the domains of biology and technology education. Overall, the results showed that the DIMenGeComS had excellent acceptance and general validity (M=3.69). Furthermore, twelve out of the fourteen categories on the acceptability questionnaire were rated as excellent, and the two that were left were rated as very good [5]. This shows that the DIMenGeComS adequately covers all areas of education and work, and the overall quality of the job is excellent. The researcher's creation of educational resources that cater to the demands of students in the twenty-first century was also commended by the experts. Additionally, they highlighted how distinctive, creative, alluring, and fascinating the DIMenGeComS is.

Additionally, they offered some suggestions for how to use and enhance the DIMenGeComS in the classroom. Similar results were noted by a study [28], which developed a comic-based method for solving geometry problems and found that all of its validation criteria were rated as "very good." The factors that

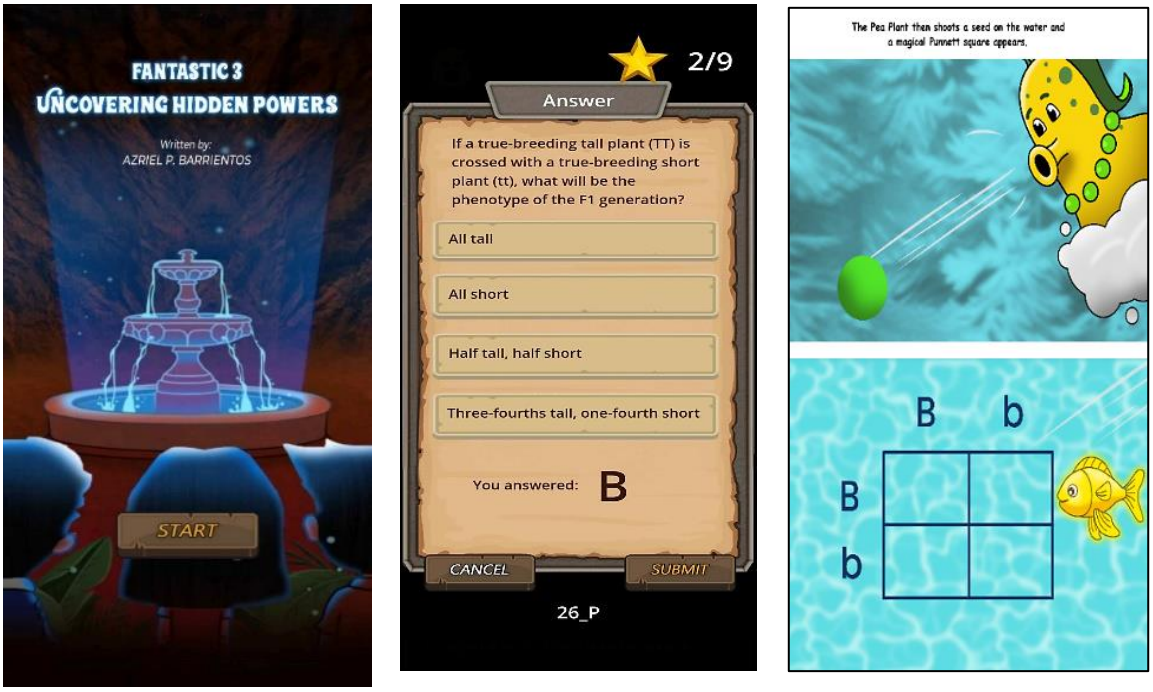
were considered included writing, organization, content, language and readability, humor structure, and presentation. According to Yang [29], comics are visually stimulating, timeless, widely accepted, and can promote critical and analytical thinking skills. For these reasons, the experts might have considered digital interactive comics to be highly acceptable and a great teaching tool for enhancing conceptual understanding of Mendelian genetics [6].

The DIMenGeComS app interface and features are illustrated in Figure 1, which presents key components of the developed digital interactive comic. The figure as a whole showcase how the app integrates narrative, problem-solving, and assessment elements to enhance student engagement and conceptual understanding in Mendelian genetics [5]. Specifically, Figure 1(a) shows the title page that welcomes users into the storyline; Figure 1(b) presents a sample word-problem page embedded in the narrative, which functions as a formative assessment; and Figure 1(c) displays an example of a Punnett-square problem page that visually represents inheritance patterns through interactive elements. Each page of the DIMenGeComS app is designed to ensure students comprehend the flow of the story while solving embedded problems that lock progression until the correct solution is given. A grading system awards up to nine-star points at the end of the story to signify task completion, encouraging accuracy and persistence through the "right-minus-wrong" scoring mechanism.

Table 1. Experts' evaluation rating to the developed DIMenGeComS

Dimensions	n	SD	Mean (M)	Description
Content	7	0.38	3.86	Excellent
Content accuracy	7	0.38	3.86	Excellent
Spelling and grammar	7	0.49	3.71	Excellent
Word accuracy	7	0.38	3.86	Excellent
Vocabulary	7	0.53	3.57	Excellent
Word-picture combination	7	0.00	4.00	Excellent
Graphics relevance	7	0.49	3.71	Excellent
Background design	7	0.00	4.00	Excellent
Font and formatting	7	0.90	3.14	Very good
Sequencing of information	7	0.49	3.71	Excellent
User-friendliness	7	0.53	3.57	Excellent
Feedback mechanism	7	1.00	3.00	Very good
Interactivity integration	7	0.49	3.71	Excellent
Impact	7	0.00	4.00	Excellent
Total	7	0.56	3.69	Excellent

Legend: excellent=3.25-4.00; very good=2.50–3.24; good=1.75-2.49; and needs improvement=1.00-1.54.



(a) (b) (c)

Figure 1. DIMenGeComS: (a) title page, (b) sample word-problem page, and (c) sample Punnett problem

3.2. DIMenGeComS' effectiveness in improving the understanding of Mendelian genetics among grade 8 students

Table 2 shows the summary of the pretest and posttest results of grade 8 students from section Linnaeus during the final implementation of the DIMenGeComS intervention at ICNHS-Main Campus. As observed from the pretest results, nobody got a grade of 85 or above and only 6.45% of the students got a satisfactory score and 3.23% got a fairly satisfactory score. The remaining 90.32% did not meet expectations according to their pretest results. However, during the posttest that was done after the exposure to the DIMenGeComS, 16.13% of the students got an outstanding score, meanwhile, 19.35% got very satisfactory scores, 25.81% got Satisfactory scores, and 25.81% or 8 students got fairly satisfactory scores. Finally, fewer students did not meet expectations from pretest results to posttest results i.e., from 28 students down to four students, indicating that the material had the potential to enhance students' conceptual understanding of Mendelian genetics. From the initial results of the pilot testing which the material was also found to be effective, a similar and more positive result was yielded upon refinement of the DIMenGeComS before the full-scale implementation. Similar findings are consistent with several research [20], [22], which demonstrated a noteworthy variation in respondents' performance when using comics. Furthermore, a study from 2021 [30], which examined the impact of digital comics on distance learning during the COVID-19 pandemic, had more depth. They talked about how the students' academic performance had improved because of using digital interactive comics.

Table 2. Summary of pretest and posttest from final implementation with 31 student participants from ICNHS-Main Campus section Linnaeus

Grading scale	Descriptor	Pretest		Posttest	
		Frequency	Percent	Frequency	Percent
90-100	Outstanding	-	-	5	16.13
85-89	Very satisfactory	-	-	6	19.35
80-84	Satisfactory	2	6.45	8	25.81
75-79	Fairly satisfactory	1	3.23	8	25.81
Below 75	Did not meet expectations	28	90.32	4	12.90
	Total	31	100	31	100
	Mean	58.28		81.94	
Standard deviation		3.45		2.22	

The dynamic and engaging features of the DIMenGeComS are responsible for the notable gains in posttest results. Students find abstract genetic concepts more relevant and concrete when story elements are incorporated with scientific knowledge. This is consistent with the dual-coding theory [23], which contends that information presented in both verbal and visual forms is more likely to be comprehended and kept. Comics, a type of multimodal writing, make good use of this idea by fusing text and graphics to explain difficult concepts. According to research [31], comics have the power to captivate readers through visual storytelling, which makes them a useful teaching tool. Through visual metaphors and analogies, comics can help simplify difficult processes, like Mendelian genetics, in the context of science education. According to the cognitive theory of multimedia learning [24], which contends that effectively created multimedia instructional messages can improve comprehension and retention of material, this visual reduction facilitates cognitive processing.

Moreover, the noteworthy decrease in the count of pupils who failed to reach the expected standards (from 28 to 4) highlights the capability of DIMenGeComS to tackle educational deficiencies. This increase in interest and motivation among students is suggestive of improved comprehension as well. Comics have been demonstrated to boost student attention and enthusiasm, which is important for learning [32]. Students are more likely to put effort into their studies and produce higher results when they are more interested.

Table 3 shows the summary of the pretest and posttest results of grade 8 students from section Sampaguita during the final implementation of the DIMenGeComS intervention at ICNHS-Main Campus. As observed from the pretest results, nobody got a grade of 80 or above and only 1 student got a Fairly satisfactory score. The remaining 44 students did not meet expectations according to their pretest results. However, during the posttest that was done after the exposure to the DIMenGeComS, 24.44% of the students got an outstanding score, meanwhile, 17.78% got Very satisfactory scores, 44.44% got Satisfactory scores, and 8.89% or 4 students got fairly satisfactory scores. Finally, fewer students did not meet expectations from pretest results to posttest results i.e., from 44 students down to two students, indicating that the material again had the potential to enhance students' conceptual understanding of Mendelian genetics for this section. Even better results were again obtained during the full-scale implementation of the DIMenGeComS tool after it was refined based on the first results of the pilot testing phase when the educational content was found to be effective. These findings are consistent with previous studies that have shown the effectiveness of interactive and visual learning tools in

improving student comprehension [18], [20], [22], [28]. The said studies discussed that there is a significant increase in the conceptual understanding of the topics and the motivation of the students after undergoing science classes with comics-based learning modules. This result is supported by the significant difference in the results of t-tests and students' interviews [20]. DIMenGeComS provides an engaging platform that helps students visualize and understand genetic concepts. The process of iterative improvement demonstrates the effectiveness and ongoing refinement of the teaching tool.

The significant improvements observed in the posttest scores indicate the effectiveness of DIMenGeComS in facilitating a deeper understanding of Mendelian genetics among students. The impressive mean score improvement from 49.63 in the pretest to 84.59 in the posttest illustrates this educational tool's capacity to change students' lives. This is consistent with the research [20], which showed that interactive materials and visual aids greatly improve students' understanding of difficult scientific ideas.

Especially striking is the drop from 44 to 2 pupils who did not achieve expectations. This notable enhancement highlights DIMenGeComS's ability to meet a wide range of learning requirements and close comprehension gaps. Learning can be made more accessible to students with different abilities by using visual-spatial representations, as proposed by a study [33]. Additionally, the change in the distribution of grades notable growth in the proportion of students receiving excellent and satisfactory ratings reflects the influence of interactive learning tools on student motivation. Comics and graphic novels have the power to hold pupils' interest and cultivate a good attitude toward learning, per a study [34]. The better performance shown in the posttest findings was potentially caused by this enhanced involvement.

Tables 4 and 5 present the analysis using paired samples t-test between the pretest and posttest scores of grades 8 students from sections Linnaeus and Sampaguita, respectively. Based on the results, the differences between the means of the test scores are 7.10 and 10.49, respectively. It yielded a t-value of 13.72 and 21.92, respectively with a computed probability value of <0.0001, which is less than 0.05 significance level for both sections. Hence, the null hypothesis was completely rejected, and the researchers concluded that there is indeed a significant difference in the normalized gain scores between the pretest and posttest of grade 8 students in ICNHS-Main Campus who underwent the DIMenGeComS intervention with a medium-level to approaching high-class gain of 57% and 69%, respectively. This also implies that the material was effective in enhancing the students' conceptual understanding of Mendelian genetics after its exposure. The results of this study are in line with the larger corpus of studies looking into the effectiveness of comic books as a teaching medium. Comics have a big impact on learning environments, as evidenced by several studies [9], [11].

Table 3. Summary of pre-test and post-test from final implementation with 31 student participants from ICNHS-Main Campus section Sampaguita

Grading scale	Descriptor	Pretest		Posttest	
		Frequency	Percent	Frequency	Percent
90-100	Outstanding	-	-	11	24.44
85-89	Very satisfactory	-	-	8	17.78
80-84	Satisfactory	-	-	20	44.44
75-79	Fairly satisfactory	1	2.22	4	8.89
Below 75	Did not meet expectations	44	97.78	2	4.44
	Total	45	100	45	100
	Mean	49.63		84.59	
	Standard deviation	3.43		1.93	

Table 4. Significant difference between pretest and posttest scores from final implementation with 31 student participants from ICNHS-Main Campus section Linnaeus

Test	Mean difference	t-statistics	p-value	Normalized gain	Interpretation
Pretest Posttest	7.10	13.72	<0.0001	0.57	Significant

Table 5. Significant difference between pretest and posttest scores from final implementation with 45 student participants from ICNHS-Main Campus section Sampaguita

Test	Mean difference	t-statistics	p-value	Normalized gain	Interpretation
Pretest Posttest	10.49	21.92	<0.0001	0.69	Significant

H_0: there is no significant difference in the normalized gain scores between the pretest and posttest of grade 8 students in ICNHS-Main Campus who undergo the DIMenGeComS intervention. Significant at $p<0.05$ alpha level.

The distinct qualities of comics as an instructional medium account for the notable increase in test results following the intervention. Comics mix textual and visual aspects to offer a multimodal learning experience that can accommodate various learning preferences. Comics' sequential graphics and storytelling, which can help make difficult subjects more approachable and remembered, are said to captivate students [31], [32]. Students in this study were able to visualize genetic concepts and processes because to the usage of DIMenGeComS, which probably improved comprehension. According to a study [33], which highlights the value of spatial thinking in science instruction, students can better understand abstract ideas when they are given visual aids. This is consistent with the performance gains that have been seen in the students, as DIMenGeComS's interactive features potentially improved their conceptual and spatial grasp of genetics.

The results align with research [34] on the visual language of comics, which emphasizes how sequential images' structure and meaning can support learning. DIMenGeComS potentially decreased cognitive burden or overload and improved learning outcomes by segmenting genetic topics into chunks, digestible, and aesthetically pleasing parts.

These investigations further show that when given educational material in the form of comic books, students perform better and have better comprehension. Comics draw in students and hold their interest through their visual and narrative components, which basically simplify and make learning difficult and complex ideas more fun. This has been consistent with the cognitive theory of multimedia learning, which postulates that effective learning outcomes are enhanced by the combination of verbal and visual information. Additionally, Samosa's [18] study expands on these conclusions by concentrating on the application of comics as a tactical intervention strategy for teaching biological topics like photosynthesis. The study found a significant difference between the pretest and posttest results for the students, showing that exposure to the created comic-based educational material significantly improved their understanding. This demonstrates how comics have the power to improve academic achievement as well as cultivate a positive attitude toward learning challenging scientific ideas. Students seem to connect well with comics' visual storytelling element, which promotes active participation and helps them understand concepts more deeply. This, in turn, leads to better learning results. Furthermore, a study in 2019 [35] emphasizes how realistic information, entertaining artwork, and humor are all combined in scientifically created comic books to improve science learning. Positive reactions to the humor and scientific information are evident in expert evaluations, suggesting that students find the visual and narrative links in science instruction engaging. In general, science comics that combine humor and careful design can potentially and effectively pique students' interest and improve their understanding of scientific ideas and concepts.

4. CONCLUSION

This study demonstrates how DIMenGeComS can successfully address persistent issues in genetics teaching. DIMenGeComS has received high marks, with an overall quality rating of 3.69 out of 4, by incorporating feedback from literature reviews, needs assessments, and pilot testing. Students' comprehension and interest in Mendelian genetics have been greatly increased by the application of dual coding and multimedia learning theories. The data shows that students' conceptual understanding has significantly improved; normalized gain scores for Linnaeus and Sampaguita are 0.57 and 0.69, respectively, indicating medium to high gains. These outcomes, along with notable improvements in pre- and posttest scores (7.10 and 10.49, respectively), show how successful DIMenGeComS is in reaching its learning objectives.

Prospectively, there exist prospects to delve deeper into the assimilation of DIMenGeComS into diverse academic environments and its enduring impact on academic achievements. Prospective studies may explore the adaptability of this digital method to many subjects or academic levels, as well as its wider implications in the field of science education. DIMenGeComS lays the path for educational technology and instructional design advancement by fusing cutting-edge digital tools with conventional teaching methods. By addressing students' changing needs and promoting a more engaging learning environment, it principally highlights the potential for improving science education.

ACKNOWLEDGMENTS

The Department of Science and Technology-Science Education Institute-Philippines (DOST-SEI) is acknowledged by the researchers for financially supporting the study.

FUNDING INFORMATION

This research was supported by the Department of Science and Technology- Science Education Institute (DOST-SEI) under the grant of Capacity Building Program in Science and Mathematics Education

(CBPSME), which provided the necessary resources in the development and implementation of DIMenGeComS.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Azriel P. Barrientos	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Monera A. Salic-Hairulla	✓	✓		✓			✓	✓		✓	✓	✓	✓	✓
Sotero O. Malayao Jr.		✓		✓			✓	✓		✓	✓	✓	✓	✓
Saddam C. Bazer		✓		✓			✓	✓		✓		✓		✓
Joy B. Bagaloyos				✓			✓	✓		✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study, including parental or guardian consent for all student participants.

ETHICAL APPROVAL

The research involving human participants was conducted in accordance with institutional and national research ethics policies. It was approved by the College of Education Research Ethics Committee of Mindanao State University–Iligan Institute of Technology, as evidenced by the approval letter dated March 22, 2024.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [APB], upon reasonable request.

REFERENCES

[1] The World Bank and UNESCO Institute for Statistics, *Learning poverty: a global challenge*. Washington, DC: World Bank, 2022.
[2] OECD, *PISA 2018 assessment and analytical framework*. OECD Publishing, 2019, doi: 10.1787/b25efab8-en.
[3] OECD, *PISA 2022 results (volume I)*. OECD Publishing, 2023, doi: 10.1787/53f23881-en.
[4] D. V Rogayan and M. M. Albino, "Filipino students' common misconceptions in biology: input for remedial teaching," *Online Science Education Journal*, vol. 4, no. 2, pp. 90–103, 2019.
[5] A. P. Barrientos, M. A. Salic-Hairulla, S. O. Malayao Jr., S. C. Bazer, and J. P. Bagaloyos, "Development and evaluation of digital interactive Mendelian genetics comic stories (DIMenGeComs) for enhancing conceptual understanding of high school students," *International Journal of Research and Innovation in Social Science*, vol. VIII, no. IIIS, pp. 1293–1302, 2024, doi: 10.47772/IJRISS.2024.803088S.
[6] N. L. P. Lawsin and G. Garcia, "Development of digital courseware in transmission genetics," Philippine Normal University, 2017.
[7] N. Ozcan, "A group of students' and teachers' perceptions with respect to biology education at high school level," The Middle East Technical University, 2003.
[8] L. R and P. S, "High school students' difficulties in learning biology concepts," *Journal of Biological Education*, vol. 26, no. 3, pp. 215–224, 1992.

[9] C. Tekkaya, O. Ozkan, and S. Sungur, "Biology concepts perceived as difficult by Turkish high school students," *Journal Education*, pp. 145–150, 1999.
[10] A. Cimer, "What makes biology learning difficult and effective: students views," *Educational Research and Reviews*, vol. 3, no. 7, pp. 61–71, 2019.
[11] A. Zeidan, "The relationship between grade 11 palestinian attitudes toward biology and their perceptions of the biology learning environment," *International Journal of Science and Mathematics Education*, vol. 8, no. 5, pp. 783–800, 2010, doi: 10.1007/s10763-009-9185-8.
[12] L. A. Mamolo, "Development of digital interactive math comics (DIMaC) for senior high school students in general mathematics," *Cogent Education*, vol. 6, no. 1, 2019, doi: 10.1080/2331186X.2019.1689639.
[13] N. Akcanca, "An alternative teaching tool in science education: educational comics," *International Online Journal of Education and Teaching (IOJET)*, vol. 7, no. 4, pp. 1550–1570, 2020.
[14] Y. Topkaya, V. Batdi, D. Burak, and A. Özkaya, "The effectiveness of using comics in education: a meta-analytic and meta-thematic analysis study," *Ahmet Keleşoğlu Eğitim Fakültesi Dergisi*, Oct. 2023, doi: 10.38151/akef.2023.92.
[15] T. T. Lam, L. Hah, and W. Elena, "Helping normal technical students with learning mathematics-a preliminary survey," *Learning Science and Mathematics Online Journal*, vol. 1, pp. 1–10, 2014.
[16] T. L. TOH, L. P. CHENG, H. JIANG, and K. M. LIM, "Use of comics and storytelling in teaching mathematics," *Developing 21st Century Competencies in the Mathematics Classroom*, pp. 241–259, 2016, doi: 10.1142/9789813143623_0013.
[17] M. M. Yunus, H. Salehi, and M. A. Embi, "Effects of using digital comics to improve ESL writing," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 4, no. 18, pp. 3462–3469, 2012.
[18] R. C. Samosa, "Cosim (Comics Cum Sim): an Innovative material in teaching biology," *European Journal of Research Development and Sustainability*, vol. 2, no. 4, pp. 19–28, 2021.
[19] J. T. D. Santos, R. Lim, and D. V. J. Rogayan, "Least mastered competencies in biology: basis for instructional intervention," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 7, no. 3, pp. 208–221, 2021, doi: 10.22219/jpbi.v7i3.17106.
[20] J. M. Badeo and B. C. U. O. K. Koc, "Use of comic-based learning module in mechanics in enhancing students' conceptual understanding and motivation," *Science Education International*, vol. 32, no. 2, pp. 131–136, 2021.
[21] J. Hosler and K. B. Boomer, "Are comic books an effectiveway to engage nonmajors in learning and appreciating science?," *CBE Life Sciences Education*, vol. 10, no. 3, pp. 309–317, 2011, doi: 10.1187/cbe.10-07-0090.
[22] O. Enteria and P. F. H. Casumpang, "Effectiveness of developed comic strips as intructional materials in teaching specific science concepts," *International Journal for Innovation Education and Research*, vol. 7, no. 10, pp. 876–882, 2019, doi: 10.31686/ijier.vol7.iss10.1835.
[23] A. Paivio, *Imagery and verbal processes*. New York: Holt, Rinehart, and Winston, 1971.
[24] R. E. Mayer, "Multimedia learning," in *Psychology of Learning and Motivation*, B. H. Ross, Ed. San Diego, CA: Academic Press, 2002, vol. 41, pp. 85–139, doi: 10.1016/S0079-7421(02)80005-6.
[25] V. L. Creswell, J.W. and Plano Clark, *Designing and conducting mixed methods research*. Los Angeles: Sage Publications.
[26] R. R. Hake, "Interactive-engagement versus traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses," *American Journal of Physics*, vol. 66, no. 1, pp. 64–74, Jan. 1998, doi: 10.1119/1.18809.
[27] V. P. Coletta and J. J. Steinert, "Why normalized gain should continue to be used in analyzing preinstruction and postinstruction scores on concept inventories," *Physical Review Physics Education Research*, vol. 16, no. 1, 2020, doi: 10.1103/PhysRevPhysEducRes.16.010108.
[28] P. Pardimin and S. A. Widodo, "Development comic based problem solving in geometry," *International Electronic Journal of Mathematics Education*, vol. 12, no. 3, pp. 233–241, 2021, doi: 10.29333/iejme/611.
[29] G. Yang, "Comics in education," California State University at Hayward, 2003.
[30] G. O. İlhan, G. Kaba, and M. Sin, "Usage of digital comics in distance learning during COVID-19," *International Journal on Social and Education Sciences*, vol. 3, no. 1, pp. 161–179, 2021, doi: 10.46328/ijonses.106.
[31] S. McCloud, *Understanding comics: the invisible art*. New York: HarperCollins Publishers, 1994.
[32] G. E. Schwarz, "Graphic novels for multiple literacies," *Journal of Adolescent & Adult Literacy*, vol. 46, no. 3, pp. 262–265, 2002.
[33] M. Hegarty, "The role of spatial thinking in undergraduate science education," presented at the *Third Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research*, National Research Council, Washington, DC, Dec. 2011.
[34] N. Cohn, *The visual language of comics : introduction to the structure and cognition of sequential images*. London: Bloomsbury, 2013, doi: 10.5040/9781472542175.
[35] N. Roswati, N. Y. Rustaman, and I. Nugraha, "The development of science comic in human digestive system topic for junior high school students," *Journal of Science Learning*, vol. 3, no. 1, pp. 12–18, 2019, doi: 10.17509/jsl.v3i1.18120.

BIOGRAPHIES OF AUTHORS

Azriel P. Barrientos is an enthusiastic researcher in the field of science education. He received his bachelor's degree in secondary education and a master's degree in science education with a biology major at Mindanao State University-Iligan Institute of Technology. Currently, he works as an instructor at Caraga State University. His research focuses on both local and national patterns, driven by a commitment to addressing the educational challenges and problems of the status quo. His academic efforts have made him a prominent figure in the development of cutting-edge digital teaching and learning, showcasing his expertise in educational research. He can be contacted at email: azriel.barrientos@g.msuiit.edu.ph or apbarrientos@carsu.edu.ph.

Monera A. Salic-Hairulla is a prominent figure at MSU-IIT for 30 years, serving in various capacities, including lecturer, department chair, and project director. She holds a bachelor's in education in Biology, a master's in biology, and a PhD in SCIENCE EDUcation. Recognized for her excellence in teaching and research, she has presented over fifty papers internationally and has numerous publications in Scopus-indexed journals. Her research focuses on technology-enhanced biodiversity education. As dean of the College of Education and Project Director of the DOSTSEI CBPSME Program, she also contributes as a master trainer for intel teach. She is married to Dr. Munap Hairula and they have six children. She can be contacted at email: monera.salic@g.msuiit.edu.ph.

Sotero O. Malayao Jr. is an associate professor of Mindanao State Unversity belonging to the Department of Science and Mathematics Education. His works are mostly in the development of learning modalities ranging from instructional materials, pedagogical approaches, and capacitation of teachers in doing action research. His latest projects involve development of science reading materials and gamified learning. He can be contacted at email: sotero.malayao@g.msuiit.edu.ph.

Saddam C. Bazer is an assistant professor at the College of Education, University of the Philippines Diliman. He is a license professional teacher with a PhD degree in education. An expert in education research and education technology, he has over 10 years of experience working with more than 10 government and intergovernmental organizations. He has extensive experiences in supporting education innovations such as mother-tongue-based multilingual education, literacy and reading interventions, development of open educational resources, and contextualization and development of education programs and policies to suit various contexts. He has co-designed and co-implemented different programs and interventions that helped the marginalized children and youth-those most impacted by inequality and discrimination in geographically isolated, disadvantaged and conflict-affected areas. He can be contacted at email: scbazer@up.edu.ph.

Joy B. Bagaloyos is a professor of Mindanao State University-Iligan Institute of Technology and the chairperson of the science, research, and STEM Department of the Integrated Developmental School. She works on morphometric studies on shells in her doctoral dissertation. Presently, she works on the development of enrichment materials in difficult topics in biology. Our school is working on to be a center of pedagogical research and innovation in Mindanao in the near future. She can be contacted at email: joy.bagaloyos@g.msuiit.edu.ph.