Development and Evaluation of Digital Inter active mendelian Genetics Comic Stories (DIMenGeComs) For Enhancing Conceptual Understanding of High School Students

Azriel P. Barrientos[1], Monera A. Salic-Hairulla,[2], Sotero O. Malayao Jr.[3], Saddam C. Bazer[4], Joy P. Bagaloyos[5]

[1,2,3,4,5]Mindanao State University-Illigan Institute of Technology/College of Education, Department of Science and Mathematics Education

DOI: https://dx.doi.org/10.47772/IJRISS.2024.803088S

Received: 26 April 2024; Revised: 13 May 2024; Accepted: 17 May 2024; Published: 18 June 2024

ABSTRACT

The goal of this study is to amplify knowledge of Mendelian genetics, a difficult topic in Biology classes. The study used a multi-phase methodology, beginning with a needs assessment to identify teaching and learning challenges using structured surveys with teachers and students. The second phase integrated teacher and student feedback into developing a Digital Interactive Mendelian Comic Stories (DIMen Ge ComS) Intervention, utilizing a sequential explanatory mixed-methods research design following the ADDIE model. In the last stage, the intervention is implemented in a Grade 8 classroom, and the conceptual gain of the students is evaluated. Thematic analysis for qualitative insights, mean computation for rating scales, and normalized gain for quantitative assessment are examples of data analysis techniques used in the study. Moreover, ethically informed permission and participant anonymity were given top priority. The main objective is to develop and provide cutting-edge teaching tool that improves students' comprehension of and interest in Mendelian genetics. The developed DIMenGeComS received an "Excellent" rating from the 7 Biology and Technology experts indicating that all areas of education and work are sufficiently covered by the DIMenGeComS, and the overall caliber of the material is excellent. Ergo, the current study suggested implementing the material and employing conceptual gains from a pre-and post-test before and after the utilization of the DIMenGeComS to assess students' understanding of Mendelian genetics.

Keywords: Mendelian Genetics, conceptual gain, digital interactive comic stories, perception, comic-based learning

INTRODUCTION

Low scores on international assessments and continuous problems incorporating resources and instructional strategies into the K–12 curriculum, especially in science education, are two examples of the ongoing challenges facing the Philippine education system (Villegas, 2021; OECD PISA, 2018, 2022). Despite the significance of Mendelian genetics in Biology education, students face major obstacles because of widespread misunderstandings and trouble understanding basic ideas (Rogayan & Albino, 2019). By examining the efficacy of digital interactive comic stories as a cutting-edge teaching tool, this study seeks to close a significant gap in genetics education. It focuses on the area that hasn't received enough attention in the Philippine context: phenotypic trait prediction based on simple patterns of inheritance (Santos et al., 2021). In a local study, Samosa (2021) used comics as a tactical intervention technique for Biology instruction. The researcher deliberately selected the respondents from a secondary school in the San Jose del Monte Bulacan Schools Division who struggled to grasp photosynthesis. The results showed that, when it came to teaching Biology concepts, specifically photosynthesis, there was a significant difference between the students' pretest and posttest scores. When the students were exposed to the developed material, the pretest score had a lower mean than the posttest mean. Furthermore, the students responded positively about studying biological concepts after being exposed to the material. Further more, Mamolo (2019) produced digital interactive math comics (DIMaC) as instructional aids. The DIMaC is beneficial in the classroom, simple to use, satisfying, and deserving of being suggested to

friends or colleagues, according to the feedback from the students. The DIMaC's combined text and visual material improves learning even further. Teachers find this to be an effective teaching tool for kids who are considered digital natives in the twenty-first century.

Although the potential of educational comics to improve student engagement and comprehension in a variety of scientific disciplines has been widely acknowledged (Hosler & Boomer, 2011), the use of digital interactive comic strips to teach Mendelian genetics is still unknown in the Philippines. This project aims to create and assess Digital Interactive Mendelian Genetics Comic Stories (DIMenGeComS) that are suited to the requirements of high school students by utilizing accessible technology tools including Microsoft Word, the Paint app, Adobe Photoshop, Adobe Illustrator, etc. By addressing the difficulties educators encounter when incorporating technology innovations into their lesson plans, these interactive comic stories seek to offer a user-friendly platform for studying Mendelian genetics. The results of this research should provide insightful information on how well comic-story-based learning might improve genetics education. This will aid in the creation of evidence-based teaching materials that will improve Biology learning outcomes for students in the Philippines (Rogayan, 2019). Through the integration of cutting-edge digital tools with conventional teaching techniques, this study aims to promote science education and enhance conceptual knowledge among Philippine high school students.

The primary objective of this study is to develop and determine the effectiveness of digital interactive comic stories (DIMenGeComS) intervention in improving the understanding of Mendelian genetics, particularly in predicting phenotypic expressions of traits following simple patterns of inheritance among grade 8 students in Iligan City National High School-Main Campus (ICNHS-MAIN Campus) in the Philippines.

METHODS

2.1 Research Design

Following Creswell and Clark (2011), this study used a sequential explanatory mixed-methods research design. Two steps made up the research design: a quantitative phase and a qualitative phase. Using survey questionnaires for grade 8 Biology teachers and grade 9 students who have finished the Mendelian genetics curriculum, a comprehensive needs assessment was carried out in the first phase. This provided both quantitative and qualitative measures. The primary objective is to understand the quantitative aspects, such as the prevalence of certain challenges, while also capturing qualitative insights through open-ended survey responses. The survey's findings will shed light on the experiences, obstacles, and problems that came up when people first learned about Mendelian genetics.

2.2 Research Subjects and Participants

The research subjects of the study were two sections of Grade 8 students of Iligan City National High School-Main Campus (ICNHS-MAIN) who were selected through purposive sampling. The inclusion criteria for the subjects are as follows: (a) currently enrolled in Grade 8; (b) have not undergone any formal lessons on Mendelian genetics; (c) have no medical or learning conditions that may affect their ability to learn; and (d) have secured the consent of their parents or guardians (e) with mobile gadget/phone. Excluded from the study would be (a) Grade 8 students who have previously undergone structured instruction in Mendelian genetics, (b) those with medical or learning disorders affecting comprehension, and (c) those lacking parental or guardian consent.

Furthermore, participants in the needs assessment phase were grade 9 students who have finished the Mendelian genetics subject and grade 8 Biology/science teachers teaching Mendelian Genetics in 6 selected public schools in the division of Iligan City. With this method, it was guaranteed that feedback came from educators who understood the difficulties and nuances of instructing the subject as well as students who have direct experience with the topic in Mendelian genetics specifically in predicting phenotypic expressions of traits following simple patterns of inheritance. Excluded from the needs assessment would be (a) Grade 9 students showing inadequate participation or engagement during assessment activities, and (b) those lacking parental or guardian consent. (a) Biology/science teachers with less than three (3) years of teaching experience in Mendelian genetics, and (b) those not actively participating or providing detailed feedback during data collection were excluded in the case

of science teachers. This structured approach ensured that participants met specific criteria for inclusion and exclusion, enhancing the quality and relevance of the study's findings.

2.3 Data Gathering Procedure (ADDIE MODEL)

The data-gathering procedure unfolded through a meticulously structured process, commencing with a needs assessment analysis of ADDIE's model involving six (6) grade 8 science teachers and twenty-one (21) grade 9 students who have undergone mendelian genetics course, advancing through the design and development with validation of the DIMenGeComS intervention, and culminating in the implementation and evaluation phase.

2.3.1 Analysis phase (Needs Assessment Phase)

Carefully planning and creating questionnaires specifically for grade 8 science teachers and grade 9 students who have finished the Mendelian genetics curriculum was the first step in the needs assessment process. Customization was given top priority during the drafting process to guarantee that the surveys were not only extremely successful in obtaining vital information but also relevant and timely. Following that, a thorough validation procedure was conducted with the knowledge of both science teachers and experts in Biology instruction. The purpose of this validation step is to evaluate the survey instruments' precision, accuracy, and quality.

The data-gathering phase started after valid survey tools were established. Participants were invited to answer the survey questionnaires. Participants were nine (9) grade 8 science teachers and twenty-one (21) grade 9 students who have undergone Mendelian genetics topic from 6 various schools. Additionally, pre-test results in pilot testing from grade 8 students were analyzed to inform concept areas that require emphasis. To identify aspects that require targeted attention and development in the latter stages of the intervention, the quantitative and qualitative data collected during this phase acted as a crucial baseline.

2.3.2 Design, Development, and Validation of DIMenGeComS

Guided by the ADDIE model, the DIMenGeComS intervention was meticulously crafted, addressing identified needs from the assessment during the analysis phase. The focus is on amplifying students' understanding of Mendelian genetics fundamental concepts, incorporating principles of inheritance, probability, and real-life applications. The researcher crafted the storyline and design of the DIMenGeComSbased on the analysis phase of the ADDIE model. This informed the researcher where the focus of the DIMenGeComS' content must be given emphasis. Characters, backgrounds, and themes were decided out on the suggestions through the students' and teachers' responses if any, or if applicably appropriate, and/or if otherwise, the researcher's discretion was the authority. After the storyline's establishment, 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 went to the illustrator for the sketches with the experts' comments and suggestions.

The revised and polished narrative was given to the illustrator during the development phase. To ensure that the traits of the cast—such as their facial features, body types, and skin tones—were depicted appropriately, the researcher attentively observed the illustrator. Although the researcher ultimately approved and offered suggestions for improving the images, the illustrator was accountable for providing the relevant background information. After which, the created illustration was submitted to the programmer to code/program the illustrations and use it on mobile phones to make it interactive as planned. The coding process for the DIMenGeComS app was completed in a span of two weeks by the programmer. The final output was checked by the panel experts, the researcher, and the adviser. All comments and suggestions made were integrated into the DIMenGeComS until the experts approved the validity. Through out the project, the programmer performed a total of nine upgrades to the app.

2.4 Data Analysis

To get significant insights from the collected data, a variety of techniques and statistical tools were used in the data analysis process. To clarify emerging patterns and themes, thematic analysis was utilized to analyze and

evaluate the qualitative data gathered throughout the needs assessment. The rating scale findings were examined by mean calculation in the meantime, providing a numerical viewpoint on comprehension, interest, aesthetic appeal, interactivity, and overall efficacy of educational intervention.

RESULTS AND DISCUSSIONS

3.1 Needs Assessment for Science Teachers

Important and pertinent data regarding the approaches, pedagogical strategies, challenges, issues, and experiences of Grade 8 science teachers in Iligan City were gathered via the needs assessment that was carried out with them. This part covers a variety of subjects, such as the teachers' years of experience, teachers' perceived knowledge levels, the instructional methods they employed, the challenges they faced, helpful resources, student misconceptions, assessment techniques, and the utilization of real-world examples. When taken as a whole, these themes give readers a complete knowledge of the perspectives held by educators about Mendelian genetics teaching and suggest ways that academia might be improved.

Table 1. Summary of Responses of the Needs Assessment for Science Teachers focusing on challenges, experiences, and difficulties encountered in teaching Mendelian genetics.

Themes	Codes	Sample Responses
Teaching Experience	Years of Teaching	"More than 10 years" (ST1, ST2, ST7), "3-5 years" (ST3, ST6, ST8), "6-10 years" (ST4, ST5, ST9)
Knowledge Level	Knowledge of Mendelian Genetics	"Very Knowledgeable" (ST1, ST2, ST4, ST9), "Moderately Knowledgeable" (ST3, ST5, ST6, ST7), "Slightly Knowledgeable" (ST8)
Challenges Faced	Comprehension Difficulties	"Learners' comprehension on some terminologies, crossing monohybrid, and dihybrid crosses" (ST1), "Concerned with the lower section; they don't have the retention ability to connect their previous knowledge" (ST2)
	Prior Knowledge Inadequacy	"Students do not have a solid foundation in basic Biology concepts" (ST4), " Students have little or no prior knowledge about Mendelian Genetics " (ST7)
	Complexity of concept	"…abstract concepts, complex terminologies, misconceptions, some mathematical aspects of genetics…" (ST6)
Instructional Methodologies	Present Teaching Methods	"Lectures, Textbooks, Group Discussions, Worksheets, Hands-on Experiments, Online Resources including virtual labs, simulations, etc., Problem-solving exercises." (ST6), "Lectures, Textbooks, Online Resources including virtual labs, simulations, etc., Video lessons, Problem-solving exercises." (ST9)
	Effective Instructional Materials	"Visual/picture, printed sample" (ST2), "GIM (Gamified Instructional Materials)" (ST5), "Links and games for fun activities (Solving Monohybrid activities)" (ST4)

Students Misconceptions	Common Misconceptions	"Genes determine all our characteristics" (ST5), "Inheritance of traits and the blending of traits" (ST4)
	Addressing Misconceptions	"I address this by providing more examples, encouraging critical thinking through Punnett square activities, and integrating real-world examples." (ST5), "By actively addressing common misconceptions and by providing accurate information to all students." (ST6).
Assessment Methodologies	Present Assessment Methods	"I use a variety of assessment methods to gauge students understanding of Mendelian genetics concepts like quizzes and tests, problem-solving exercises, lab activities, homework, assignments, group projects, in-class discussions, and performance tasks." (ST6), "I usually assess students' understanding of Mendelian Genetics through in-class discussions" (ST9).
Real-life examples	Integrating Real-Life Examples	"Provide real-life examples such as Human traits (common human traits: eye color, hair color, height, etc.)" (ST4), "By giving examples on the different disorders related to Mendelian Genetics" (ST9).
Digital Teaching	Utilization of Digital Interactive Tools	"No, I haven't." (ST2)," Not yet." (ST7), "No." (ST1,ST3,ST4,ST5,ST6,ST8,ST9)
Suggestions for Improvement	Teaching Enhancements	"Use of multimedia resources such as videos, animations, and interactive simulations to visually illustrate concepts such as genetic crosses, Punnett squares, and patterns of inheritance. These resources can enhance students' understanding and engagement with the material." (ST4), "Provide materials that will be of good use in enhancing lesson retention such as interactive instructional materials and the like." (ST7).

This study thoroughly examined the difficulties, challenges, and methods related to teaching grade eight-level students in Iligan City on Mendelian genetics. It has revealed how different the Grade 8 teachers' backgrounds were and how much they knew about Mendelian genetics. It also brought to light the main issues that must be resolved to teach the topic effectively, such as students' lack of understanding of abstract terminology and fundamental biological ideas. This was supported by Çimer (2004) who contended that several Biology concepts, including Mendelian genetics, do pose notable challenges for high school students due to their complexity. This sentiment is further supported by Tek kaya et al. (2001), who identify challenging ideas related to secondary students' comprehension, ranging from Mendelian genetics, nervous system intricacies, hormones, chromosomes, mitosis, genes, and meiosis. To overcome these difficulties and increase student participation, teachers used a variety of teaching techniques and tools, such as lectures, group discussions, and internet resources. The survey also revealed common misconceptions held by students, and suggestions for driving out these misconceptions and enhancing comprehension included the application of real-world examples and critical thinking activities. Overall, the thematic analysis above highlighted the relevance and importance of tailored teaching approaches, bridging theoretical concepts with practical applications, and optimally leveraging digital interactive tools for enhanced Mendelian genetics education. Board works Education research in 2022 claims that interactive classes increase student engagement, satisfaction in reaching learning objectives, perseverance despite difficulties, and drive to comprehend the subject matter more deeply. Furthermore, research on the creation of educational resources using an interactive scientific approach discovered that these resources might be beneficial for students (Abadi, MK et al., 2017). These results imply that interactive learning resources might improve student engagement and learning in scientific classes.

3.2 Needs Assessment for Students

In this thematic analysis, issues related to learning Mendelian genetics were investigated, along with effective instructional methods, digital learning opportunities, and student preferences. Important aspects that were emphasized included student preferences, a digital interactive comic-based learning environment's usability, the impact of visual aids, the difficulty of terminology, and the usefulness of resources. A better understanding of Mendelian genetics among eighth graders was collected from the experiences, opinions, and recommendations of the Grade 9 students who have undergone the said topic. These topics are relevant to the first research goal, which sought to understand the difficulties in learning and understanding Mendelian genetics by conducting a needs assessment with ninth-grade students who experienced confronting the subject. The primary findings about this purpose are compiled in the theme analysis table that follows.

Table 2. Summary of Responses of the Needs Assessment for Grade 9 focusing on Challenges, Instructional Methods, Digital Learning, and Student Preferences in Mendelian Genetics Education.

Themes	Codes	Sample Responses
Challenges in Learning	Difficulty & Terminology	"Understanding probability in genetic cross problems was challenging." (NAS6) "Terms in Genetics were difficult to grasp." (NAS8)
	Lack of Visual Aids	"Teacher's limited use of visual aids made learning genetics difficult." (NAS2) "Textbooks lacked clear explanations." (NAS5)
Effective Instructional Methods/Resources	Visual Aids & Interactivity	"Visual aids and hands-on activities would enhance understanding."(NAS11) "YouTube videos helped me grasp complex concepts. (NAS8)
	Online Resources	"Online resources like simulations improved hands-on learning." (NAS17)
Digital Interactive Comic-Based Learning Usability	Interactive Simulations	"…interactive features such as clickable diagrams, animations, and quizzes can enhance understanding by allowing learners to actively engage with the material and test their comprehension as they progress through the comics." (NAS1) "Digital interactive comics could help understand genetics because they provide engaging visuals and interactive features that make learning more exciting." (NAS2)
	Engaging Visual Learning	"…it lets us visualize how things work in genetics which focuses on our imagination, and it doesn't let us have to read paragraph by paragraph the explanation on a particular example problem."(NAS5)"Digital interactive comics combine visuals and personalized learning, creating an immersive and engaging learning experience." (NAS6)
Student Preferences in Comics	Themes, Genre, Characters	"…if I were to choose possible themes, characters, genre, etc., that I would be interested in would be fantasy with a sprinkle of science fiction but in a way that it would make sense in order to understand the topic." (NAS13) "I think I would be interested in a fictional adventure genre. I would like to explore interactive environments and learn new information as the story progresses." (NAS6)

The above thematic analysis of student responses shows an intricate landscape of issues, instructional approaches, digital learning resources, and student preferences related to teaching and learning Mendelian genetics. Students discussed how their understanding was hampered by genetic terminology and the lack of visual aids under the Challenges in Learning subject. This highlights the vital necessity of precise explanations and visual aids to promote learning. The theme of Effective Instructional Methods/Resources emerged as a central idea, stressing the significance of digital resources, practical exercises, and visual aids in augmenting comprehension. The fact that students support interactive tools and simulations underpins how effective these resources can be in filling in conceptual gaps and creating a more engaging learning environment. This narrative is bolstered by Samosa (2021) who studied and created comics as a tactical intervention tool for Biology instruction in different local research. The findings demonstrated that there was a significant difference between the student's pretest and post-test scores when it came to teaching Biology concepts, with the pretest score having a mean lower than the post-test mean when the students were exposed to the developed material. Additionally, after being introduced to the information, the students responded with a very favorable attitude toward studying biological ideas.

The investigation on Digital Interactive Comic-Based Learning Usability demonstrated how much students like the interactive elements, customized learning paths, and captivating images that digital interactive comics provide. The usefulness of interactive learning resources in simplifying and engaging difficult concepts like Mendelian genetics is demonstrated by this theme. Parallel to the result of Mamolo (2019) who produced digital interactive math comics (DIMaC) as instructional aids. The DIMaCwas found to be beneficial in the classroom, simple to use, satisfying, and deserving of being suggested to friends or colleagues, according to the feedback from the students. The DIMaC's combined text and visual material improves learning even further. Teachers find this to be an effective teaching tool for kids who are considered digital natives in the twenty-first century. Furthermore, the significance of matching educational materials to students' interests and preferences—particularly in science fiction and fantasy genres—was underscored by Student Preferences in Comics. This observation highlights the importance of using captivating topics and personalities to improve student comprehension and engagement. To maximize the teaching and learning experience in Mendelian genetics education, the theme analysis emphasizes the importance of utilizing cutting-edge instructional techniques, utilizing digital resources, and customizing instructional materials to fit the preferences of students.

Table 3. Experts' Evaluation Rating to the developed DIMenGeComS

DIMENSIONS	n	E1	E2	E3	E4	E5	E6	E7	Mean	DESCRIPTION
CONTENT	7	4	4	4	4	3	4	4	**3.86**	Excellent
CONTENT ACCURACY	7	4	4	4	4	4	4	3	**3.86**	Excellent
SPELLING AND GRAMMAR	7	4	4	3	4	4	4	3	**3.71**	Excellent
WORD ACCURACY	7	4	4	3	4	4	4	4	**3.86**	Excellent
VOCABULARY	7	3	3	4	4	4	3	4	**3.57**	Excellent
WORD-PICTURE COMBINATION	7	4	4	4	4	4	4	4	**4.00**	Excellent
GRAPHICS RELEVANCE	7	4	4	3	4	4	3	4	**3.71**	Excellent
BACKGROUND DESIGN	7	4	4	4	4	4	4	4	**4.00**	Excellent
FONT AND FORMATTING	7	3	4	2	3	4	4	2	**3.14**	Very Good

SEQUENCING OF INFORMATION	7	4	4	3	4	4	4	3	**3.71**	Excellent
USER-FRIENDLINESS	7	3	4	3	4	4	4	3	**3.57**	Excellent
FEEDBACK MECHANISM	7	3	3	4	1	3	4	3	**3.00**	Very Good
INTERACTIVITY INTEGRATION	7	4	4	3	4	4	4	3	**3.71**	Excellent
IMPACT	7	4	4	4	4	4	4	4	**4.00**	Excellent
TOTAL	7	3.71	3.86	3.43	3.71	3.86	3.86	3.43	**3.69**	Excellent

Legend: Excellent 3.25 – 4.00; Very Good 2.50 – 3.24; Good 1.75 – 2.49; Needs Improvement 1.00 – 1.54

Table 3 displays the evaluation results of seven experts in the fields of Biology and technology education for the Digital Interactive Mendelian Genetics Comic Stories (DIMenGeComS). All things considered, the data indicated that the DIMenGeComS had excellent general validity and acceptance (M = 3.69). In addition, 12 of the 14 acceptability questionnaire categories received an excellent rating, with the two that remained receiving a very good rating. This indicates that all areas of education and work are sufficiently covered by the DIMenGeComS, and the overall caliber of the work is excellent. The experts also commended the researcher for creating educational materials of this type that meet the needs of students in the twenty-first century. They also emphasized how unique, inventive, captivating, and interesting interactive the DIMenGeComS is. They also made some recommendations about how to improve the DIMenGeComS and how to use it in the classroom. Comparable outcomes were observed by Pardimin and Widodo (2017), who created a comic-based approach to solve geometry problems and discovered that all of its validation criteria were "very good." The following factors were taken into consideration: language and readability, writing, organization, presentation, content, and comedy structure. Given that comics, according to Yang (2003), are visually stimulating, permanent, popular, and can foster analytical and critical thinking abilities, the experts may have found them to be highly acceptable and an excellent instructional tool to be used in leveraging conceptual understanding on Mendelian Genetics.

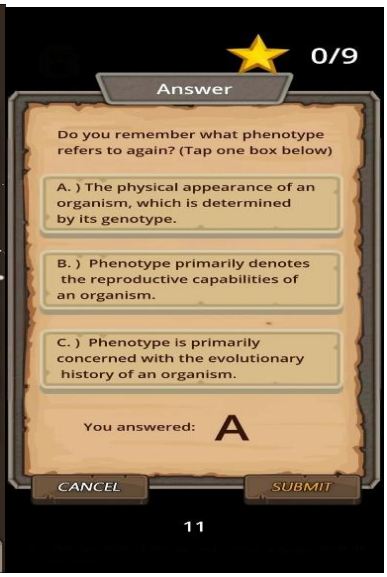

Figure 1 Figure 2 Figure 3

Figure 1 above shows the Title page of the DIMEnGeComS app. Figure 2 and Figure 3 are snapshots of the pages that are challenges or problems embedded in the app to assess students' understanding of the concept through the story. Each page that has a problem/question embedded serves as a formative assessment to ensure that the students follow the flow of the story. The page will be locked once a problem is encountered, and students must be able to solve the problem first before they can proceed to the next page of the story and eventually finish

it. There will be a pointing system and a total of 9 possible star points will be awarded at the end of the story indicating that the student has completed the story. Each failed attempt to answer the question or solve the problem will also be recorded and the teacher will inform the students that the scoring will be a "right minus wrong" system, so students must be very careful in choosing or answering each question.

CONCLUSION AND RECOMMENDATION

The comprehensive needs assessment of grade 9 students and science teachers that was carried out as part of this study's topic analyses has illuminated important obstacles, experiences, and problems related to teaching and learning Mendelian genetics. The knowledge acquired has greatly influenced the creation and evaluation of the Digital Interactive Mendelian Genetics Comic Stories (DIMenGeComS) intervention. It has addressed everything from language barriers to the value of visual aids and the efficacy of different teaching resources. This was undergirded by the evaluation rating of seven (7) Biology and Technology experts, for which the DIMenGeComS received an "Excellent" rating for acceptability. This study has established a solid basis for assessing DIMenGeComS' efficacy in enhancing grade 8 students' comprehension of Mendelian genetics at Iligan City National High School-Main Campus by detecting current knowledge gaps and comprehending student and teacher perceptions. These results highlight the value of cutting-edge teaching resources such as DIMenGeComS in filling in gaps in genetics education, particularly when it comes to predicting phenotypic expressions of traits that follow simple patterns of inheritance. Thus, the present study recommends the use of the DIMenGeComS to evaluate students' comprehension of Mendelian genetics using conceptual gains obtained from a pre-and post-test before and after the utilization thereof.

REFERENCES

1. Abadi, M. K., Pujiastuti, H., & Assaat, L. D. (2017, February). Development of teaching materials based interactive scientific approach towards the concept of social arithmetic for junior high school student. In Journal of Physics: Conference Series (Vol. 812, No. 1, p. 012015). IOP Publishing.
2. Board works Education. (2022.). The Measurable Impact of Interactive Learning Materials. Board works Education.
3. Çimer, A. (2004). A study of Turkish Biology teachers' and students' views of effective teaching in schools and teacher education (Published Doctoral Dissertation). The University of Nottingham, Nottingham, U.K. https://www.researchgate.net/publication/233358366
4. Creswell, J. W., & Clark, V. L. P. (2011). Designing and conducting mixed methods research. Sage Publications.
5. Department of Education. (2013). K to 12 curriculum guide: Science. Philippines Department of Education.
6. Hosler, J., & Boomer, K. B. (2011). Are comic books an effective way to engage nonmajors in learning and appreciating science? CBE—Life Sciences Education, 10(3), 309-317.
7. Mamolo, L. A. (2019). Development of digital interactive math comics (DIMaC) for senior high school students in general mathematics. Cogent Education, 6(1), 1689639.
8. OECD (2019), PISA 2018 Assessment and Analytical Framework, PISA, OECD Publishing, Paris, https://doi. org/10.1787/b25efab8-en.
9. OECD (2023), PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, OECD Publishing, Paris, https://doi.org/10.1787/53f23881-en
10. Rogayan, D. V. Jr., &Dollete, L. F. (2019). Development and validation of physical science workbook for senior high school. Science Education International, 30(4), 284-290. https://doi.org/10.33828/sei.v30. i4.5
11. Rogayan, Jr. D., & Albino, M. (2019). Filipino students' common misconceptions in Biology: Input for Remedial Teaching. 4, 90-103. https://www.researchgate.net/publication/337683279 Filipino Students' Common Misconceptions in Biology Input for Remedial Teaching
12. Samosa, R. C. (2021). Cosim (comics cum sim): an innovative material in teaching Biology.
13. Santos, J. T. D., Lim, R., & Danilo Jr, V. (2021). Least mastered competencies in Biology: Basis for instructional intervention. JPBI (Jurnal Pendidikan Biologi Indonesia), 7(3), 208-221.Schwab, K., &

Sala-i-Martín, X. (2016). The global competitiveness report 2013–2014: Full data edition. http:// repositorio.colciencias.gov.co:8080/handle/11146/223

14. Villegas, B. (2021). Addressing the Philippine education crisis.
15. Yang, G. (2003). Comics in education (Master's Thesis). California State University at Hayward. Retrieved from www.humblecomics.com/comicsedu/index.htm
16. Pardimin, & Widodo, S. A. (2017). Development comic based problem solving in geometry. International Electronic Journal of Mathematics Education, 12(3), 233–241. Retrieved from http://www.iejme.com/