

Development of Digital Interactive Comics for Grade 8 Learners in Cell Division

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ABSTRACT

This study developed a digital interactive comic for Grade 8 learners in cell division. The developed interactive cell division comic is an instructional material which will provide meaningful experience and for learners to have active involvement in the process of teaching and learning enhancing learners' understanding of the topic. In the study, Successive Approximation Model (SAM) design was used in development approach of the instructional tool including needs assessment, designing, and developing. The needs assessment of science teachers and grade 9 students has shed light about teaching and learning about cell division which presents numerous challenges, including difficulty in understanding complex concepts, unfamiliar terminology, struggles with visualization, and issues with retention. The needs assessment has proved the need for creative teaching methods in cell division education. This signaled the development of an instructional tool that is interesting, student-centered, engaging and support a deeper understanding of the lesson cell division and meet the needs of 21st century learners as a whole. Five science education experts evaluated and rated the developed digital interactive comics in terms of its content quality, instructional quality, technical quality, and other aspects using the Department of Education's (DepEd) Evaluation Rating Sheet for Non-Print Materials. The developed material was highly recommended and approved for possible use in classrooms as it passed factors for content quality (38.8 out of 40), instructional quality (38.6 out of 40), technical quality (50.8 out of 52), and other findings (16 out of 16). Evaluators' comments and recommendations were incorporated. Continuous improvement and modification are essential to further enhance the developed interactive digital comics for teaching and learning cell division, maximizing the full benefits of these kind of instructional tools in science education.

Keywords: Cell Division, digital interactive comics, comic-based learning

INTRODUCTION

Understanding the concepts and processes of science is a fundamental goal of science education (National Research Council, 2012) as it is vital to successfully participate and secure economic progress and social engagement in today's society (Cardinot & Fairfield 2019). According to Karagöz (2018) that with this in mind instructional materials should be enriched in learning and teaching environments as these variables directly affect the teaching and learning of students.

Cell division, which is among the topics in science, is perceived to be the most difficult by many learners. This is supported by Sanchez et al (2020) who used true experimental research design and the obtained results showed that cell division was among the least mastered topics in Biology. Successful teaching of its learning competencies may pose a challenge for educators most especially if there is only one learner material provided and that it is only taught for a limited amount of time. With this in mind, teachers can find other ways to interact with students in more engaging ways, as highlighted by Mamolo (2019). One such avenue is the development of teaching materials best suited for 21st century learners. One kind of instructional material that might be contributed is the utilization of comics that will be upgraded to be digital and that can be interactive

and are designed to meet the needs of 21st century learners who are considered digital natives.

Comics are a type of media in which ideas (realistic, imaginary, and possibly humorous) are communicated via the use of visual pictures or sequence of images, which are typically made up of cartoons (Toh et al., 2016). Positive results on the use of printed comics as a material in science education (Özdemir, 2017; Shin et al., 2013; Matuk et al., 2019; Affeldt et al., 2018; Spiegel et al., 2013; Badeo et al. 2021; Samosa, 2021; and Enteria and Casumpang, 2019) and the effectiveness of comics in changing student attitudes toward science in a positive way, increasing their interest in learning on the use of digital interactive math comics (DIMaC) as instructional material (Mamolo, 2019) has motivated the researcher to conduct this study. The study's aims to develop a digital interactive cell division comic among Grade 8 learners.

Objectives of the Study

The study's main objective is to develop digital interactive comics for Grade 8 learners in cell division. This study was aimed at the following objectives:

1. Identify teachers' experiences, difficulties and challenges in teaching Cell Division through needs assessment.
2. Identify students' experiences, difficulties and challenges in learning Cell Division through needs assessment.
3. Develop digital interactive cell division comics.

METHODS

This study employed a Successive Approximation Model (SAM) design. SAM represents an emerging and viable alternative model in instructional design. Developed by Allen Interactions Inc., SAM emphasizes iterative, incremental steps to address common challenges such as rigidity, time constraints, linearity, and stability often encountered with the traditional ADDIE model (Allen, 2012; E Learning, 2014).

To come up with the developed digital interactive cell division comics, the researcher did the following procedure following the SAM model as the developmental framework.

Preparation Phase

Collecting information was the first step carried out in this research.

Background: A literature review of existing literature was conducted about the challenges in teaching and learning cell division. Also, a needs assessment was carried out to find out if there is a need to design and develop a material and the needs of the existence of this research. This was to identify the teachers' and students' experiences, difficulties and challenges in teaching and learning Cell Division survey questionnaire and open-ended questions. To gather this information, a developed survey questionnaires was administered tailored for both teachers and students. The survey questions were carefully customized to prioritize relevance and timeliness, ensuring they effectively gathered essential information. Following the development of these instruments, science and education experts conducted a validation process to evaluate the precision, accuracy, and quality of the needs assessment questionnaires. After valid survey instruments were established, the actual data collection process commenced. Participants were ten (10) Grade 8 Science/Biology teacher and thirty-one (31) Grade 9 students who had finish the topic of cell division during Grade 8.

Iterative Design Phase

The material was meticulously created addressing the identified needs from the conducted needs assessment during preparation phase.

At this phase, there are three activities:

Prototype: (storyboard) this involved writing of the storyline and choosing characters that was based on the students’ responses from the survey questionnaire then some from the researcher’s imagination. Most of the students from the survey responded that they preferred “fantasy, adventure” themed story with fictional characters. And so, the storyline revolves around the cell cycle city where three characters Deoxy, Chroma and Mito explored and encountered concepts of cell division. The selection of characters and plot was primarily influenced by researcher’s imagination. The inclusion of the competencies of cell division in the storyline was design in a way to prevent boredom and overwhelm at the same time fostering motivation, striking a balance between the conceptual and narrative aspects. The researcher aims to engage students in reading the storyline while answering questions enthusiastically by crafting an exciting plot.

Reviews: once the storyboard/storyline was completed, it was presented to one of the research panel members regarding concept integration, coherence, accuracy, and appropriateness of the material. Necessary revisions were carried out as per comments from the evaluation. Afterward, the researcher produced the second version of the storyline and was sent to illustrators to craft the initial sketches.

Design: designing or sketching of the characters of the digital comics then commenced by illustrators with the help of the researcher considerations for the characteristics of the casts like facial features, body size, skin color, and others. Revisions was carried out if seen necessary. Duration for the creation took 2 months for illustrator, and was upgraded or revised for 5th time before proceeding to the next level.

Iterative Development Phase

Development: The digital comics was further developed into a more complete version as the programmer coded/programmed the illustrations to enable the usage of it on phones and create an interactive experience. It took two and half months for the developer to create and complete the project. It underwent a total of four upgrades. The developed digital comics was subjected to face and content validation on its acceptability for classroom use. Chosen Science education experts served as the participants. Evaluators’ comments and recommendations were incorporated to further enhance the developed digital interactive cell division comics.

RESULTS AND DISCUSSIONS

Needs Assessment for Science Teachers

Significant and relevant data concerning the methodologies, teaching strategies, challenges, problems and experiences of Grade 8 science educators in District Tabina and Pitogo, DepEd Division of Zamboanga del Sur were compiled through a needs assessment conducted with them. The different themes included in the needs assessment provide a comprehensive understanding of educators' viewpoints on teaching Cell Division. The data revealed the needs to develop a digital interactive comics in learning cell division.

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

(NT1, NT2, NT3 and so on was systematically assigned to each needs assessment teacher respondents.)

Themes	Subthemes	Sample Responses
Challenges Encountered in Teaching	Complexity of Topic	The challenge for me is to study in advance for me to present well the topic in class (NT7). It’s a bit difficult to students, not unless if they learn it in an engaging (NT6).
	Lack of Learning Resources	Students find it difficult to fully comprehend since we could not make/perform other lab-related experiments about it (NT2).
	Low Performance	Low student performance in science because as per experience, it takes time to introduce the lesson and takes time for them to

	and Interest	understand (NT3). The students often struggle to stay engaged, with many distractions making it challenging to capture their attention (NT5, NT8).
oping Techniques	Utilization of Multimedia	Presented the lesson through video presentation as well as PowerPoint presentation for the students to understand the topics better and afterwards, give additional insights (NT6, NT7, NT9).
	Research on the Topic	Let or ask students to research in the internet videos about cell division (NT2, NT8, NT10)
Pedagogical Approaches Employed	Inquiry-Based Approach	Collaboration, inquiry-based approach is what I employ as this approach emphasizes active learning and encourage learners to construct their own knowledge (NT1, NT2, NT5).
	Hands-on Activities	By giving them hands-on activities like building model of cells and the process of mitosis/meiosis using clay, beads, etc. (NT7, NT9).
Benefits of utilizing Digital Interactive Materials in instruction	Improved Teaching-Learning Process	The learners can understand better as they are more participative and attentive (NT1, NT4, NT5). It is more advantageous because students are more comfortable in using gadgets so it's easy for them to access/understands (NT3, NT6). It helps students understand more easily, enabling effective teaching and have an interactive, meaningful discussions. (NT7, NT8, NT9, NT10).
Challenges in integrating digital interactive instructional material	Lack of Resources	The main challenge would be the lack of access to functional devices such tablets and cellphones with many students and even teachers lacking the necessary gadgets or having limited digital skills, particularly in rural areas, along with slow internet connectivity (NT1, NT4, NT5, NT6, NT7, NT9).

Table 4.1 is a thematic analysis of the gathered data from the needs assessment which shows main issues and difficulties encountered that must be resolved to teach cell division effectively. Teaching cell division presents significant challenges, primarily due to the inherent difficulty of the topic. Moreover, the dynamic nature of these processes and the molecular mechanisms underlying them add layers of complexity that may further hinder comprehension. This is supported by the study conducted by Özbudak and Özkan (2014), whose analysis revealed that teachers struggled to teach this topic effectively. The challenges were attributed to several factors: the unit was not conducive to hands-on experiments and observations (NT2, and the subject matter failed to capture student interest (NT3).

In addition, the lack of learning resources can contribute to students' low performance in understanding cell division and can also influence students' ability to comprehend and retain information (NT2). Addressing these challenges requires the development of innovative teaching strategies and the creation of interactive and engaging learning materials ultimately improving student performance and achievement in this complex subject area.

The coping techniques is also one of the themes gathered and one prevalent approach observed among educators is the integration of multimedia resources, such as video presentations and PowerPoint slides, into their lessons. By incorporating these multimedia elements, teachers like NT6, NT7, and NT9 aim to enhance students' comprehension by providing visual and auditory stimuli that reinforce key concepts.

One of the primary benefits emphasized by teachers with regards to the incorporation of digital interactive materials in instructional practices, such as NT1, NT3, and NT5, is the improved understanding and participation among students. By tapping into digital interactive materials, educators can create dynamic and

engaging learning experiences that meet the preferences and learning styles of modern students.

According to Asare (2022), differentiated instruction significantly improves students' understanding of cell division. This not only fosters better comprehension of the subject matter but also encourages active participation, as students are more likely to be attentive and involved in interactive lessons compared to traditional lectures.

Additionally, teachers' perceptions of using digital interactive comics for teaching cell division indicate a promising approach to positive learning outcomes. This method in their opinion effectively sustains student interest. This is in line with what Taarique-Ahmad (2022), discussed that students taught using alternative learning methods for cell division, maintained their interest and demonstrated enhanced understanding as the approach facilitated easier understanding.

Teaching cell division is challenging due to its complexity and the lack of proper learning materials. This calls for creative teaching methods to make it easier to understand. Moreover, the data gathered suggests that digital interactive cell division comics as instructional material presents a compelling opportunity to enhance teaching effectiveness and student engagement, ultimately contributing to more successful learning experiences.

Needs Assessment for Students

Needs assessment for students' analysis focused on the challenges encountered in learning the Cell Division, as well as their coping techniques, effective method for them in learning the topic, perception about digital learning, and preferences. These discussions align with one of the research objectives, which aimed in grasping the challenges or problem encountered in learning Cell division through a needs assessment conducted with Grade 9 students who had encountered the topic. The findings relevant to the objective presents a compelling case that digital interactive comics hold promising potential as an educational tool as they can simplify complex concepts and engage students in a visually appealing and interactive manner, it aligns with students' learning preferences, ultimately enhancing their understanding.

Table 2 Summary of Responses of the Needs Assessment of Grade 9 students who had already encountered and learned the topic Cell Division.

(NS1, NS2, NS3 and so on was systematically assigned to each needs assessment student respondents.)

Themes	Subtheme	Sample Responses
Challenges Encountered in learning	Difficult Topic	Difficult to learn and understand the topic (NS5, NS11, NS12, NS14, NS18, NS20, NS34, NS35). Challenging because it is in the interior part of the body and you can't easily see it (NS2). Difficult to understand as that almost all of it looks the same, and their names as well is hard to memorize (NS13, NS26, NS27, NS29).
	Forget Easily	I easily forget what the names of each of the phases (NS7). I can't remember everything that the science teacher discussed (NS16, NS19).
	Does Not Have an idea	I don't know (NS17). I did not get to learn about it I was absent (NS21, NS24).
Coping Techniques	Ask Help from Teacher and Peers	I ask my teacher or classmate to cope with my difficulties and listened carefully so I can understand (NAS-S7, NAS-S10, NAS-S18).
	Dedicate More Time Studying	I analyze the topic even more (NS2, NS21). I study more/hard to understand it (NS3, NS5, NS8, NS9, NS13, NS16, NS20, NS22, NS24, NS28, NS31). I draw the process of cell division and its meaning to enhance my learning skills (NS26, NAS27).

	Done research	If I don't understand I research them on internet for better understanding (NS23, NS29). I gather more data to learn more from the internet (NS30).
	Done nothing	I've done nothing about it (NAS-S17).
Effective Methods in Instruction	Discussion	Discussion (because I can understand it more) (NS3, NS10, NS24, NS31). Discussion with PPT is effective, because I can understand it more (NS8, NS15, NS17, NS20, NS26, NS30). Discussion, activities and videos (NS16, NS19, NS29)
	Multimedia videos	Effective in learning the topic is to watch videos (NS4, NS21, NS25). The teaching method which is effective in learning the topic is videos because it is clearly presented on screen (NS2, NS7).
	Activities	Activities, because you would really understand what you are doing (NS13, NS14, NS22).
Recalling Cell Division	Able to recall but not all	Metaphase, Anaphase and Prophase (NS11, NS13, NS14, NS16, NS19, NS21, NS24, NS25). Anaphase, metaphase (NS6, NS7). Metaphase, Anaphase, Telophase, Meiosis and Mitosis (NS22)
	Unable to recall	I can't remember it anymore (NS4, NS18, NS27). I can't remember because it's difficult (NS8, NS17, NS20). I can't remember, it's long time ago (NS23, NS26, NS27, NS28, NS29, NS30). I easily forget (NS9, NS10). No, because I'm not good in memorizing previous topic. (NS5, NS31)
Perception About the Digital Interactive Comics	Helpful in understanding	It's useful and it can help it to understand more and to learn more (NS1, NS9, NS12, NS16, NS23, NS24). If you don't get the lesson, it can help you learn about the topic and study (NS34). It's useful to understand the concepts (NS6, NS8, NS19, NS21). It is more fun and relatable (NS3, NS10). It helps understand the cell division by using a gadget (NS2, NS15). It's useful because our generation uses gadgets more, which makes students like me enjoy reading it on our cellphones and find it easier to understand. (NS5). It is useful in understanding the concepts in cell divisions because we can see it (NS7, NS29).
Digital Interactive Comics Potential	Engaging/ Interesting	It's more engaging because its digital compared to traditional (NS6, NS12, NS14, NS18). Digital interactive could make learning about cell division more engaging because you can understand more (NS11, NS15, NS31, NS4, NS23). It will make us interested or amaze because it will attract and it will convince us to read (NS5, NS8, NS9, NS22).
	Improved Understanding	I can understand it more because I will understand it if it's in a story (NS10, NS21). The student will understand the lessons better and easy. Compare to traditional methods because some student getting bored on lessons (NS25). It can be used to easily understand the topic through cellphone and help to study at home (NS31). It can provide immediate feedback (NS7, NS27)

Table 4.2 has shed light about students' learning about cell division which presents numerous challenges, including difficulty in understanding complex concepts (NS5, NS11, NS12, NS14, NS18,), unfamiliar terminology (NS13, NS26, NS27, NS29), struggles with visualization (NS2), and issues with retention ((NS7). The study by Rafat et al. (2023) revealed that students hold several misconceptions, one of which pertains to cell division, therefore, teachers must actively work to identify and address any challenges and difficulties that

students may have to systematically organized teaching strategies to not only fosters deeper comprehension and retention of information but also encourages students to take greater ownership of their learning processes.

In *effective methods in instruction* theme, discussions are viewed favorably, with many participants stating that they find them effective for understanding topics like cell division. Abdulkaki et al. (2018) found that discussions create a great chance for students and teachers to interact, ask questions, share ideas, and better understand complex topics. This interactive environment made learning more engaging and supportive. This emphasizes that discussions should be part of the learning process to better understand complex topics like cell division and should not be removed. Notably, discussions supplemented with PowerPoint presentations (PPT) are particularly effective, as highlighted by a larger group of students, suggesting that visual aids significantly improve comprehension. Additionally, a combination of discussions, activities, and videos is acknowledged as beneficial, with several students finding them effective for learning due to their clarity and engaging presentation style.

In the theme *perception about the digital interactive comics*, many participants view comics helpful in enhancing their comprehension and learning (NS1, NS9, NS12, NS16, NS23, NS24). It will contribute to a deeper understanding as it is more relatable and enjoyable (NS3, NS10). Additionally, the accessibility of it on gadgets like cell phones makes reading and learning more engaging (NS2, NS15), as integration of technology appeals to the current generation (NS5). The potential visual nature of digital interactive comics allows students to grasp the concepts better, as they can see the processes involved more clearly (NS7, NS29).

The last theme generated was *digital interactive comics potential*, the digital interactive comics are perceived as more engaging than traditional comics or textbooks (NS6, NS12, NS14, NS18), attracts readers attention (NS5, NS8, NS9, NS22) indicating that this learning format stimulate curiosity and motivate learners, which is crucial for educational effectiveness. Students also find it challenging, interesting, and convenient, with the added advantage of immediate feedback (NS7, NS27) to improve understanding and create a better learning experience.

Overall, data presents a compelling case that digital interactive comics hold promising potential as an educational tool as they can simplify complex concepts and engage students in a visually appealing and interactive manner, it aligns with students' learning preferences, ultimately enhancing their understanding.

Designing Phase of the Cell Division Comics

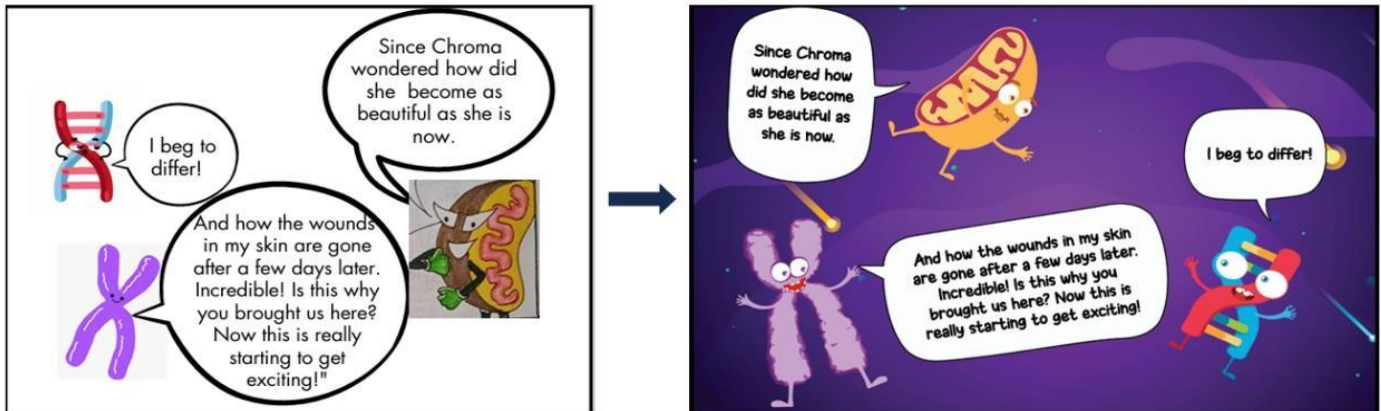
During the needs assessment phase, Grade 9 students were asked about their preferences for characters and themes in a comic. This feedback was crucial in guiding the researcher to write a storyline that integrates the target competencies related to cell division. Most of the students expressed a preference for fictional characters and an adventure-themed narrative. The selection, crafting, and development of the characters were primarily shaped by the researcher's imagination and creativity, with input and approval from the adviser and one of the panel members.

The story revolves around Chroma (the Chromosome) and his alter friend Deoxy (DNA) as they embark on a journey with Mito the Explorer. Mito brought them to the bustling cityscape of a cell undergoing mitosis and meiosis, where they seek answers to their questions about their observations and experiences. Along the way, the characters witness the dynamic events of the cell cycle including cell division.

The researcher designed the storyline to engage students by capturing their interest and maintain an equilibrium between educational content and entertainment, ensuring that students are neither bored by the concepts nor overwhelmed by the information. The goal is to keep students interested and motivated to read the storyline and enthusiastically answer questions by crafting an exciting and captivating plot.

The completed storyboard was presented, evaluated, and approved by a panel member with expertise in both biology and English, focusing on concept integration, coherence, accuracy, and the appropriateness of the content. Based on the feedback, necessary revisions were made to enhance the material. The revised and updated storyboard was then provided to graphic artist/illustrators to begin creating the initial sketches.

Figure 1. Transformation of Storyboard to Appealing Visual Illustrations



The visual elements were crafted to explain cell division concepts clearly and effectively. The figure 1 shows an example of transforming storyboard to visually appealing illustrations. The visuals use bright colors and detailed illustrations to grab attention and maintain student engagement.

With guidance from the researcher, the illustrators designed the setting, backgrounds and characters for the cell division comics, taking into account comics branding and various features such as facial expressions, size, color and other characteristics. Revisions were made whenever necessary to ensure accuracy and quality. The entire process took about two months, with the illustrations undergoing five rounds of improvements before moving on to the next phase. Extensive preparation was invested to create visually appealing, curriculum aligned, and engaging content that would not only educate but also entertain the students.

Development Phase of the Digital Interactive Cell Division Comics

The cell division comics was further developed into a fully interactive digital format, coded by the programmer for mobile compatibility and user engagement. This development phase, managed by the programmer, spanned two and a half months and went through four rounds of iterations to refine the material. The digital comics underwent face and content validation for classroom use, involving feedback from science education experts. After establishing the validity of the modified developed material, incorporating their suggestions, the material was finalized and prepared for pilot-testing.

Core Features of the Digital Interactive Cell Division Comics

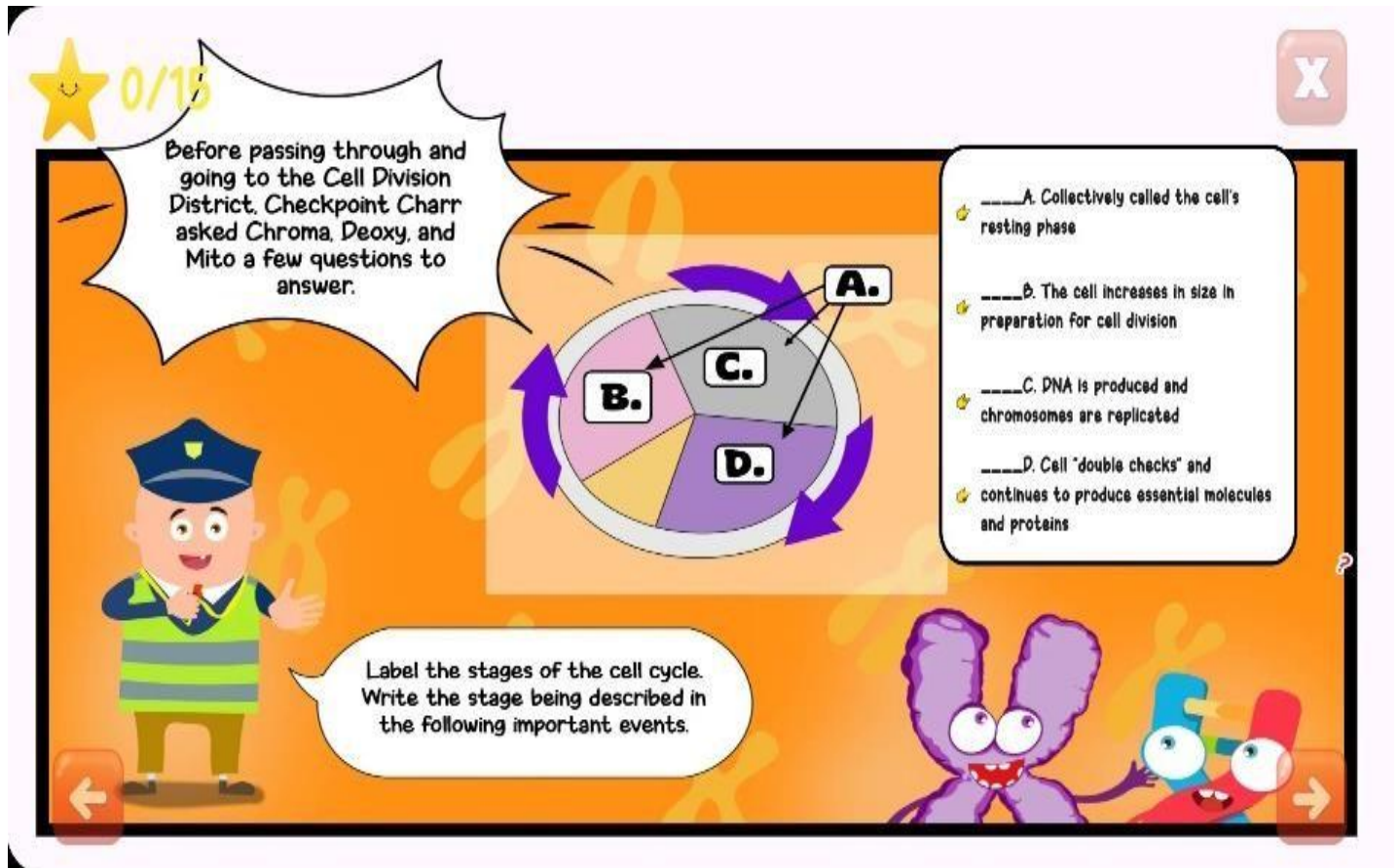
A programmer worked on integrating the developed illustrations and storyline into an interactive digital format. Coding was used to enable functionalities like navigation buttons and key features of a digital app. The app icon in figure 2 below is basically just the title of the story where all characters appeared. This is picture that will appear on the list of your apps in mobile phone.

Figure 2. The Digital Interactive Cell Division App Icon



The digital interactive comics was developed in goals of capturing students’ attention and keep them engaged when presenting them cell division concepts. One key aspect that make it a valuable tool educational tool is the vividly and visually appealing illustrations. It uses visually storytelling strategies to simplify complex concepts, making it easier for students to understand and remember the material.

Figure 3. The Interactive Feature of the Digital Interactive Cell Division



Another feature is the incorporated interactive elements such as clickable questions where they can type their answer that allow students to engage actively (Figure 3). The interactive questions embedded provide immediate feedback that allow for self-assessment, helping students gauge their understanding of the topic in real-time.

To help sustain interest and motivation, students cannot unlock new sections of the story if they answer questions incorrectly. This means that they really have to carefully read the story to be able to answer and proceed to the next.

The digital interactive app can be used on smartphones offline, giving students the flexibility to access the material anytime and anywhere. This mobile-friendly approach accommodates different learning environments, including traditional classrooms and remote learning. The interface is user-friendly, with intuitive navigation features like touch-to-click elements, arrow buttons for next and back, pinching to zoom and dragging to pan the image, ensuring that students of all tech-savvy levels can use the comics effectively.

Overall, the digital interactive cell division comic was well designed and developed to provide captivating learning experience through storytelling and interactivity.

Validation of the Developed Digital Interactive Cell Division App by Science Education Experts

Science education experts, each with at least a master’s degree in biological science education, evaluated the digital interactive cell division comic. Five experts rated its content quality, instructional quality, technical quality, and other aspects using the Department of Education’s (DepEd) Evaluation Rating Sheet for Non-Print

Materials. To meet the evaluation criteria, the following ranges must be achieved: content quality (30-40), instructional quality (30-40), technical quality (39-52), and other findings (16).

Table 4.3 Summary of Ratings of the Science Education Experts on Digital Interactive Cell Division Comics

Factors	Total Points (Science Education Experts)					SD	Mean	Remarks
	E1	E2	E3	E4	E5			
A. Content Quality	36	40	38	40	40	1.79	38.8	Passed
Instructional Quality	35	40	39	39	40	2.07	38.6	Passed
C. Technical Quality	51	51	51	50	50	0.45	50.8	Passed
D. Other Findings	16	16	16	16	16	0	16	Passed

As shown in Table 4.3, the digital interactive cell division comics passed all four factors after it was evaluated by the science education experts. They also provided feedback, especially on the technical quality, suggesting improvements to the background music that is more appropriate as educational background music to enrich the overall user experience. These recommendations were used to further enhance the digital interactive cell division comic.

Summary of Evaluation of the Developed Digital Interactive Cell Division Comics

1. The texts are very straightforward and are so easy to understand.
2. The lesson presented is very self-explanatory and learners are able to comprehend.
3. The background music must be change to more appropriate as educational background music to enrich the overall user experience.
4. The developed material is exceptional, however, to avoid confusion it is important to provide clear instruction and supervision when using the app.
5. Consider enlarging key text elements to enhance readability, while removing any nonessential text to streamline content and improve clarity.
6. Incorporate a display of total earned points to motivate students and give them a sense of accomplishment as they complete the story.

Figure 4. The Incorporated Display of Total Earned Points



The developed digital interactive cell division comics was returned to the developer for a week for refinement and incorporation of the feedback from the evaluation of the science education experts. Figure 4 is an example of the refinement of the development of the material, incorporating a display of total earned points. Typographical errors such as missing comma were taken corrected. The background music was also changed to a more new or timely to learners than can stimulate learning. Overall, the developed material was further improved to increase educational effectiveness.

CONCLUSION

The needs assessment of science teachers and grade 9 students have proved the need for creative teaching methods in cell division education. This signaled the development of an instructional tool that is interesting, student-centered, engaging and support a deeper understanding of the lesson cell division and meet the needs of 21st century learners as a whole.

A digital interactive cell division comic was developed extensively, taking into account students' preferences in the needs assessment, several literature and studies, and validation. The developed material was highly recommended and approved for possible use in classrooms as it passed factors for content quality (38.8 out of 40), instructional quality (38.6 out of 40), technical quality (50.8 out of 52), and other findings (16 out of 16). Continuous improvement and modification are essential to further enhance the developed interactive digital comics for teaching and learning cell division, maximizing the full benefits of these kind of instructional tools in science education.

REFERENCES

1. Abdulbaki, K., Suhaimi, M., Alsaqqaf, A., & Jawad, W. (2018). The Use of the Discussion Method at University: Enhancement of Teaching and Learning. *International Journal of Higher Education*, 7(6), 118-128.
2. Affeldt, F., Meinhart, D. & Eilks, I. (2018). The use of comics in experimental instructions in a non-formal chemistry learning context. *International Journal of Education in Mathematics, Science and Technology*, 6(1), 93- 104.
3. Asare, E. J. (2022). Using differentiated instruction to improve SHS students' performance of cell division (Doctoral dissertation, University of Education, Winneba).
4. Badeo, J. M. & Koc, B. C. O. K. (2021). Use of Comic-based Learning Module in Mechanics in Enhancing Students' Conceptual Understanding and Motivation. *Science Education International*, 32(2), 131-136.
5. Cardinot, A. & Fairfield, J. (2019). Game-Based Learning to Engage Students with Physics and Astronomy Using a Board Game. *International Journal of Game based learning*. Retrieved from
6. Enteria, O. & Casumpang, P. F. H. (2019). Effectiveness of Developed Comic Strips as Intructional Materials in Teaching Specific Science Concepts. *International Journal for Innovation Education and Research*, 7(10), 876-882.
7. Karagöz, B. (2018). Applicability to the strategies of determining and interpreting interdisciplinary content of educational comic novels: the case of "adam olmuş çocuklar ve kahraman kadınlarımız series". *Erzincan University Journal of Education Faculty*, 20(3), 637-661.
8. Mamolo, L. (2019). Analysis of Senior High School Students' Competency in General Mathematics. *Universal Journal of Educational Research*, 7(9), 1938–1944.
9. doi:10.13189/ujer.2019.070913
10. Matuk, C., Hurwich, T., Spiegel, A. & Diamond, J. (2019). How do teachers use comics to promote engagement, equity, and diversity in science classrooms? *Research in Science Education*, 1-48.
11. National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington DC: The National Academies Press.
12. Özbudak, Z. & Özkan, M. (2014). An analysis of teacher's views on the unit regarding cell division and heredity. *Procedia-Social and Behavioral Sciences*, 152, 714-719.
13. Özdemir, E. (2017). Comics in modern physics: Learning blackbody radiation through quasihistory of physics. *Studies in Educational Research and Development*, 1(1), 41-59.

14. Rafat, F. A. R. H. E. E. N. & Ali, M. A. H. M. O. O. D. (2023). A Study on Misconceptions in Cell Division and Reproduction among Secondary School Students in Relation to Their Preferred Teaching Styles. *International Journal of Applied Social Science*, 10(5-6), 335-340.
15. Samosa, R. C. (2021). Cosim (comics cum sim): an innovative material in teaching biology.
16. Sanchez, R. M. S., Garcia, G. S. & Tondo, J. E. (2020). Differentiated Teaching Strategies of Selected Topics in Biology. *IOER International Multidisciplinary Research Journal*, 2(3), 155-163.
17. Spiegel, A. N., McQuillan, J., Halpin, P., Matuk, C. & Diamond, J. (2013). Engaging teenagers with science through comics. *Research in science education*, 43(6), 23092326.
18. Taarique-Ahmad, Y. (2022). The effect of computer assisted instruction on student performance on selected concepts in cell division (Doctoral dissertation, University of Education, Winneba).
19. Toh, T. L., Cheng, L. P., Jiang, H. & Lim, K. M. (2016). Use of comics and storytelling in teaching mathematics. In *Developing 21st Century Competencies in the Mathematics Classroom: Yearbook 2016*, Association of Mathematics Educators (pp. 241-259).